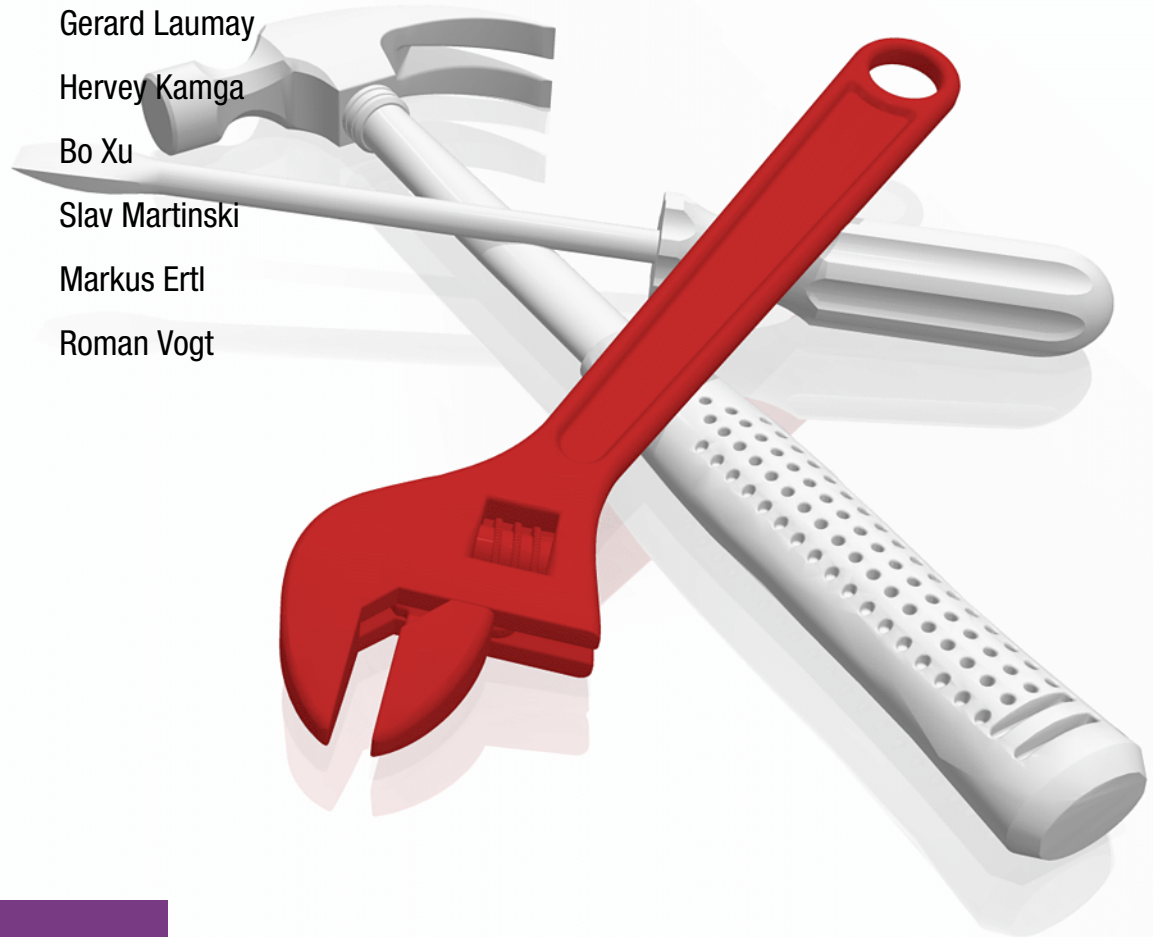


IBM z16 (3931) Technical Guide

Octavian Lascu
Bill White
Ewerson Palacio
John Troy
Jannie Houlbjerg
Martijn Raave
Kazuhiro Nakajima
Paul Schouten
André Spahni
Anna Shugol

Gerard Laumay
Hervey Kamga
Bo Xu
Slav Martinski
Markus Ertl
Roman Vogt



IBM Z

Note: Before using this information and the product it supports, read the information in “Notices” on page xiii.

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Preface

This IBM® Redbooks® publication describes the features and functions of the latest member of the IBM Z® platform that was built with the IBM Telum processor: the IBM z16™ (machine type 3931). It includes information about the IBM z16 processor design, I/O innovations, security features, and supported operating systems.

The IBM Z platform is recognized for its security, resiliency, performance, and scale. It is relied on for mission-critical workloads and as an essential element of hybrid cloud infrastructures. The IBM z16 server adds capabilities and value with innovative technologies that are needed to accelerate the digital transformation journey.

The IBM z16 is a state-of-the-art data and transaction system that delivers advanced capabilities, which are vital to any digital transformation. The IBM z16 is designed for enhanced modularity, which is in an industry standard footprint.

This system excels at the following tasks:

- ▶ Providing AI inference with Integrated Accelerator for Artificial Intelligence
- ▶ Making use of multicloud integration services
- ▶ Securing data with pervasive encryption
- ▶ Accelerating digital transformation with agile service delivery
- ▶ Transforming a transactional platform into a data powerhouse
- ▶ Getting more out of the platform with IT Operational Analytics
- ▶ Accelerating digital transformation with agile service delivery
- ▶ Revolutionizing business processes
- ▶ Blending open source and IBM Z technologies

This book explains how this system uses new innovations and traditional IBM Z strengths to satisfy growing demand for cloud, analytics, and open source technologies. With the IBM z16 as the base, applications can run in a trusted, reliable, and secure environment that improves operations and lessens business risk.

Authors

This book was produced by a team of specialists from around the world working at IBM Redbooks, Poughkeepsie Center.

Octavian Lascu is an IBM Redbooks Project Leader with over 25 years of IT infrastructure experience. He specializes in designing, implementing, and supporting complex IT infrastructure environments (systems, storage, and networking), including high availability and disaster recovery solutions and high-performance computing deployments. He has developed materials for and taught over 50 workshops for technical audiences around the world. He is the author of several IBM publications.

Bill White is an IBM Redbooks Project Leader and Senior Networking and Connectivity Specialist at IBM Redbooks, Poughkeepsie Center.

Ewerson Palacio is an IBM Redbooks Project Leader. He holds Bachelor's degree in Math and Computer Science. Ewerson worked for IBM Brazil for over 40 years and retired in 2017 as an IBM Distinguished Engineer. Ewerson co-authored many IBM Z Redbooks, and created and presented ITSO seminars around the globe.

John Troy is an IBM Z and storage hardware National Top Gun in the northeast area of the US. He has over 40 years of experience in the service field. His areas of expertise include IBM Z servers and high-end storage systems technical and customer support and services. John has also been an IBM Z hardware technical support course designer, developer, and instructor for the last eight generations of IBM high-end servers.

Jannie Houlbjerg is a Systems Programmer working at JN Data in Denmark. She has more than 20 years of experience in the IBM Z field. Her areas of expertise include IBM Z hardware and infrastructure, IBM Parallel Sysplex®, connectivity, performance, IBM GDPS®, and technical project management and documentation.

Martijn Raave is an IBM Z and LinuxONE Client Architect and Hardware Technical Specialist for IBM Northern Europe. Over a period of over 20 years, his professional career has revolved around the mainframe platform, supporting several large Dutch customers in their technical and strategic journey on IBM Z. His focus areas are hardware, resiliency, availability, architecture, and any other topics about IBM Z.

Kazuhiro Nakajima is a Senior IT Specialist in IBM Japan. He has almost 30 years career in IBM Japan and he has been active as an advanced Subject Matter Expert of IBM Z products for over 20 years. His areas of expertise include IBM Z hardware, performance, z/OS®, and IBM Z connectivity. He has been a co-author of several IBM Z configuration set up IBM Redbooks publications from the IBM zEC12 to the IBM z14®.

Paul Schouten is an IBM Z Client Technical Specialist based in Sydney, Australia. During his 40 years supporting mainframe systems, he has performed many roles, including Certified IT Architect, Systems Software developer, and Systems Programming. He has extensive experience developing and documenting high availability solutions for IBM's enterprise customers.

André Spahni is an IBM Z Client Technical Specialist based in Zurich, Switzerland. He has 20 years of experience working with and supporting IBM Z clients. André has worked for EMEA 2nd level supporter and national Top Gun. His areas of expertise include IBM Z hardware, HMC/SE, and connectivity.

Anna Shugol is a mainframe technical specialist with IBM UK. She has over 8 years of Mainframe experience and has worked with clients in various geographies. Large system performance is one of her key areas of expertise. Anna holds a Computer Science degree from Bauman Moscow State Technical University.

Gerard Laumay is an IBM Z Technical Specialist based in Montpellier Center, France. A member of the IBM New Technology Introduction (NTI) team, he is managing early programs, supporting IBM customers during the introduction of new IBM Z products. Gerard has over 37 years of experience on IBM Mainframe. His areas of expertise include IBM Z hardware, operating systems (z/OS, z/VM®, and Linux for IBM Z), and new workloads. As a member of the worldwide IBM Z technical community, Gerard teaches at numerous external and internal IBM events and participates in international projects. He is the co-author of several IBM Redbooks publications.

Hervey Kamga is an IBM Z Product Engineer with the EMEA I/O Connectivity Team in Montpellier, France. Before serving in his current role, he was a Support Engineer and Engineer On Site for 13 years with Sun Microsystems and Oracle in EMEA. Hervey's areas of expertise include Oracle Solaris (operating system and hardware products), virtualization (VMware and virtualBox), Linux, and IBM Z I/O features and protocols (IBM FICON® and OSA) while co-authoring several IBM Redbooks publications.

Bo Xu is a consulting product Service SSR in China. He has more than 20 years of experience with IBM Z platform maintenance support. He has been working in IBM's Global Technology Services department to provide IBM Z platform support to clients as a local Top Gun, and as second-level support for IBM DS8000® as one of the country's Top Gun & Skill Owners. His areas of expertise include IBM Z platform hardware, channel connectivity, and IBM DS8000 storage.

Slav Martinski works as a hardware technical support specialist for IBM Europe. He has more than 5 years experience working on IBM Power Servers. Currently, he is working in IBM's Z Systems support team. Slav holds a Computer Science degree from Delaware County College.

Markus Ertl is a Senior IT Specialist in IBM Germany. He has more than 15 years of experience with IBM Z, working with clients from various industries. His area of expertise includes IBM Z hardware and infrastructure, performance, and Capacity on Demand topics.

Roman Vogt is an Senior IT Specialist based in Hamburg, Germany. He is currently working for IBM Global Techline for IBM Z and LinuxONE hardware. Roman has worked more than 25 years in the mainframe area, including more than 15 years as customer engineer and eight years in Techline.

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Introducing the IBM z16

The IBM Z platform is recognized for its long-standing commitment to delivering best-in-industry security, resiliency, performance, and scalability. IBM Z is relied on for mission-critical workloads and as an essential element of hybrid cloud infrastructures.

The new member of the IBM Z family, IBM z16, continues that commitment and adds value with innovative technologies that can help accelerate the digital transformation journey.

The IBM z16 is the first IBM Z system that is built with the IBM Telum processor¹. It is designed to help businesses meet the following goals:

- ▶ Create value in every interaction and to optimize decision making, with the on-chip Artificial Intelligence (AI) accelerator. The Accelerator for AI can deliver the speed and scale that is required to infuse AI inferencing into workloads with no impact on service delivery.
- ▶ Act now to protect today's data against current and future threats with quantum-safe protection immediately through quantum-safe cryptography APIs and crypto discovery tools.
- ▶ Enhance resiliency with flexible capacity to dynamically shift system resources across locations to proactively avoid disruptions.
- ▶ Modernize and integrate applications and data in a hybrid cloud environment with consistent and flexible deployment options to innovate with speed and agility.
- ▶ Reduce cost and keep up with changing regulations through a solution that helps simplify and streamline compliance tasks.

This chapter describes the basic characteristics of the IBM z16 platform. It includes the following topics:

- ▶ 1.1, "IBM z16 A01 highlights" on page 2
- ▶ 1.2, "IBM z16 A01 technical overview" on page 6
- ▶ 1.3, "Hardware management" on page 12
- ▶ 1.4, "Reliability, availability, and serviceability" on page 13

¹ [IBM Telum Processor: the next-gen microprocessor for IBM Z and IBM LinuxONE](#)

1.1 IBM z16 A01 highlights

Each new IBM Z platform continues to deliver innovative technologies. The IBM z16 is no exception. It has a new processor chip design with each processor unit (PU) running at 5.2 GHz. IBM 16 provides 17% more processor capacity per CPC drawer compared to the IBM z15.

The new processor chip design has a new cache hierarchy, on-chip AI accelerator that is shared by the PU cores, transparent memory encryption, and increased uniprocessor capacity (single thread and SMT similar).

The on-chip AI scoring logic provides submicrosecond AI inferencing for deep learning and complex neural network models.

The redesigned cache structure features the following cache sizes:

- ▶ 256 KB L1 per PU core
- ▶ 32 MB semi-private L2 per PU core
- ▶ 256 MB (logical) shared victim virtual L3 per chip
- ▶ 2 GB (logical) shared victim virtual L4 per CPC drawer

The result is improved system performance and scalability with 1.5x more cache capacity per core over the IBM z15 and reduced average access latency through a flatter topology.

The IBM z16 (machine type 3931) has one model: the A01. The maximum number of characterizable processor units (PUs) with the IBM z16 is represented by feature names: Max39, Max82, Max125, Max168, and Max200.

The number of characterizable PUs, spare PUs, System Assist Processors (SAPs), and Integrated Firmware Processors (IFP) are included with each IBM z16 feature (see Table 1-1).

Table 1-1 IBM z16 A01 processor unit (PU) configurations

Feature name	Number of CPC drawers	Feature Code	Characterizable PUs	Standard SAPs ^a	Spare PUs
Max39	1	0667	1 - 39	5	2
Max82	2	0668	1 - 82	10	2
Max125	3	0669	1 - 125	15	2
Max168	4	0670	1 - 168	20	2
Max200	4	0671	1 - 200	24	2

a. More SAPs can be ordered by using Feature Code 1963.

The IBM z16 memory subsystem uses proven redundant array of independent memory (RAIM) technology to ensure high availability. Up to 40 TB (10 TB per CPC drawer) of addressable memory per system can be ordered.

The IBM z16 also has unprecedented capacity to meet consolidation needs with innovative I/O features for transactional and hybrid cloud environments.

The IBM z16 (maximum configuration) can support up to 12 PCIe+ I/O drawers. Each I/O drawer can support up to 16 I/O or special purpose features for storage, network, and clustering connectivity, and cryptography.

The following features were introduced with the IBM z16:

- ▶ FICON Express32S
- ▶ OSA-Express7S 1.2
- ▶ RoCE Express3 (Long Reach and Short Reach)
- ▶ Coupling Express2 Long Reach
- ▶ Crypto Express8S

The IBM z16 is more flexible and features simplified on-demand capacity to satisfy peak processing demands and quicker recovery times with built-in resiliency capabilities. The Capacity on Demand (CoD) function can dynamically change available system capacity. This function can help respond to new business requirements with flexibility and precise granularity.

The IBM Tailored Fit Pricing for IBM Z options delivers unmatched simplicity and predictability of hardware capacity and software pricing, even in the constantly evolving era of hybrid cloud. Consider the following points:

- ▶ The IBM z16 enhancements in resiliency include a capability that is called IBM Z Flexible Capacity for Cyber Resiliency. With Flexible Capacity for Cyber Resiliency, you can remotely shift capacity and production workloads between IBM z16 systems at different sites on demand with no onsite personnel or IBM intervention. This capability is designed to help you proactively avoid disruptions from unplanned events and planned scenarios, such as site facility maintenance.
- ▶ IBM z16 System Recovery Boost enhancements provide boosted processor capacity and parallelism for specific events. Client-selected middleware starts and restarts to expedite recovery for middleware regions and restore steady-state operations as soon as possible. IBM SAN Volume Controller memory dump processing and HyperSwap configuration load and reload are boosted to minimize the effect on running workloads.
- ▶ On IBM z16, the enhanced ICA-SR coupling link protocol provides up to 10% improvement for read requests and lock requests, and up to 25% for write requests and duplexed write requests, compared to CF service times on IBM z15 systems. The improved CF service times for CF requests can translate into better Parallel Sysplex coupling efficiency; therefore, the software costs can be reduced for the attached z/OS images in the Parallel Sysplex.
- ▶ IBM z16 provides improved CF processor scalability for CF images. Compared to IBM z15, the relative scaling of a CF image beyond a 9-way is significantly improved; that is, that the effective capacity of IBM z16 CF images continues to increase meaningfully all the way up to the maximum of 16 processors in a CF image.

The IBM z16 also added functions to protect today's data now, and from future cyberattacks that can be initiated by quantum computers. The IBM z16 provides the following quantum-safe capabilities:

- ▶ Key generation
- ▶ Encryption
- ▶ Key encapsulation mechanisms
- ▶ Hybrid key exchange schemes
- ▶ Dual digital signature schemes

In addition to these quantum-safe cryptographic capabilities, tools (such as IBM Application Discovery and Delivery Intelligence [ADDI], Integrated Cryptographic Service Facility [ICSF], and IBM Crypto Analytics Monitor [CAT]) can help you discover where and what cryptography is used in applications. This knowledge can aid in developing a cryptographic inventory for migration and modernization planning.

1.1.1 Supported upgrade paths

The supported upgrade paths for the IBM z16 A01 are shown in Figure 1-1.

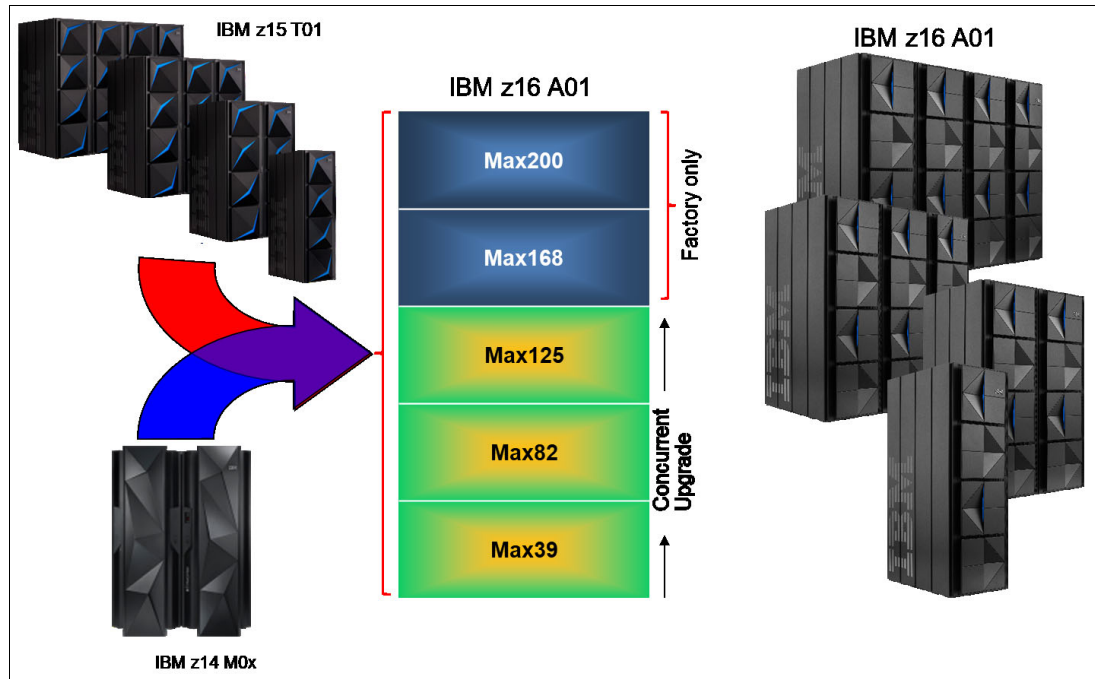


Figure 1-1 IBM z16 A01 upgrade paths

1.1.2 Capacity and performance

The IBM z16 A01 offers 317 capacity levels. In all, 200 capacity levels are based on the number of physically used CPs, plus up to 117 extra subcapacity models for the first 39 CPs.

The IBM z16 provides increased processing and enhanced I/O capabilities over its predecessor, the IBM z15 T01. This capacity is achieved by increasing the number of PUs per system, redesigning the system cache, and introducing new I/O technologies.

The IBM z16 feature Max200 is estimated to provide up to 17% more total system capacity than the IBM z15 Model Max190, with the same amount of memory and power requirements. With up to 40 TB of main storage and enhanced SMT, the performance of the IBM z16 A01 processors deliver considerable improvement. Uniprocessor performance also increased significantly. An IBM z16 Model 701 offers average performance improvements of up to 11% over the IBM z15 Model 701.²

The Integrated Facility for Linux (IFL) and IBM Z Integrated Information Processor (zIIP) processor units on the IBM z16 can be configured to run two simultaneous threads in a single processor (SMT). This feature increases the capacity of these processors with 25% in average² over processors that are running single thread. SMT is also enabled by default on System Assist Processors (SAPs).

Within each single drawer, IBM z16 provides 25% greater capacity than IBM z15 for standard models and 40% greater capacity on the maximum configured model, which enables efficient partition scaling.

² Observed performance increases vary depending on the workload types.

This comparison is based on the Large System Performance Reference (LSPR) mixed workload analysis. The range of performance ratings across the individual LSPR workloads is likely to feature a large spread. More performance variation of individual logical partitions (LPARs) is available when an increased number of partitions and more PUs are available. For more information, see Chapter 12, “Performance and capacity planning” on page 477.

For more information about performance, [see the LSPR website](#).

For more information about millions of service units (MSUs) ratings, see the [IBM Z Software Contracts](#) website.

1.1.3 Supported operating systems

The IBM z16 is supported by a large set of software products and programs, including independent software vendor (ISV) applications. Use of various features might require the latest releases.

The following operating systems are supported on the IBM z16:

- ▶ z/OS Version 2 Release 5 with PTFs
- ▶ z/OS Version 2 Release 4 with PTFs
- ▶ z/OS Version 2 Release 3 with PTFs
- ▶ z/OS Version 2 Release 2 with PTFs (toleration support only)
- ▶ z/VM Version 7 Release 3
- ▶ z/VM Version 7 Release 2 with PTFs
- ▶ z/VM Version 7 Release 1 with PTFs
- ▶ z/VSE Version 6 Release 2 with PTFs
- ▶ z/TPF Version 1 Release 1 (compatibility support)

IBM plans to support 21st Century Software VSEⁿ V6.3 on IBM z16. For more information, see 7.2.4, “21st Century Software z/VSEⁿ V6.3” on page 255.

IBM plans to support the following Linux on IBM Z distributions on IBM z16:

- ▶ SUSE SLES 15 SP3 and SUSE SLES 12 SP5
- ▶ Red Hat RHEL 8.4 and Red Hat RHEL 7.9
- ▶ Ubuntu 22.04 LTS, Ubuntu 21.10, and Ubuntu 20.04.1 LTS

The support statements for the IBM z16 also cover the KVM hypervisor on distribution levels that have KVM support.

For more information about the features and functions that are supported on IBM z16 by operating system, see Chapter 7, “Operating system support” on page 251.

1.1.4 Supported IBM compilers

The following IBM compilers for IBM Z can be used with the IBM z16:

- ▶ Enterprise COBOL for z/OS
- ▶ Enterprise PL/I for z/OS
- ▶ Automatic Binary Optimizer
- ▶ z/OS XL C/C++
- ▶ XL C/C++ for Linux on IBM Z

The compilers increase the return on your investment in IBM Z hardware by maximizing application performance by using the compilers’ advanced optimization technology for IBM z/Architecture®.

Through their support of web services, XML, and Java, they allow for the modernization of assets in web-based applications. They also support the latest IBM middleware products (CICS®, Db2, and IMS), which allows applications to use their latest capabilities.

To fully use the capabilities of the IBM z16, you must compile it by using the minimum level of each compiler. To obtain the best performance, you must specify an architecture level of 14 by using the **ARCH(14)** option.

For more information, see 7.5.8, “z/OS XL C/C++ considerations” on page 325.

1.2 IBM z16 A01 technical overview

This section briefly reviews the following main elements of the IBM z16:

- ▶ Frames
- ▶ CPC drawers
- ▶ I/O subsystem and I/O drawers
- ▶ Storage connectivity
- ▶ Network connectivity
- ▶ Clustering connectivity
- ▶ Cryptography
- ▶ Supported connectivity and crypto features
- ▶ Special-purpose features and functions

1.2.1 Frames

The IBM z16 A01 uses 19-inch frames and industry-standardized power and hardware. It can be configured as a one-, two-, three-, or four-frame system. The IBM z16 A01 packaging is compared to the two previous IBM Z platforms in Table 1-2.

Table 1-2 IBM z16 configuration options compared to IBM z14 and IBM z15 configurations

System	Number of frames	Number of CPC drawers	Number of I/O drawers	I/O and power connections	Power options	Cooling options
IBM z16 A01	1 - 4	1 - 4	0 - 12 ^a	Rear only	PDU or BPA	Radiator (air) only
IBM z15 T01	1 - 4	1 - 5	0 - 12 ^b	Rear only	PDU or BPA	Radiator (air) or water-cooling unit (WCU)
IBM z14 M0x	2	1 - 4	0 - 5	Front and rear	BPA	Radiator (air) or WCU

a. Maximum of 12 if ordered with a PDU or maximum of 10 if ordered with a BPA.

b. Maximum of 12 if ordered with a PDU or maximum of 11 if ordered with a BPA.

1.2.2 CPC drawers

The IBM z16 A01 can be configured with up to four CPC drawers (three in the A Frame and one in the B Frame). Each CPC drawer contains the following elements:

- ▶ Telum processor chips that use Extreme ultraviolet (EUV) process with 7 nm silicon lithography technology. Each processor chip consists of eight PU cores. Two processor chips are packaged in the dual-chip module (DCM).
- ▶ DCMs
Four DCMs that contain 64 physical cores per drawer interconnected (each cooled by an internal water loop). Each DCM can have 9 - 11 or 10 - 15 active PU cores (depending on the configuration that is used).
- ▶ Memory:
 - A minimum of 512 GB and a maximum of 40 TB of memory per system can be ordered, which does not include 256 GB for hardware system area (HSA).
 - Up to 48 dual inline memory modules (DIMMs) that are 32 GB, 64 GB, 128 GB, 256 GB, or 512 GB are plugged in a CPC drawer.
- ▶ Fan-outs
Each CPC drawer supports up to 12 PCIe+ fan-out adapters to connect to the PCIe+ I/O drawers, and Integrated Coupling Adapter Short Reach (ICA SR) coupling links:
 - Two-port PCIe 16 gigabytes per second (GBps) I/O fan-out, each port supports one domain in the 16-slot PCIe+ I/O drawers.
 - ICA SR1.1 and ICA SR PCIe fan-outs for coupling links (two links, 8 GBps each).
- ▶ Three or four Power Supply Units (PSUs), depending on the configuration (PDU or BPA), which provide power to the CPC drawer and are accessible from the rear. Loss of one PSU leaves enough power to satisfy the power requirements of the entire drawer. The PSUs can be concurrently maintained.
- ▶ Two dual-function Base Management Cards (BMCs)\Oscillator Cards (OSCs), which provide redundant interfaces to the internal management network and provide clock synchronization to the IBM Z platform.
- ▶ Two dual-function Processor Power Cards (PPC), which control Voltage Regulation, PSU and Fan control. The PPCs are redundant and can be concurrently maintained.
- ▶ Five fans are installed at the front of the drawer to provide cooling airflow for the resources that are installed in the drawer except for the PU SCMs, which are internally water-cooled.

With the IBM z16, Virtual Flash Memory (VFM) feature is offered from the main memory capacity in 0.5 TB units to increase granularity for the feature. VFM can provide much simpler management and better performance by eliminating the I/O to the adapters in the PCIe+ I/O drawers.

1.2.3 I/O subsystem and I/O drawers

The IBM z16 supports a PCIe I/O infrastructure. PCIe features are installed in PCIe+ I/O drawers. Up to 12 I/O drawers per IBM z16 can be ordered, which allows for up to 192 PCIe I/O and special purpose features.

For a four CPC drawer system, up to 48 PCIe+ fan-out slots can be populated with fan-out cards for data communications between the CPC drawers and the I/O infrastructure, and for coupling. The multiple channel subsystem (CSS) architecture allows up to six CSSs, each with 256 channels.

The IBM z16 implements PCIe Generation 4, which is used to connect the PCIe+ Gen3 dual port fan-out features in the CPC drawers. The I/O infrastructure is designed to reduce processor usage and I/O latency, and provide increased throughput and availability.

PCIe+ I/O drawer

Together with the PCIe features, the PCIe+ I/O drawer offers finer granularity and capacity over previous I/O infrastructures. It can be concurrently added and removed in the field, which eases planning. Only PCIe cards (features) are supported, in any combination.

1.2.4 Storage connectivity

Storage connectivity is provided on the IBM z16 by FICON Express and the IBM zHyperLink Express features.

FICON Express

FICON Express features follow the established Fibre Channel (FC) standards to support data storage and access requirements, along with the latest FC technology in storage and access devices. FICON Express features support the following protocols:

- ▶ FICON

This enhanced protocol (as compared to FC) provides for communication across channels, channel-to-channel (CTC) connectivity, and with FICON devices, such as disks, tapes, and printers. It is used in z/OS, z/VM, IBM z/VSE® (Virtual Storage Extended), z/TPF (Transaction Processing Facility), and Linux on IBM Z environments.

- ▶ Fibre Channel Protocol (FCP)

This standard protocol is used for communicating with disk and tape devices through FC switches and directors. The FCP channel can connect to FCP SAN fabrics and access FCP/SCSI devices. FCP is used by z/VM, KVM, z/VSE, and Linux on IBM Z environments.

FICON Express32S features are implemented by using PCIe cards, and offer better port granularity and improved capabilities over the previous FICON Express features. FICON Express32S features support a link data rate of 32 gigabytes per second (Gbps) (8, 16, or 32 Gbps auto-negotiate), and it is the preferred technology for new systems.

zHyperLink Express

zHyperLink was created to provide fast access to data by way of low-latency connections between the IBM Z platform and storage.

The zHyperLink Express1.1 feature allows you to make synchronous requests for data that is in the storage cache of the IBM DS8900F. This process is done by directly connecting the zHyperLink Express1.1 port in the IBM z16 to an I/O Bay port of the IBM DS8000. This short distance (up to 150 m [492 feet]), direct connection is designed for low-latency reads and writes, such as with IBM DB2® for z/OS synchronous I/O reads and log writes.

Working with the FICON SAN Infrastructure, zHyperLink can improve application response time, which cuts I/O-sensitive workload response time in half without requiring application changes.³

Note: The zHyperLink channels complement FICON channels, but they do *not* replace FICON channels. FICON remains the main data driver and is mandatory for zHyperLink usage.

³ The performance results can vary depending on the workload. Use the zBNA tool for the zHyperLink planning.

1.2.5 Network connectivity

The IBM z16 is a fully virtualized platform that can support many system images at once. Therefore, network connectivity covers not only the connections between the platform and external networks with Open Systems Adapter-Express (OSA-Express) and RoCE Express features, it supports specialized internal connections for intra-system communication through IBM HiperSockets and Internal Shared Memory (ISM).

OSA-Express

The OSA-Express features provide local area network (LAN) connectivity and comply with IEEE standards. In addition, OSA-Express features assume several functions of the TCP/IP stack that normally are performed by the PU, which allows significant performance benefits by offloading processing from the operating system.

OSA-Express7S 1.2 features continue to support copper and fiber optic (single-mode and multimode) environments.

HiperSockets

IBM HiperSockets is an integrated function of the IBM Z platforms that supplies attachments to up to 32 high-speed virtual LANs, with minimal system and network overhead.

HiperSockets is a function of the Licensed Internal Code (LIC). It provides LAN connectivity across multiple system images on the same IBM Z platform by performing memory-to-memory data transfers in a secure way.

The HiperSockets function eliminates the use of I/O subsystem operations. It also eliminates having to traverse an external network connection to communicate between LPARs in the same IBM Z platform. In this way, HiperSockets can help with server consolidation by connecting virtual servers and simplifying the enterprise network.

RoCE Express

The 25 GbE and 10 GbE RoCE Express3 features⁴ use Remote Direct Memory Access (RDMA) over Converged Ethernet (RoCE) to provide fast memory-to-memory communications between two IBM Z platforms.

These features help reduce consumption of CPU resources for applications that use the TCP/IP stack (such as IBM WebSphere® that accesses an IBM Db2® database). They also can help reduce network latency with memory-to-memory transfers by using Shared Memory Communications over RDMA (SMC-R).

With SMC-R, you can transfer huge amounts of data quickly and at low latency. SMC-R is transparent to the application and requires no code changes, which enables rapid time to value.

The RoCE Express3 features also can provide LAN connectivity for Linux on IBM Z, and comply with IEEE standards. In addition, RoCE Express features assume several functions of the TCP/IP stack that normally are performed by the PU, which allows significant performance benefits by offloading processing from the operating system.

⁴ RoCE Express features also can be used as general-purpose Network Interface Cards (NICs) with Linux on IBM Z.

Internal Shared Memory

ISM is a virtual Peripheral Component Express (PCI) network adapter that enables direct access to shared virtual memory. It provides a highly optimized network interconnect for IBM Z platform intra-communications.

Shared Memory Communications-Direct Memory Access (SMC-D) uses ISM. SMC-D optimizes operating systems communications in a way that is transparent to socket applications. It also reduces the CPU cost of TCP/IP processing in the data path, which enables highly efficient and application-transparent communications.

SMC-D requires no extra physical resources (such as RoCE Express features, PCIe bandwidth, ports, I/O slots, network resources, or Ethernet switches). Instead, SMC-D uses LPAR-to-LPAR communication through HiperSockets or an OSA-Express feature for establishing the initial connection.

z/OS and Linux on IBM Z support SMC-R and SMC-D. Now, data can be shared by way of memory-to-memory transfer between z/OS and Linux on IBM Z.

1.2.6 Clustering connectivity

A Parallel Sysplex is an IBM Z clustering technology that is used to make applications that are running on logical and physical IBM Z platforms highly reliable and available. The IBM Z platforms in a Parallel Sysplex are interconnected by way of coupling links.

Coupling connectivity on the IBM z16 use Coupling Express2 Long Reach (CE2 LR) and Integrated Coupling Adapter Short Reach (ICA SR and ICA SR1.1) features. The ICA SR feature supports distances up to 150 meters (492 feet); the CE2 LR feature supports unrepeated distances of up to 10 km (6.21 miles) between IBM Z platforms. ICA SR features provide sysplex and timing connectivity direct to the CPC drawer, while Coupling Express2 LR features connect into the PCIe+ I/O Drawer.

Coupling links also can carry timing information (such as Server Time Protocol [STP]) for synchronizing time across multiple IBM Z CPCs in a Coordinated Time Network (CTN).

For more information about coupling and clustering features, see 4.5, “I/O features” on page 160.

1.2.7 Cryptography

IBM z16 provides two main cryptographic functions: CP Assist for Cryptographic Functions (CPACF) and Crypto-Express8S.

CPACF

CPACF is a high-performance, low-latency coprocessor that performs symmetric key encryption operations and calculates message digests (hashes) in hardware. The following algorithms are supported:

- ▶ AES
- ▶ Data Encryption Standard (DES) and Triple Data Encryption Standard (TDES)
- ▶ Secure Hash Algorithm (SHA)-1
- ▶ SHA-2
- ▶ SHA-3

CPACF supports Elliptic Curve Cryptography (ECC) clear key, improving the performance of Elliptic Curve algorithms. The following algorithms are supported:

- ▶ EdDSA (Ed448 and Ed25519)
- ▶ ECDSA (P-256, P-384, and P-521)
- ▶ ECDH (P-256, P-384, P521, X25519, and X448)
- ▶ Support for protected key signature creation

Crypto-Express8S

The tamper-sensing and tamper-responding Crypto-Express8S features provide acceleration for high-performance cryptographic operations and support up to 85 domains with the IBM z16 A01. This specialized hardware performs AES, DES and TDES, RSA, Elliptic Curve (ECC), SHA-1, and SHA-2, and other cryptographic operations.

It supports specialized high-level cryptographic APIs and functions, including those functions that are required with quantum-safe cryptography and in the banking industry.

Crypto-Express8S features are designed to meet the Federal Information Processing Standards (FIPS) 140-2 Level 4 and PCI HSM security requirements for hardware security modules.

IBM z16 is the industry's first quantum-safe system⁵. Consider the following points:

- ▶ IBM z16 quantum-safe secure boot technology helps to protect IBM Z firmware from quantum attacks by using a build-in dual signature scheme with no changes required.
- ▶ IBM z16 quantum-safe technology and key management services were developed to help you protect data and keys against a potential future quantum attack, such as harvest now, decrypt later.
- ▶ IBM z16 positions customers to use quantum-safe cryptography along with classic cryptography as they begin modernizing existing applications and building new applications.

For more information about cryptographic features and functions, see Chapter 6, "Cryptographic features" on page 213.

1.2.8 Supported connectivity and crypto features

The IBM z16 provides a PCIe-based infrastructure for the PCIe+ I/O drawers to support the following features:

- ▶ Storage connectivity:
 - zHyperLink Express1.1 (new build and carry forward)
 - zHyperLink Express (carry forward only)
 - FICON Express32S (new build only)
 - FICON Express16SA (carry forward only)
 - FICON Express16S+ (carry forward only)
- ▶ Network connectivity:
 - OSA-Express7S 1.2 (new build only)

⁵ DISCLAIMER: IBM z16 with the Crypto Express 8S card provides quantum-safe APIs and access to quantum-safe algorithms that were selected as finalists during the PQC standardization process that was conducted by NIST (<https://csrc.nist.gov/Projects/post-quantum-cryptography/round-3-submissions>). *Quantum-safe cryptography* refers to efforts to identify algorithms that are resistant to attacks by classic and quantum computers to keep information assets secure, even after a large-scale quantum computer is built. (<https://www.etsi.org/technologies/quantum-safe-cryptography>). These algorithms are used to help ensure the integrity of several firmware and boot processes. IBM z16 is the Industry-first system that is protected by quantum-safe technology across multiple layers of firmware.

- OSA-Express7S (carry forward only)
- OSA-Express6S (carry forward only)
- RoCE Express3 (new build only)
- RoCE Express2.1 (carry forward only)
- RoCE Express2 (carry forward only)
- ▶ Cryptographic features:
 - Crypto Express8S, one or two HSMs⁶ (new build only)
 - Crypto Express7S, 1- or 2-port⁷ (carry forward only)
 - Crypto Express6S (carry forward only)
- ▶ Clustering connectivity⁸:
 - ICA SR1.1 (new build or carry forward)
 - ICA SR (carry forward only)
 - Coupling Express2 Long Reach (new build only)

1.2.9 Special-purpose features and functions

When it comes to designing and developing the IBM Z platform, IBM takes a total systems view. The IBM Z stack is built around digital services, agile application development, connectivity, and system management. This design approach creates an integrated, diverse platform with specialized hardware and dedicated computing capabilities.

The IBM z16 delivers a range of features and functions that allows PUs to concentrate on computational tasks, while distinct, specialized features take care of the rest. For more information about these features and other IBM z16 features, see in 3.5, “Processor unit functions” on page 100.

1.3 Hardware management

The Hardware Management Consoles (HMCs) and Support Elements (SEs) are appliances that together provide platform management for IBM Z.

The HMC is an appliance that provides a single point of control for managing local or remote hardware elements.

For IBM z16 new built systems, IBM Z Hardware Management Appliance (FC 0129) is the only available HMC. The HMC Appliance and SE Appliance run virtualized on the SE hardware.

Older stand-alone HMCs (rack-mounted or tower) can be carried forward during an MES upgrade to IBM z16.

For more information, see Chapter 10, “Hardware Management Console and Support Element” on page 411.

⁶ The Crypto Express8S is available with either one or two hardware security modules (HSM). The HSM is the IBM 4770 PCIe Cryptographic Coprocessor (PCIeCC).

⁷ The Crypto Express7S comes with either one (1-port) or two (2-port) hardware security modules (HSM). The HSM is the IBM 4769 PCIe Cryptographic Coprocessor (PCIeCC).

⁸ ICA SR and ICA SR1.1 features connect directly into the CPC (processor) Drawer, while Coupling Express2 Long Reach connects into the PCIe+ I/O Drawer.

1.4 Reliability, availability, and serviceability

System reliability, availability, and serviceability (RAS) is an area of continuous IBM focus and a defining IBM Z platform characteristic. The RAS objective is to reduce (or eliminate, if possible) all sources of planned and unplanned outages while providing adequate service information if an issue occurs. Adequate service information is required to determine the cause of an issue without the need to reproduce the context of an event.

IBM Z platforms are designed to enable highest availability and lowest downtime. These facts are recognized by various IT analysts, such as ITIC⁹ and IDC¹⁰. A comprehensive, multi-layered strategy includes the following features:

- ▶ Error Prevention
- ▶ Error Detection and Correction
- ▶ Error Recovery
- ▶ System Recovery Boost

With a suitably configured IBM z16, further reduction of outages can be attained through First Failure Data Capture (FFDC), which is designed to reduce service times and avoid subsequent errors. It also improves nondisruptive replace, repair, and upgrade functions for memory, drawers, and I/O adapters. IBM z16 supports the nondisruptive download and installation of LIC updates.

IBM z16 RAS features provide unique high-availability and nondisruptive operational capabilities that differentiate IBM Z in the marketplace. IBM z16 RAS enhancements are made on many components of the CPC (processor chip, memory subsystem, I/O, and service) in areas, such as error checking, error protection, failure handling, error checking, faster repair capabilities, sparing, and cooling.

The ability to cluster multiple systems in a Parallel Sysplex takes the commercial strengths of the z/OS platform to higher levels of system management, scalable growth, and continuous availability.

The IBM z16 builds on the RAS of the IBM z15™ family with the following RAS improvements:

- ▶ System Recovery Boost
 - System Recovery Boost was introduced with IBM z15. It offers customers more Central Processor (CP) capacity during system recovery operations to accelerate the startup (IPL), shutdown, or stand-alone memory dump operations (at image level - LPAR¹¹). System Recovery Boost requires operating system support. No other IBM software charges are made during the boost period.

System Recovery Boost can be used during LPAR shutdown or start to make the running operating system and services available in a shorter period.

The System Recovery Boost provides the following options for the capacity increase:

- Subcapacity CP speed boost: During the boost period, subcapacity engines that are allocated to the boosted LPAR are transparently activated at their full capacity (CP engines).
- zIIP Capacity Boost: During the boost period, all active zIIPs that are assigned to an LPAR are used to extend the CP capacity (CP workload is dispatched to zIIP processors during the boost period).

⁹ For more information, see [ITIC Global Server Hardware, Server OS Reliability Report](#).

¹⁰ For more information, see [Quantifying the Business Value of IBM Z](#).

¹¹ LPAR that is running an Operating System image.

- ▶ System Recovery Boost enhancements that are delivered with the IBM z16 maximize service availability by using tailored short-duration boosts to mitigate the effect of the following recovery processes:
 - IBM SAN Volume Controller memory dump boost boosts the system on which the IBM SAN Volume Controller memory dump is taken to reduce system affect and expedite diagnostic capture. It is possible to enable, disable, or set thresholds for this option.
 - Middleware restart/recycle boost boosts the system on which a middleware instance is being restarted to expedite resource recovery processing, release retained locks, and so on. It is applicable to planned restarts, or restarts after failure, automated, or ARM-driven restarts. System Recovery Boost do not boost any system address spaces by default and must be configured by the WLM policy specification.
 - IBM HyperSwap® configuration load boost boosts the system in which the HyperSwap configuration and policy information are being loaded or reloaded. This boost applies to Copy Services Manager (CSM) and GDPS. HyperSwap Configuration Load boost is enabled by default. No thresholds or criteria are applied to the boost request based on the size or number of devices that are present in the HyperSwap configuration.

Through System Recovery Boost, the IBM z16 continues to offer more CP capacity during specific system recovery operations to accelerate system (operating system and services) start when the system is being started or shutdown. System Recovery Boost is operating system-dependent. No other hardware, software, or maintenance charges are required during the boost period for the base functions of System Recovery Boost.

- At the time of this writing, the main System Recovery Boost users are z/OS (running in an LPAR), z/VM, z/VSE, and z/TPF) and stand-alone memory dump (SADMP).

z/VM uses the System Recovery Boost if it runs on subcapacity CP processors only (IFLs are always at their full clock speed). Second-level z/VM guest operating systems¹² can inherit the boost if they are running on CPs.

For more information about RAS and System Recovery Boost, see *Introducing IBM Z System Recovery Boost*, [REDP-5563](#).

- ▶ Level 2 (physical), Level 3, and Level 4 (virtual) cache enhancements include the use symbol ECC to extend the reach of older IBM Z generations cache and memory improvements for augmented availability.

The L2, L3, and L4 cache powerful symbol ECC makes it resistant to more failure mechanisms. Preemptive DRAM marking is added to the main memory to isolate and recover failures more quickly.

¹² z/OS that is configured as a guest system under z/VM does not use the boost.



Central processor complex hardware components

This chapter provides information about the new IBM z16™ and its hardware building blocks, and how these components physically interconnect. This information is useful for planning purposes and can help in defining configurations that fit your requirements.

Naming: The IBM z16 Model A01, Machine Type (M/T) 3931, is further identified in this document as IBM z16, unless otherwise specified.

This chapter includes the following topics:

- ▶ 2.1, “Frames and configurations” on page 16
- ▶ 2.2, “CPC drawer” on page 22
- ▶ 2.3, “Dual chip modules” on page 30
- ▶ 2.4, “PCIe+ I/O drawer” on page 35
- ▶ 2.5, “Memory” on page 38
- ▶ 2.6, “Reliability, availability, and serviceability” on page 49
- ▶ 2.7, “Connectivity” on page 52
- ▶ 2.8, “Model configurations” on page 56
- ▶ 2.9, “Power and cooling” on page 60
- ▶ 2.10, “Summary” on page 67

2.1 Frames and configurations

The IBM z16 Model A01 system is designed in a 19-inch form factor with configuration of 1 - 4 frames that can be easily installed in any data center. The IBM z16 A01 (M/T 3931) can include from one to four 42U EIA (19-inch) frames, which are bolted together. The configurations can include up to four central processor complex (CPC) drawers and up to 12 Peripheral Component Interconnect® Express+ (PCIe+) I/O drawers.

The redesigned CPC drawer and I/O infrastructure also lower power consumption, reduces the footprint, and allows installation in virtually any data center. The IBM z16 server is rated for ASHRAE class A3¹ data center operating environment.

The IBM z16 server is similar to IBM z15, but differentiates itself from previous IBM Z server generations through the following significant changes to the modular hardware:

- ▶ All external cabling (power, I/O, and management) is performed at the rear of the system
- ▶ Flexible configurations: Frame quantity is determined by the system configuration (1 - 4 frames)
- ▶ Choice of power Intelligent Power Distribution Unit (iPDU or PDU) or Bulk Power Assembly (BPA)
- ▶ Feature codes that reserve slots for plan-ahead CPC drawers
- ▶ Internal water cooling plumbing for systems with more than three CPC drawers (Frames A and B)
- ▶ PCIe+ Gen3 I/O drawers (19-inch format) supporting 16 PCIe adapters

The power options include PDU-based power or BPA-based power. The IBM z16 A01 system is designed as a radiator (air) cooled system.

The IBM z16 A01 includes the following basic hardware building blocks:

- ▶ 19-inch 42u frame (1 - 4)
- ▶ CPC (Processor) drawers (1 - 4)
- ▶ PCIe+ Gen3 I/O drawers (up to 12)
- ▶ Radiator cooling assembly (RCA) for CPC drawers cooling
- ▶ Power, with choice of:
 - Intelligent Power Distribution Units (iPDU) pairs (2 - 4 per frame, maximum 8, depending on the configuration).
 - Bulk Power Regulators (1 - 6 pairs, depending on the configuration)
- ▶ Support Elements combined with optional Hardware Management Appliance (two):
 - Single Keyboard, Mouse, Monitor (KMM) device (USB-C connection)
 - Optional IBM Hardware Management Appliance feature
- ▶ 24-port 1 GbE Switches (two or four, depending on the system configuration)
- ▶ Hardware for cable management at the rear of the system

¹ For more information, see Chapter 2, Environmental specifications in *IBM 3931 Installation Manual for Physical Planning*, GC28-7015.

An example of a fully configured system with PDU-based power, four CPC drawers, and up to 12 PCIe+ I/O drawers is shown in Figure 2-1.

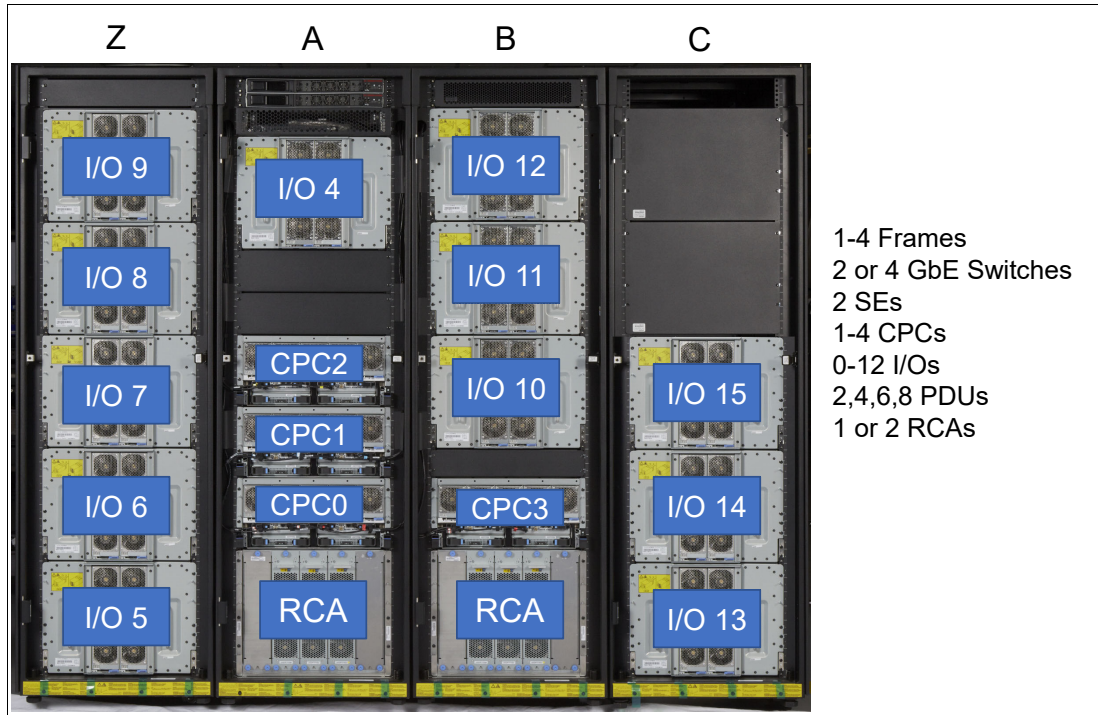


Figure 2-1 Maximum configuration, PDU-based powered system (front view)

An example of a BPA-based powered system, and a maximum of four CPC drawers and 10 PCIe+ I/O drawers is shown in Figure 2-2.

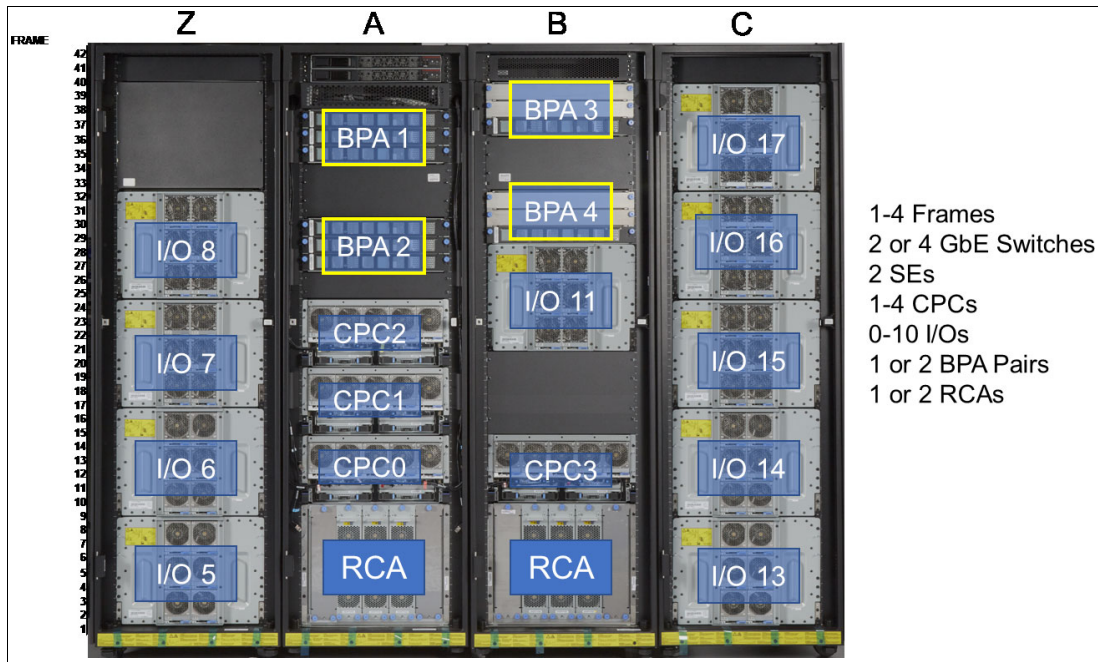


Figure 2-2 Maximum configuration, BPA-based powered system (front view)

The key features that are used to build the system are listed in Table 2-1. For more information about the various configurations, see Appendix E, “Frame configurations Power Distribution Units and Bulk Power Assembly-based systems” on page 533.

Table 2-1 Key features that influence the system configurations

Feature Code	Description	Comments
0508	Model A01	Supports CPs and specialty engines
0667	One CPC Drawer	Feature Max39
0668	Two CPC Drawers	Feature Max82
0669	Three CPC Drawers	Feature Max125
0670	Four CPC Drawers	Feature Max168
0671	Four CPC Drawers	Feature Max200
2981	CPC1 reserve	Reserve A15 location for future add CPC1 (Max39 to Max82 upgrade)
2982	CPC2 reserve	Reserve A20 location for future add CPC2 (Max82 to Max125 upgrade)
Frames and cooling		
4040	A Frame	Radiator (air cooled)
4041	B Frame	Radiator (air cooled)
4043	Z Frame	I/O drawers only
4044	C Frame	I/O drawers only
PDU power		
0645	200 - 208 V 30/60A 3-Phase (Delta)	North America and Japan
0646	380 - 415 V 32A 3 Phase (Wye)	Worldwide (except North America and Japan)
BPA power		
0648	Bulk Power Assembly (BPA)	Quantity 1 = 2 Bulk Power Enclosures Quantity 2 = 4 Bulk Power Enclosures
3003	Balanced Power Plan ahead	Only available with BPA
3017	Bulk Power Regulator (BPR)	Quantity per BPA feature: Min. 2, max 6 (in pairs)
I/O		
4023	PCIe+ I/O drawer	Max. 12 (PDU) or max. 10 (BPA)
7898	Top Exit Cabling	Includes cable management top hat
7899	Bottom Exit Cabling	Includes rear tailgate hardware at bottom of frame
7816	Top Exit Cabling without Tophat	Uses rear slide plates at top of frame

Power Options

The 3931 (z16 A01) has the power options shown in Table 2-2 on page 19:

Table 2-2 IBM z16 A01 Power Options

Feature Description	iPDU	BPA
Number of line cords	2,4,6 or 8	2 or 4
3-Phase Line cords	Yes	Yes
200-240VAC (4 wire), 60A (Low Voltage)	Yes	Yes
380-415VAC (5 wire) 30/32A (High Voltage)	Yes	Yes
480VAC (5 wire Wye) ^a	No	Yes
PCIe+ I/O drawer max	12	10
Water Cooling	No	No
Radiator Cooling	Yes	Yes
Internal Battery Feature	No	No
Phase loss immunity	No	Yes
Balanced Power	No	Yes
DC Power available	No	No

a. Wye cords require five wires, three for Power phases, one for Neutral and one for Ground.

Caution: Installation of a *low voltage system* to a *high voltage facility* will cause significant damage to the system's power components.

Considerations

Consider the following points:

- ▶ A-Frame is always present in every configuration
- ▶ 1u Support Elements (x2) are always in A-Frame at locations A41 and A42
- ▶ 1u 24-port internal Ethernet switches (x2) are always at locations A39 and A40
More Ethernet switches (x2) are available when necessary in Frame C or B
- ▶ I/O PCHID numbering starts with 0100 and increments depending on the number of features that is ordered. No PCHID number affinity is available to a fixed PCIe+ I/O drawer location as with previous systems.

2.1.1 IBM z16 cover (door) design

The standard cover set for IBM z16 model A01 is shown in Figure 2-3.



Figure 2-3 IBM z16 Frames

2.1.2 Top and bottom exit I/O and cabling

For the IBM z16 Model A01 server, the top exit of all cables for I/O or power is always an option with no feature codes required. Adjustable cover plates are available for the openings at the top rear of each frame.

All external I/O cabling enters the system at the rear of the frames for all adapters, management LAN, and power connections.

The Top Exit feature code (FC 7898) provides an optional Top Exit *cover enclosure*. The optional Top Exit cover enclosure provides a fiber cable organizer within the enclosure to optimize the fiber cable storage and strain relief. It also provides mounting locations to secure Fiber Quick Connector (FQC) MPO² brackets (FC 5827) on the top of the frames.

Consider the following points:

- ▶ FC 7899 provides bottom exit cabling and power support. When ordered with FC 5827, it provides harness brackets for the bottom tailgate and fiber bundle organizer hardware.
- ▶ FC 7816 is for top exit cabling and power, a bottom seal plate is installed.
- ▶ FC 5827 provides the MPO mounting brackets that cable harnesses connect to in the top and or bottom exit tailgates.

Note: Overhead I/O cabling is contained within the frames. Extension “chimneys” that were featured with systems before IBM z15 systems are no longer used.

A view of the top rear of the frame and the openings for top exit cables and power is shown in Figure 2-4. When FC 7898 is installed, the plated adjustable shields are removed, and the top exit enclosure is installed.

² MPO - Multi-fiber Push On connector

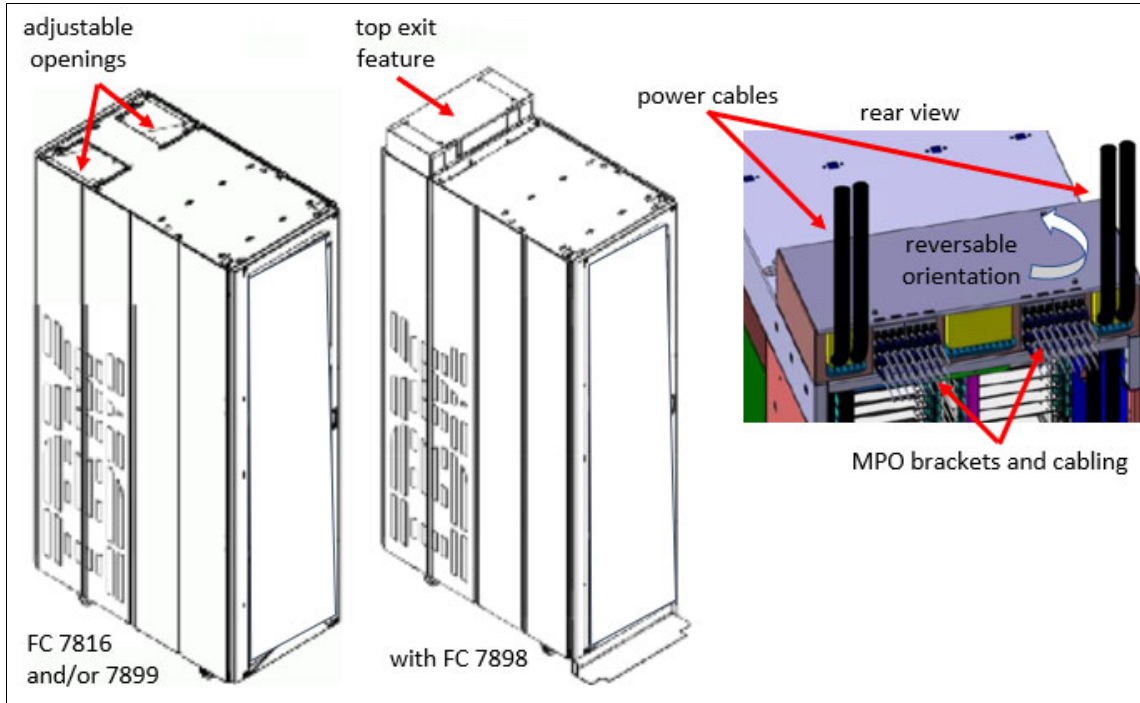


Figure 2-4 Top exit without and with FC7898

Care must be taken when ordering the Feature Codes (see Table 2-3) for cables that are entering the frames from above the floor, below the floor, or both, and if the Top Exit feature is wanted, which provides Top Hat.

Table 2-3 IBM z16 Model A01 cabling Feature Code combinations

Environment	Bottom exit	Top exit	Feature Code	Comments
Raised Floor	Yes	No	7899 only	Bottom FQC support only
Raised Floor	Yes	Yes (no Top Hat)	7899 and 7816	Bottom FQC support only
Raised Floor	Yes	Yes (with Top Hat)	7899 and 7898	Top and Bottom FQC support
Raised Floor	No	Yes (no Top Hat)	7816	<ul style="list-style-type: none"> ▶ No FQC support ▶ Ships bottom seal plate
Raised Floor	No	Yes (with Top Hat)	7898	<ul style="list-style-type: none"> ▶ Top FQC support ▶ Ships bottom seal plate
Non-Raised Floor	No	Yes (no Top Hat)	7998 and 7816	<ul style="list-style-type: none"> ▶ No FQC support ▶ Ships bottom seal plate
Non-Raised Floor	No	Yes (with Top Hat)	7990 and 7898	<ul style="list-style-type: none"> ▶ Top FQC support ▶ Ships bottom seal plate

A vertical cable management guide (“spine”) can assist with proper cable management for fiber, copper, and coupling cables. A top to bottom spine is present from manufacturing with cable organizer clips that are installed for frames Z and C when present. Frames A and B contain mini-spines that serve the same purpose.

The cable retention clips can be relocated for best usage. All external cabling to the system (from top or bottom) can use the spines to minimize interference with the PDUs that are mounted on the sides of the rack.

The rack with the spine mounted and the optional fiber cable organizer hoops is shown in Figure 2-5. If necessary, the spine, and organizer hoops can be easily relocated for service procedures.

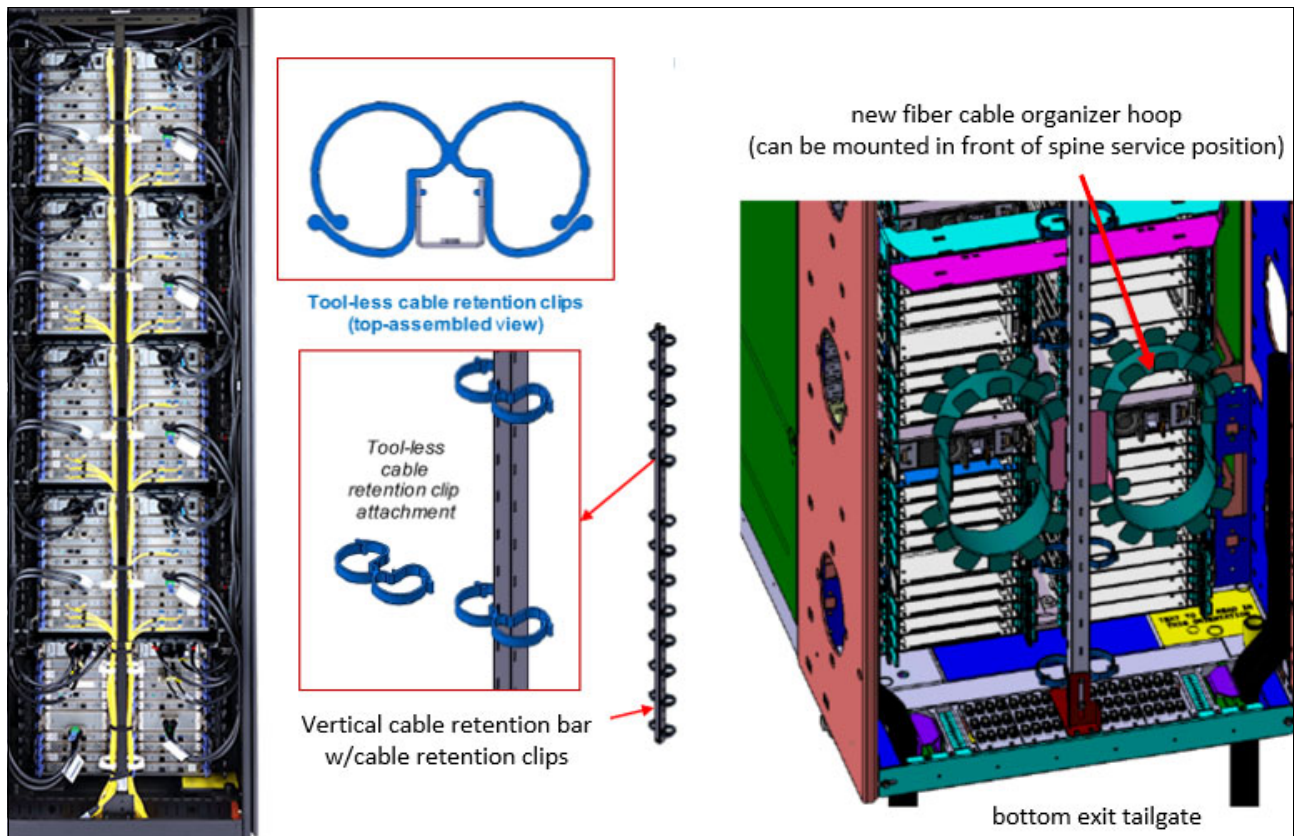


Figure 2-5 I/O cable management spine and fiber cable organizer (rear view)

2.2 CPC drawer

The IBM z16 Model A01 (machine type 3931) features some design changes (compared to IBM z15), primarily with the processor modules and memory packaging in the drawers. An IBM z16 A01 CPC drawer includes the following features:

- ▶ Four Dual chip modules (DCMs)
- ▶ Up to 48 Memory DIMMs
- ▶ Symmetric multiprocessor (SMP) connectivity
- ▶ Connectors to support PCIe+ Gen3 fan-out cards for PCIe+ I/O drawers or coupling fan-outs for coupling links to other CPCs

The IBM z16 A01 can be configured with 1 - 4 CPC drawers (three in the A frame and one in the B frame). A CPC drawer and its components are shown in Figure 2-6.

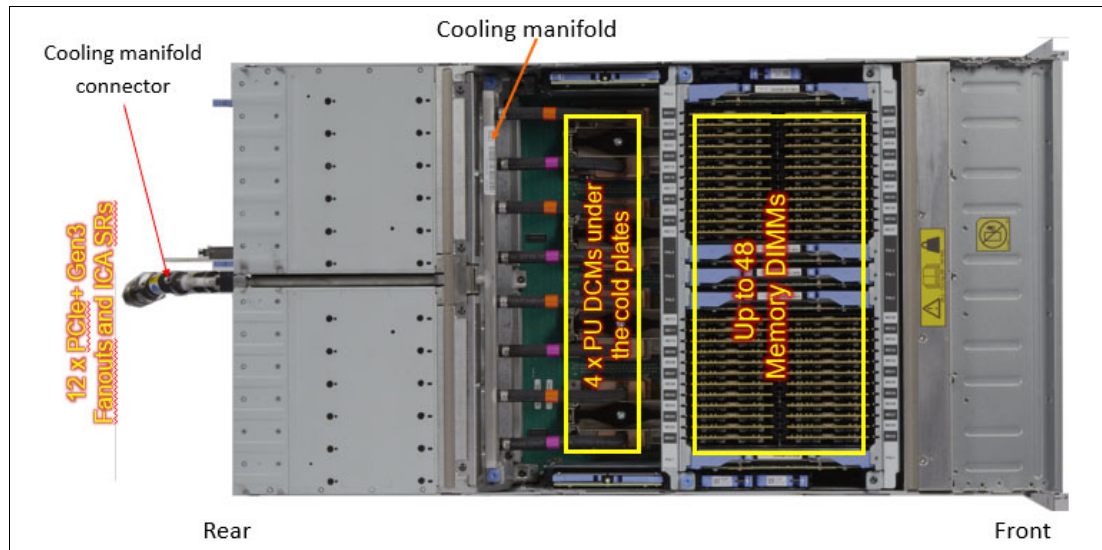


Figure 2-6 CPC drawer components (top view)

The IBM z16 Model A01 5u CPC drawer always contains four Processor Unit (PU) DCMs, and up to 48 memory DIMMs.

Depending on the feature, the IBM z16 A01 contains the following CPC components:

- ▶ The number of CPC drawers installed is driven by the following feature codes:
 - FC 0667: One CPC drawer, Max39, up to 39 characterizable PUs
 - FC 0668: Two CPC drawers, Max82, up to 82 characterizable PUs
 - FC 0669: Three CPC drawers, Max125, up to 125 characterizable PUs
 - FC 0670: Four CPC drawers, Max168, up to 168 characterizable PUs
 - FC 0671: Four CPC drawers, Max200, up to 200 characterizable PUs
- ▶ The following Processor Unit DCM is used:

PU DCM contains two PU chips ([Telum](#)) on one single module that use 7 nm silicon wafer technology, 22.5 billion transistors, and a core that is running at 5.2 GHz (designed with 8 cores per chip, 16 cores per PU DCM).
- ▶ Memory plugging:
 - Six memory controllers per drawer (two each on DCM2/DCM1; one each on DCM3/DCM0)
 - Each memory controller supports eight DIMM slots
 - All eight DIMMs on one memory controller are the same size
 - 4 - 6 memory controllers per drawer are populated (up to 48 DIMMs)
 - Different memory controllers can have different size DIMMs

- ▶ Up to 12 PCIe+ Gen3 fan-out slots that can host:
 - 2-port PCIe+ Gen3 I/O fan-out for PCIe+ I/O drawers (ordered in pairs and connected for availability)
 - ICA SR 1.1 and ICA SR PCIe fan-out for coupling (two ports per feature)
- ▶ Management elements: Two dual function base management controllers (BMC) and oscillator cards (OSC) for system control and to provide system clock (N+1 redundancy).
- ▶ CPC drawer power infrastructure consists of the following components:
 - Three or four Power Supply Units (PSUs) that provide power to the CPC drawer. The loss of one power supply leaves enough power to satisfy the drawer's power requirements (N+1 redundancy). The power supplies can be concurrently removed and replaced individually.
 - 5x 12v distribution point-of-load (POL) that plug in slots that divide the memory banks.
 - 3x Voltage Regulator Modules that plug outside of the memory DIMMs.
 - Two Processor Power Control cards to control the five CPC fans at the front of the CPC drawer, and contain the ambient temperature sensors.
- ▶ Six SMP9 connectors (three pairs for redundancy) that provide the CPC drawer to CPC drawer SMP/NUMA communication.

The front view of the CPC drawer, which includes the cooling fans, BMC/OSC and processor power cards (PPC), is shown in Figure 2-7.

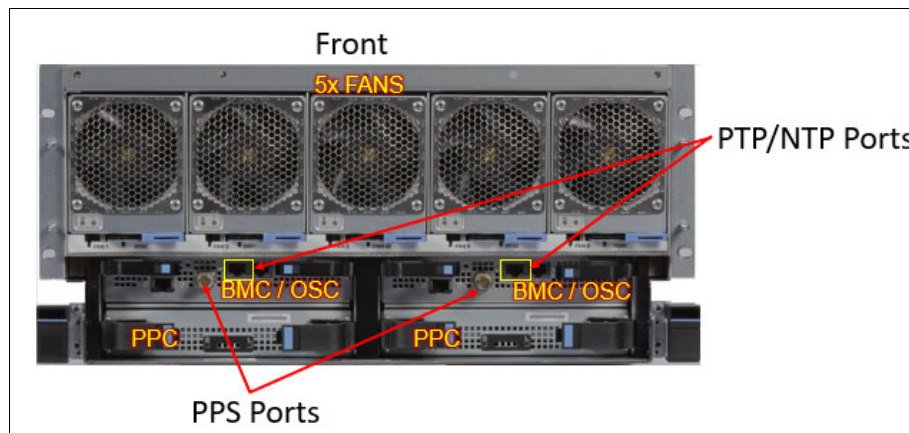


Figure 2-7 Front view of the CPC drawer

The rear view of a fully populated CPC Drawer is shown in Figure 2-8.

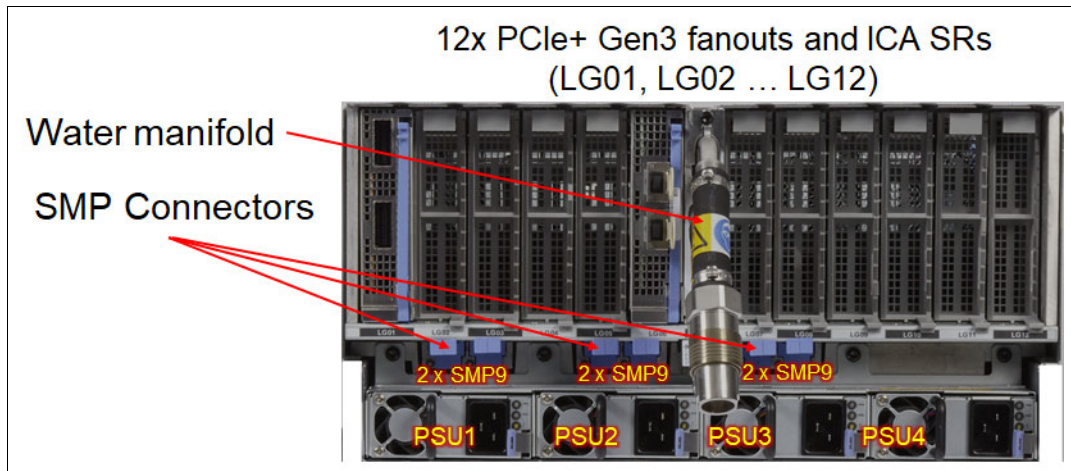


Figure 2-8 Rear view of the CPC drawer

Dual port I/O fan-outs and ICA SR adapters are plugged in specific slots for best performance and availability. Redundant power supplies and six SMP9 ports also are shown. Each pair of SMP9 ports is redundant. If a single cable fails, the repair can be performed concurrently.

The CPC drawer logical structure, component connections are shown in Figure 2-9.

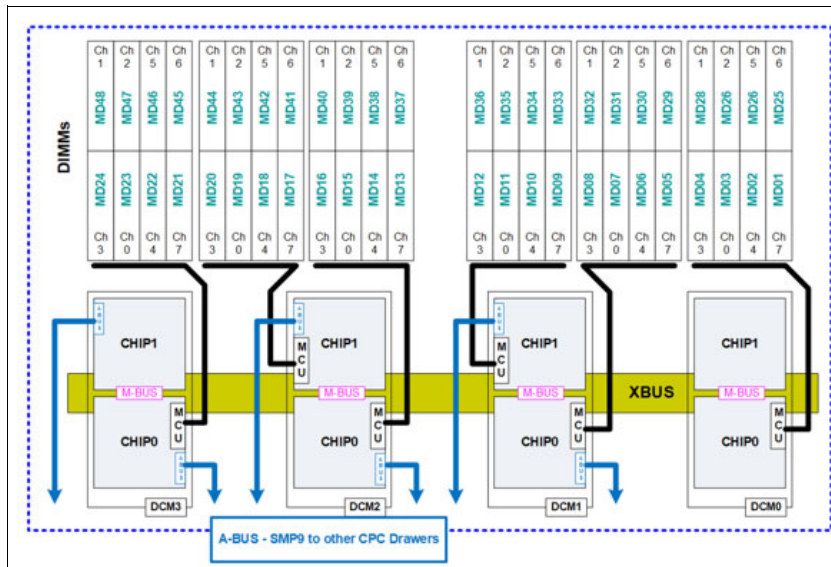


Figure 2-9 CPC drawer logical structure

Memory is connected to the DCMs through memory control units (MCUs). Up to six MCUs are available in a CPC drawer (one or two per DCM) and provide the interface to the DIMM controller. A memory controller uses eight DIMM slots.

The buses are organized in the following configurations:

- ▶ The M-bus provides interconnects between PU chips in the same DCM
- ▶ The X-bus provides interconnects between PU chips to each other, in the same drawer
- ▶ The A-bus provides interconnects between different drawers by using SMP9 cables

2.2.1 CPC drawer interconnect topology

The point-to-point SMP9 connection topology for CPC drawers is shown in Figure 2-10. Each CPC drawer communicates directly to all of the other CPC drawers DCMs by using point-to-point links.

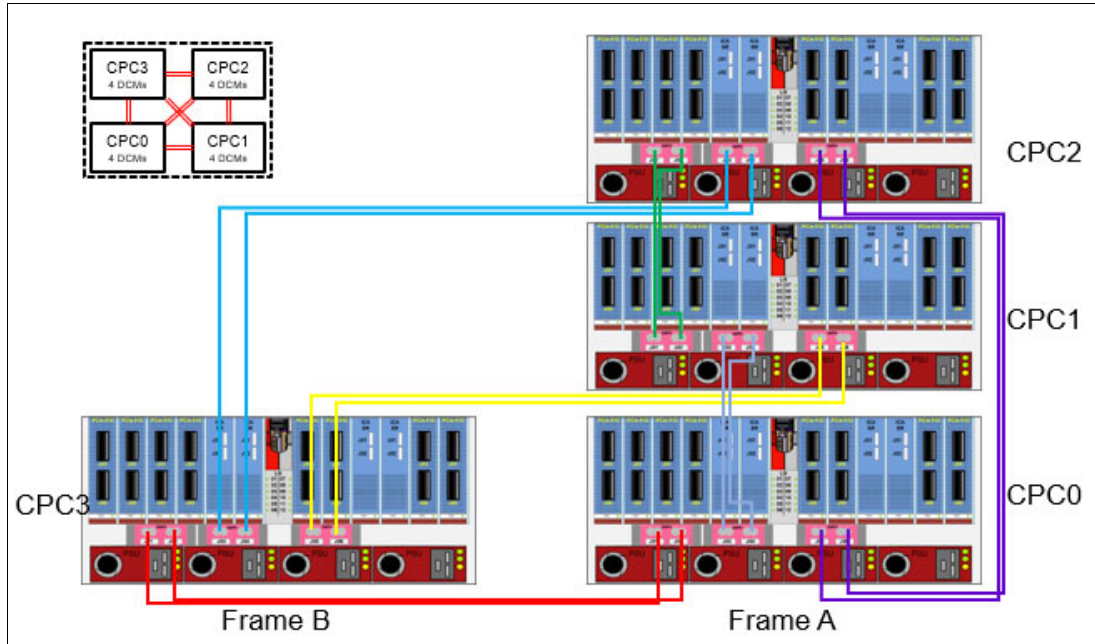


Figure 2-10 Maximum CPC drawer SMP connections (rear view)

The CPC drawers that are installed in Frame A and Frame B are populated from bottom to top.

The order of CPC drawer installation is listed in Table 2-4.

Table 2-4 CPC drawer installation order and position

CPC drawer ^a	CPC0	CPC1	CPC2	CPC3
Installation order	First	Second	Third	Fourth
Position in Frame A	A10B	A15B	A20B	B10B

a. CPC3 is factory-installed only (no field MES available).

CPC drawer installation in the A frame is concurrent. Nondisruptive addition of CPC1 or CPC2 drawers is possible in the field (MES upgrade) if the reserve features (FC 2981 or FC 2982) are included with the initial system order.

Concurrent drawer repair requires a minimum of two CPC drawers.

2.2.2 Oscillator card

With IBM z16 Model A01, the oscillator card design and signal distribution scheme are improved; however, the RAS strategy for redundant clock signal and dynamic switchover is unchanged. One primary OSC card and one backup are used. If the primary OSC card fails, the secondary detects the failure, takes over transparently, and continues to provide the clock signal to the CPC.

Manage System Time

HMC level 2.16.0 (Driver 51) is required to manage system time for IBM z16 Model A01.

Network Time Protocol

The SEs provide the Simple Network Time Protocol (SNTP) client function. When Server Time Protocol (STP) is used, the time of an STP-only Coordinated Timing Network (CTN) can be synchronized to the time that is provided by a Network Time Protocol (NTP) server. This configuration allows time-of-day (TOD) synchronization in a heterogeneous platform environment and throughout the LPARs running on the CPC.

Precision Time Protocol

For IBM z16 Model A01, Precision Time Protocol (PTP, IEEE 1588) also can be used as an external time source for IBM Z Server Time Protocol (STP) for an IBM Z Coordinated Timing Network (CTN). The initial implementation for PTP connectivity is provided by using the IBM Z Support Element (SE).

On IBM z16, the external time source (PTP or NTP) is connected directly to the CPC and bypasses the SE connection. This IBM z16 feature allows more accurate sync with the external time source.

The accuracy of an STP-only CTN is improved by using an NTP or PTP server with the PPS output signal as the External Time Source (ETS). Devices with PPS output are available from several vendors that offer network timing solutions.

Consider the following points:

- ▶ A redesigned card combines the BMC and OSC that are implemented with IBM z16 Model A01. The internal physical cards (BMC and OSC) are separate, but combined as a single FRU because of a packaging design.
- ▶ Two local redundant oscillator cards are available per CPC drawer, each with one PPS port and one ETS port (RJ45 Ethernet, for both PTP and NTP).
- ▶ Current design requires Pulse Per Second signal use for providing maximum time accuracy for both NTP and PTP.
- ▶ An augmented precision oscillator (20 Parts Per Million [PPM] versus 50 PPM on previous systems) is used.
- ▶ The following PPS plugging rules apply (see Figure 2-11 on page 28):
 - Single CPC drawer plugs left and right OSC PPS coaxial connectors.
 - Multi-drawer plug CPC0 left OSC PPS and CPC1 left OSC PPS coaxial connectors.
 - Cables are routed from rear to front by using a pass-through hole in the frame, and under the CPC bezel by using a right-angle Bayonet Neill-Concelman (BNC) connector that provides the pulse per second (PPS) input for synchronization to an external time source with PPS output.
 - Cables are supplied by the customer.

- Connected PPS ports must be assigned in the Manage System Time menus on the HMC.

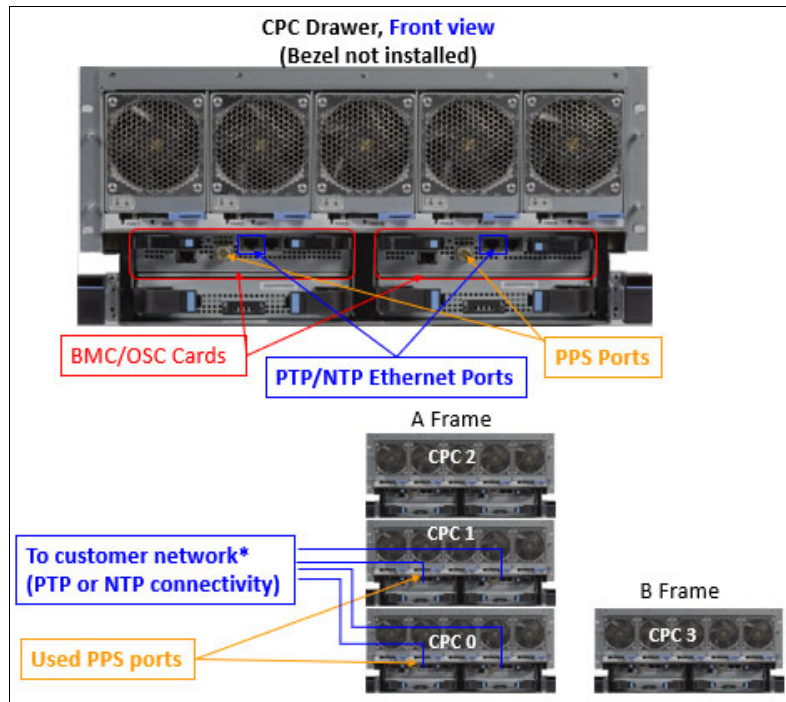


Figure 2-11 Recommended PPS cabling

Tip: STP is available as FC 1021. It is implemented in the Licensed Internal Code (LIC), and allows servers to maintain time synchronization with each other and synchronization to an ETS. In a multi-server STP Coordinated Timing Network (CTN) coupling/timing links are required for STP communication

For more information, see *IBM Z Server Time Protocol Guide*, [SG24-8480](#).

2.2.3 System control

The various system elements are managed through the base management cards (BMCs). The BMC is the replacement for the previous Flexible Support Processors (FSPs) that were used in previous systems.

With IBM z16 Model A01, the CPC drawer BMC is combined with the Oscillator card in a single Field Replaceable Unit (FRU). Two combined BMC/OSC cards are used per CPC drawer.

Also, the PCIe+ I/O drawer has an improved BMC. Each BMC card has one Ethernet port that connects to the internal Ethernet LANs through the internal network switches (SW1, SW2, and SW3, SW4, if configured). The BMCs communicate with the SEs and provide a subsystem interface (SSI) for controlling components.

An overview of the system control design is shown in Figure 2-12.

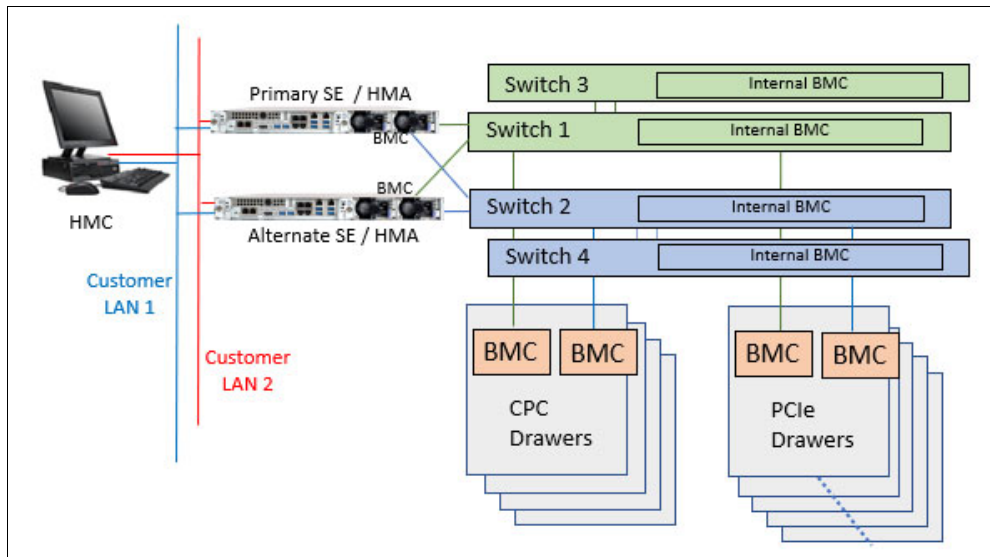


Figure 2-12 Conceptual overview of system control element

Note: The maximum IBM z16 A01 system configuration features four GbE switches, four CPC drawers, and up to 12 PCIe I/O drawers.

A typical BMC operation is to control a power supply. An SE sends a command to the BMC to start the power supply. The BMC cycles the various components of the power supply, monitors the success of each step and the resulting voltages, and reports this status to the SE.

SEs are duplexed ($N+1$), and each element has at least one BMC. Two internal Ethernet LAN switches and two SEs, for redundancy, and crossover connectivity between the LANs, are configured so that both SEs can operate on both LANs.

The Hardware Management Consoles (HMCs) and SEs are connected directly to one or two Ethernet Customer LANs. One or more HMCs can be used.

With IBM z16 current ordered systems, the Hardware Management Appliance (HMA, FC 0129) is the only HMC-orderable feature. The HMA is running on the same hardware (virtual appliance) with the Support Elements (the SE code runs as a guest of the HMA).

2.2.4 CPC drawer power

The power for the CPC drawer is a new design. It uses the following combinations of PSUs, Points of Load (POLs), Voltage Regulator Modules (VRMs), and Processor Power Control Cards:

- ▶ PSUs: Provide AC to 12 V DC bulk or standby power and are installed at the rear of the CPC. The quantity that is installed depends on the following configurations:
 - Three PSUs for configurations that use BPA power
 - Four PSUs for configurations that use PDU power
- ▶ POLs: Seven Point of Load N+2 Redundant cards are installed next to the Memory DIMMs.

- ▶ VRMs: seven Voltage Regulator Modules (N+2 redundancy).
- ▶ Processor Power Control Card (PPC): Redundant processor power and control cards connect to the CPC trail board. The control function is powered from 12 V standby that is provided by the PSU. The PPC card also includes pressure, temperature, and humidity sensors.

2.3 Dual chip modules

The DCM is a multi-layer metal substrate module that holds two PU chips. The PU chip size is 530 mm² and has 22.5 billion transistors. Each CPC drawer has four PU DCMs.

The PU DCM is shown in Figure 2-13. The DCM features a thermal cap that is placed over the chips. Each DCM is water-cooled by way of a cold plate manifold assembly.

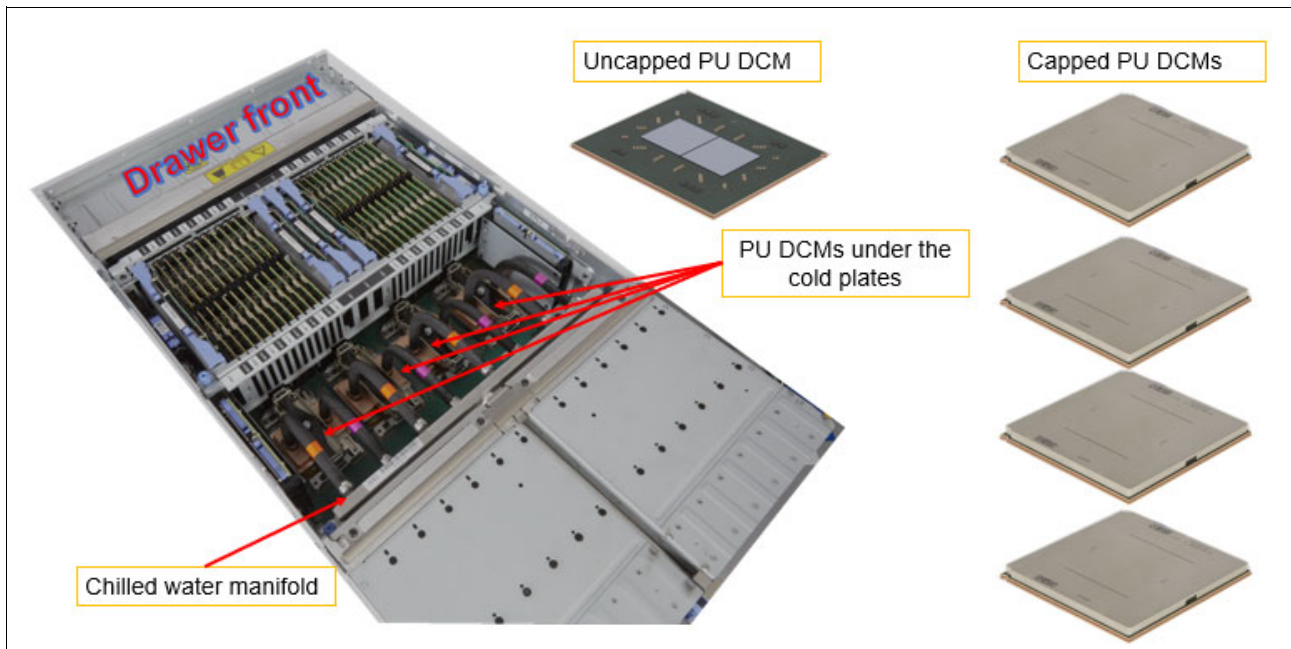


Figure 2-13 Dual chip modules (PU DCM)

PU chips use 7 nm FinFET process, each DCM socket contains 4753 pins, and the module size is 71.5 mm x 79 mm.

The DCMs are each plugged into a socket that is part of the CPC drawer packaging. Each DCM is cooled by water flowing through a manifold assembly where cold plates are attached and used to help remove the heat from the processor chips.

2.3.1 Processor unit chip

A schematic representation of the PU chip is shown in Figure 2-14.

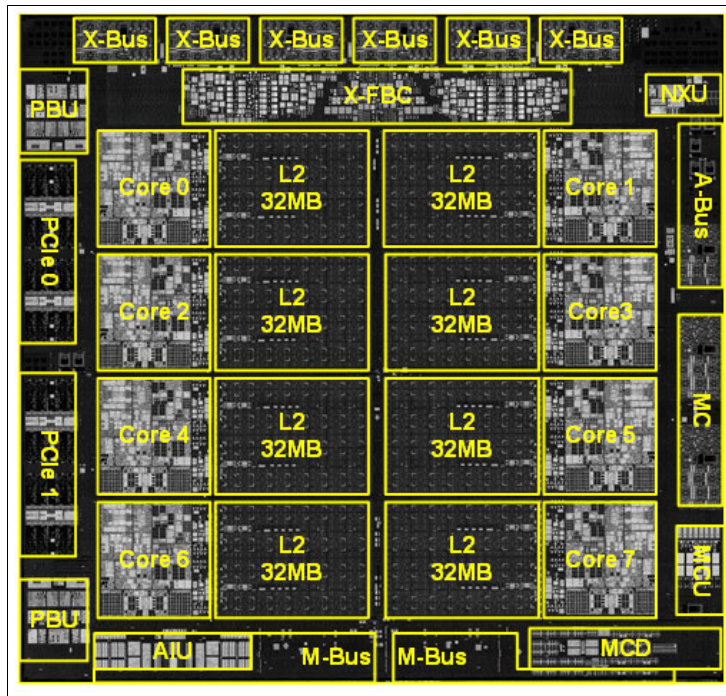


Figure 2-14 Single PU chip floor plan

The IBM z16 Model A01 PU chip (two packaged on each DCM) includes the following features and improvements:

- ▶ 7 nm silicon lithography wafer technology
- ▶ 530 mm² chip size
- ▶ 22.5 billion transistors
- ▶ 5.2 GHz base clock frequency
- ▶ Eight core design (versus 12 for IBM z15) with increased on-chip cache sizes
- ▶ Two PCIe Gen4 interfaces
- ▶ DDR4 memory controller
- ▶ 2x M-Bus to support DCM internal chip to chip connectivity
- ▶ 6x X-Bus to support DCM to DCM connectivity in the CPC drawer
- ▶ 1x A-Bus to support drawer to drawer connectivity
- ▶ New cache structure design compared to IBM z15 PU:
 - L1D(ata) and L1I(nstruction) cache - ON-core (128 kB each)
 - L2 - 32 MB dense SRAM - outside the core, semi-private to the core
 - L3 (virtual) - up to 256 MB
 - L4 (virtual) - up to 2048 MB
- ▶ New Core-Nest Interface compared to IBM z15:

- ▶ Improved branch prediction design by using SRAM
- ▶ On chip Artificial Intelligence Unit (AIU): Deep learning focus for AI inference
- ▶ Significant architecture changes: COBOL compiler and more

2.3.2 Processor unit (core)

Each processor unit, or core, is a superscalar and out-of-order processor that supports 10 concurrent issues to execution units in a single CPU cycle. Figure 2-15 shows the core floor plan, which contains the following units:

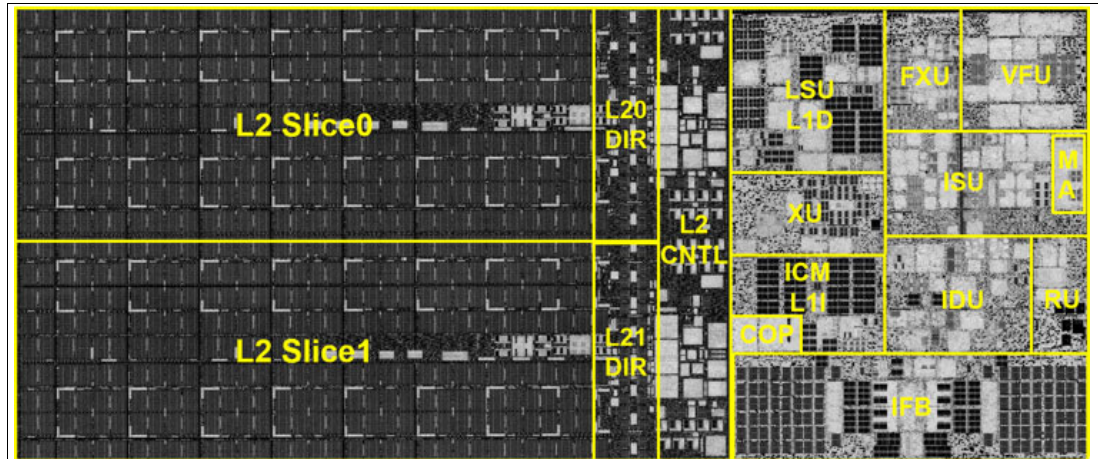


Figure 2-15 Processor core floor plan

- ▶ Fixed-point unit (FXU): The FXU handles fixed-point arithmetic.
- ▶ Load-store unit (LSU): The LSU contains the data cache. It is responsible for handling all types of operand accesses of all lengths, modes, and formats as defined in the z/Architecture.
- ▶ Instruction fetch and branch (IFB) (prediction) and Instruction cache and merge (ICM). These two sub units (IFB and ICM) contain the instruction cache, branch prediction logic, instruction fetching controls, and buffers. Its relative size is the result of the elaborate branch prediction.
- ▶ L1D and L1I are incorporated into the LSU and ICM, respectively.
- ▶ Instruction decode unit (IDU): The IDU is fed from the IFU buffers and is responsible for parsing and decoding of all z/Architecture operation codes.
- ▶ Translation unit (XU): The XU has a large translation lookaside buffer (TLB) and the Dynamic Address Translation (DAT) function that handles the dynamic translation of logical to physical addresses.
- ▶ Instruction sequence unit (ISU): This unit enables the out-of-order (OoO) pipeline. It tracks register names, OoO instruction dependency, and handling of instruction resource dispatch.
- ▶ Instruction fetching unit (IFU) (prediction): These units contain the instruction cache, branch prediction logic, instruction fetching controls, and buffers. Its relative size is the result of the elaborate branch prediction design.
- ▶ Recovery unit (RU): The RU keeps a copy of the complete state of the system that includes all registers, collects hardware fault signals, and manages the hardware recovery actions.

- ▶ Dedicated Co-Processor (CoP): The dedicated coprocessor is responsible for data compression and encryption functions for each core.
 - ▶ Core pervasive unit (PC) for instrumentation and error collection.
 - ▶ Modulo arithmetic (MA) unit: Support for Elliptic Curve Cryptography
- Vector and Floating point Units (VFU):
- BFU: Binary floating point unit
 - DFU: Decimal floating point unit
 - DFx: Decimal fixed-point unit
 - FPD: Floating point divide unit
 - VXx: Vector fixed-point unit
 - VXs: Vector string unit
 - VXp: Vector permute unit
 - VXm: Vector multiply unit
- ▶ L2 – Level 2 cache

2.3.3 PU characterization

The PUs are characterized for client use. The characterized PUs can be used in general to run supported operating systems, such as z/OS, z/VM, and Linux on IBM Z. They also can run specific workloads, such as Java, XML services, IPsec, and some Db2 workloads, or clustering functions, such as the Coupling Facility Control Code (CFCC).

The maximum number of characterizable PUs depends on the IBM z16 Model A01 CPC drawer feature code. Some PUs are characterized for system use; some are characterized for client workload use.

By default, one spare PU is available to assume the function of a failed PU. The maximum number of PUs that can be characterized for client use are listed in Table 2-5.

Table 2-5 PU characterization

Feature	CPs	IFLs	Unassigned IFLs	zIIPs	ICFs	IFPs	Std SAPs	Add'l SAPs	Spare PUs
Max39	0 - 39	0 - 39	0 - 38	0 - 38	0 - 39	2	5	0 - 8	2
Max82	0 - 82	0 - 82	0 - 81	0 - 81	0 - 82		10		
Max125	0 - 125	0 - 125	0 - 124	0 - 124	0 - 125		15		
Max168	0 - 168	0 - 168	0 - 167	0 - 167	0 - 168		20		
Max200	0 - 200	0 - 200	0 - 199	0 - 199	0 - 200		24		

The rule for the CP to zIIP purchase ratio, that for every CP purchased, up to two zIIPs can be purchased has been removed on z16.

Converting a PU from one type to any other type is possible by using the Dynamic Processor Unit Reassignment process. These conversions occur concurrently with the system operation.

Note: The addition of ICFs, IFLs, zIIPs, and SAP to the IBM z16 Model A01 does not change the system capacity setting or its million service units (MSU) rating.

2.3.4 Cache level structure

The cache structure comparison between CPC drawers on IBM z16 A01 and IBM z15 T01 is shown in Figure 2-16.

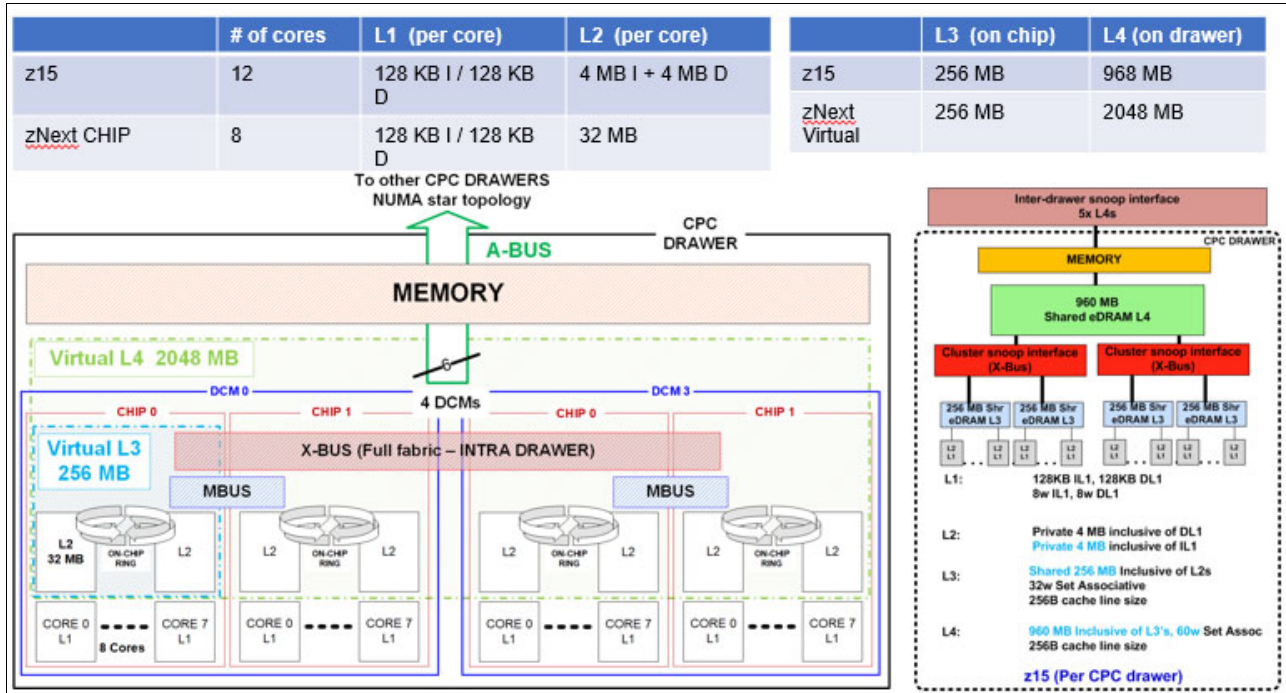


Figure 2-16 Cache structure comparison: IBM z15 versus IBM z16

2.4 PCIe+ I/O drawer

As shown in Figure 2-17, each PCIe+ I/O drawer includes 16 slots to support the PCIe I/O infrastructure with a bandwidth of 16 GBps and includes the following features:

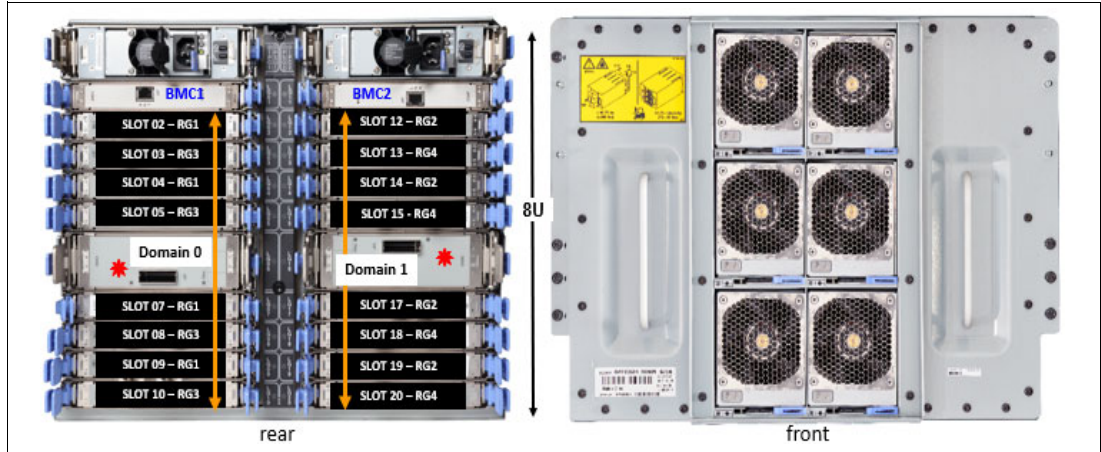


Figure 2-17 PCIe I/O drawer (front and rear view)

- ▶ A total of 16 I/O cards are spread over two I/O domains (0 and 1):
 - Each I/O slot reserves four PCHIDs.
 - Left-side slots are numbered LG01 - LG10 and right side slots are numbered LG11 - LG20 from the rear of the rack. A location and LED identifier panel is at the center of the drawer.
 - With IBM z16 Model A01, the numbering of the PCHIDs is not related to a fixed location in a frame as with previous generations of IBM Z. Instead, the first configured I/O location starts with PCHID 100 and continues the incremental sequence to the next configured PCIe I/O drawer.

For more information about examples of the various configurations, see Appendix E, “Frame configurations Power Distribution Units and Bulk Power Assembly-based systems” on page 533.
- ▶ Two PCIe+ switch cards provide connectivity to the PCIe+ Gen3 fan-outs that are installed in the CPC drawers.
- ▶ Each I/O drawer domain has four dedicated support partitions (two per domain) to manage the native PCIe cards.
- ▶ Two Baseboard Management Controllers (BMC) cards are used to control the drawer function.
- ▶ Redundant N+1 power supplies (two) are mounted on the rear and redundant blowers (six) are mounted on the front.

The following configuration examples and how the configurations are different from the power selection (PDU or BPA), number of CPC drawers and I/O features ordered, the layout of the PCIe+ I/O drawers, and PCHID numbering are shown in Figure 2-18:

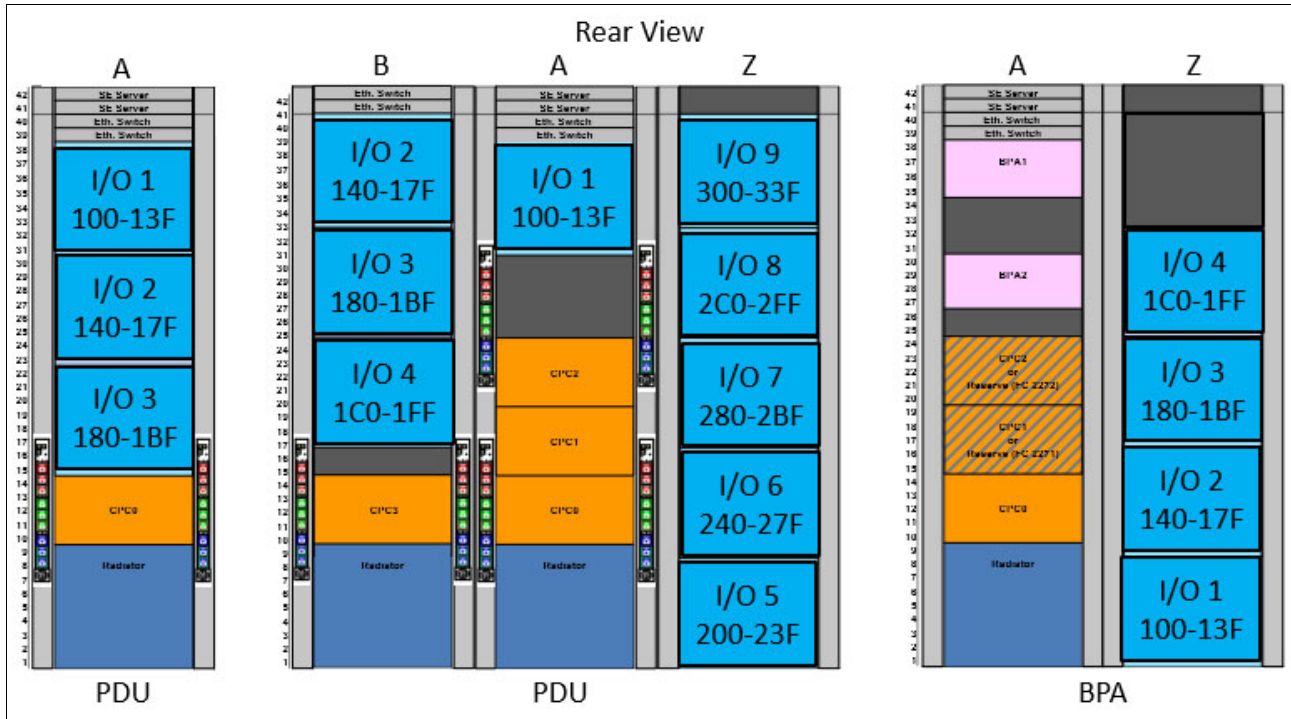


Figure 2-18 Configuration examples with PCHID numbering

- ▶ The first, a single frame system, ordered with PDU power, radiator cooling, one CPC drawer, and greater than 32 I/O features to drive three I/O drawers. PCHID numbering is consecutive from top to bottom.
- ▶ The second, a three frame system, ordered with PDU power, radiator cooling, four CPC drawers, and greater than 128 I/O features to drive nine I/O drawers. PCHID numbering starts in the A-frame, resumes in the B-frame from top down, and continues to the Z-frame working from the bottom up.
- ▶ The third, a two frame system, ordered with BPA, radiator cooling, one CPC drawer, two reserved CPC drawer slots for future CPC drawer add MES, and greater than 48 I/O features to drive four I/O drawers. PCHID numbering starts in the Z-frame, from the bottom and working up.

Consideration for PCHID identification:

In previous PCIe I/O drawers (introduced with zEC12), the orientation of the I/O features were vertical. For IBM z16 Model A01, the orientation of the PCIe features is horizontal. The top of the card is now closest to the center of the drawer for the left and right side of the drawer.

The vertical card collapsed horizontal and the awareness of the port and PCHID layout where the top of the adapter (port D1) is closest to the location panel on both sides of the drawer are shown in Figure 2-19.

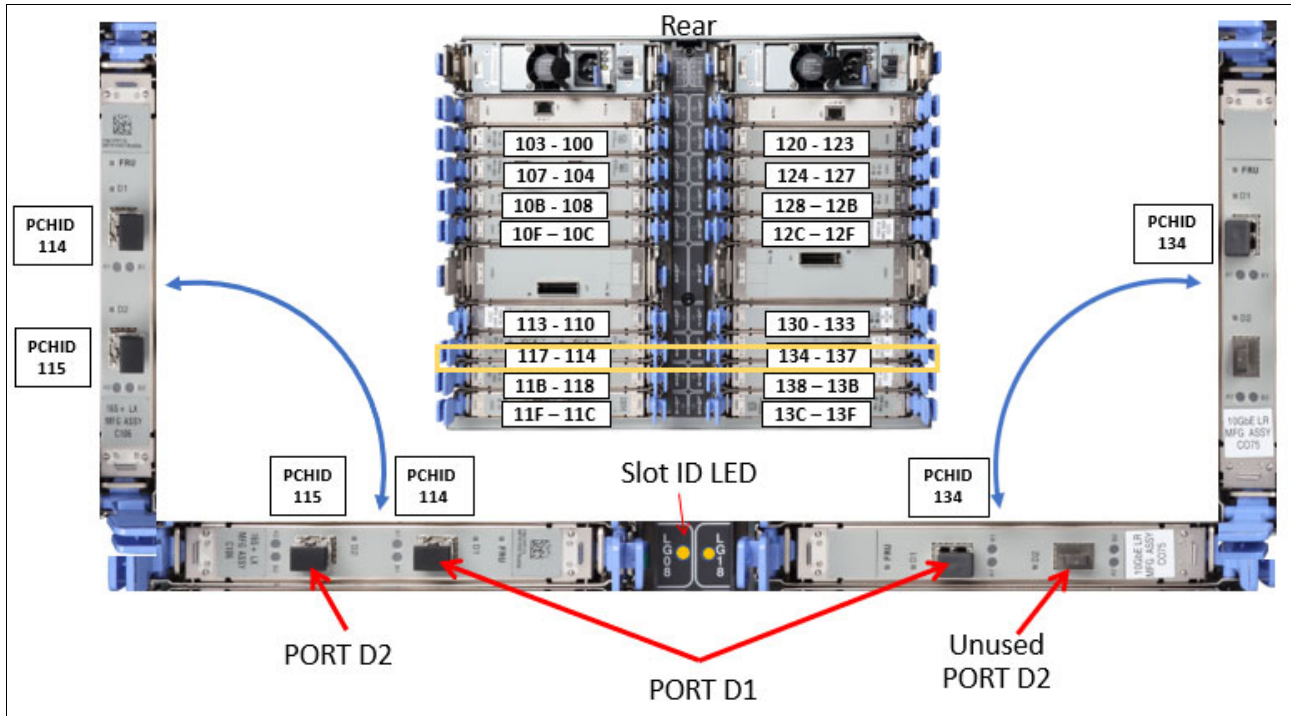


Figure 2-19 I/O feature orientation in PCIe I/O drawer (rear view)

Note: The CHPID Mapping Tool (available on ResourceLink) can be used to print a CHPID Report that displays the drawer and PCHID/CHPID layout.

2.5 Memory

The maximum physical memory size is directly related to the number of CPC drawers in the system. Each CPC drawer can contain up to 10 TB of customer memory, for a total of 40 TB of memory per system.

Note: IBM z16 with Bulk Power Adapter option can be configured with only 5 TB of memory per CPC drawer (BPA systems maximum memory is 20 TB).

The minimum and maximum memory sizes that you can order for each IBM z16 Model T01 feature are listed in Table 2-6.

Table 2-6 Purchased memory that is available for assignment to LPARs

Feature	Number of CPC drawers	Customer memory GB	Flexible memory GB
Max39	1	512 - 9984	NA
Max82	2	512 - 20224	512 - 9984
Max125	3	512 - 30464	512 - 20224
Max168	4	512 - 40704	512 - 30464
Max200	4	512 - 40704	512 - 30464

The following memory types are available:

- ▶ Purchased: Memory that is available for assignment to LPARs.
- ▶ Hardware System Area (HSA): Standard 256 GB of addressable memory for system use outside of customer memory.
- ▶ Standard: Provides minimum physical memory that is required to hold customer purchase memory plus 256 GB HSA.
- ▶ Flexible: Provides more physical memory that is needed to support that activation of base customer memory and HSA on a multiple CPC drawer IBM z16 with one drawer out of service (concurrent drawer replacement; not available on Max39 feature).

The memory granularity, which is based on the installed customer memory, is listed in Table 2-7.

Table 2-7 Customer offering memory increments

Memory increment (GB)	Offered memory sizes (GB)
64	512 - 768
128	896 - 2048
256	2304 - 3840
512	4352 - 17152
1024	18176 - 32512
2048	34560 - 40704

2.5.1 Memory subsystem topology

The IBM z16 memory subsystem uses high-speed, differential-ended communications memory channels to link a host memory to the main memory storage devices.

The CPC drawer memory topology of an IBM z16 is shown in Figure 2-20.

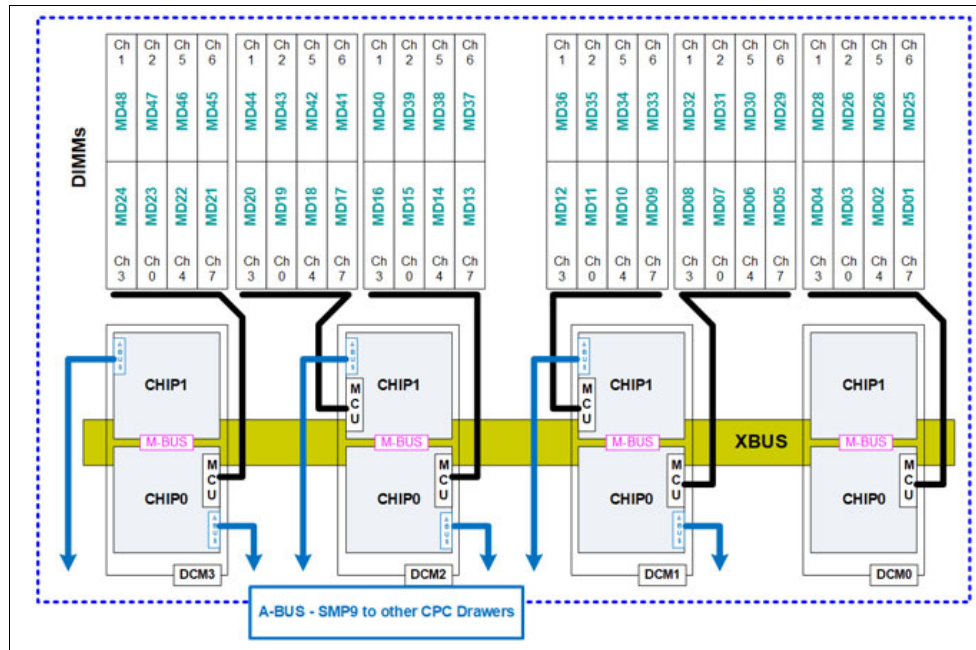


Figure 2-20 CPC drawer memory topology at maximum configuration

Consider the following points regarding the topology:

- ▶ Six memory controllers populated per drawer, one per PU chip (two chips do not have their MCUs populated).
- ▶ Each memory controller supports eight DIMM slots.
- ▶ The eight DIMMs on a controller are all the same size.
- ▶ Four, five, or six memory controllers per drawer are populated (32, 40, or 48 DIMMs).
- ▶ Different memory controllers might have different size DIMMs.
- ▶ Features with different DIMMs sizes can be mixed in the same drawer.
- ▶ The eight DIMMs per MCU must be the same size.
- ▶ Addressable memory is required for partitions and HSA.

2.5.2 Redundant array of independent memory

The IBM z16 Model A01 server uses the enhanced RAIM design. Installed Physical Memory (DIMM capacity) in configuration reports is addressable memory size. Memory is protected by RAIM. DIMM size includes RAIM overhead.

Servers are configured with the most efficient configuration of memory DIMMs that can support Addressable Memory that is required for Customer Ordered Memory plus HSA. In some cases, Available Addressable Memory might be available to support one or more concurrent LIC CC Customer Memory upgrades with no DIMM changes.

IBM z16 implements enhanced RAIM design that includes the following features:

- ▶ Eight Channel Reed-Solomon³ RAIM (IBM z15 uses 5-channel RAIM)
- ▶ 90 → 80 DRAMs accessed across memory channels (11% reduction, excluding unused spare)
- ▶ Staggered Memory Refresh → Leverage RAIM to hide memory refresh penalty
- ▶ z16 Memory Buffer Chip Interface:
 - OpenCapi Memory Buffer (OCMB); Fully (meso)synchronous OCMB
 - Lane sparing replaced with lane degrade
 - 256 B fetch support, remove 128 B store support
- ▶ Up to 2 TB / MCU → 10TB / Drawer (with six MCUs populated)
- ▶ Host-side Memory Encryption

Encryption occurs post-RAIM encoding, decryption pre-RAIM decoding (support unique key per memory channel)

2.5.3 Memory configurations

Memory sizes in each CPC drawer do not have to be similar. RAIM is now built into the bank of eight DIMMs (included in the reported memory; no longer be part of the RAIM memory equation). Consider the following points:

- ▶ A total of 14 configurations that support memory is available per drawer (numbered 22 - 35).
- ▶ Different CPC drawers can contain different amounts of memory.
- ▶ A drawer can have a mix of DIMM sizes (see Table 2-8).
- ▶ Total memory includes HSA. Customer memory is remaining memory that is available to customer after HSA is subtracted.
- ▶ Each drawer contains minimum 1024 GB of memory.

Supported drawer memory configurations are listed in Table 2-8. Each CPC drawer is included from manufacturing with one of these memory configurations.

Table 2-8 Drawer memory plugging configurations (all values in GB)

CFG number	M0CP0 MD01-04 and MD25-28	M1CP0 MD05-08 and MD29-32	M1CP1 MD09-12 and MD33-36	M2CP0 MD13-16 and MD37-40	M2CP1 MD17-20 and MD41-44	M3CP0 MD21-24 and MD45-48	Physical	INC	-HSA 256 GB
22	0	32	32	32	32	0	1024		768
23	0	64	32	64	32	0	1536	512	1280
24	0	64	64	64	64	0	2048	512	1792
25	64	64	64	64	64	0	2560	512	2304
26	64	64	64	64	64	64	3072	512	2816
27	128	64	64	64	64	64	3584	512	3328
28	128	64	64	64	64	128	4096	512	3840
29	128	128	64	64	64	128	4608	512	4352

³ Reed-Solomon error correction

CFG number	M0CP0 MD01-04 and MD25-28	M1CP0 MD05-08 and MD29-32	M1CP1 MD09-12 and MD33-36	M2CP0 MD13-16 and MD37-40	M2CP1 MD17-20 and MD41-44	M3CP0 MD21-24 and MD45-48	Physical	INC	-HSA 256 GB
30	128	128	64	64	128	128	5120	512	4864
31	128	128	128	128	128	128	6144	1024	5888
32	256	128	128	128	128	128	7168	1024	6912
33	256	128	128	128	128	256	8192	1024	7936
34	256	256	128	128	128	256	9216	1024	8960
35	256	256	128	128	256	256	10240	1024	9984

Consider the following points:

- ▶ A CPC drawer contains a minimum of 32 (4x8) 32 GB DIMMs as listed in drawer configuration number 22 in Table 2-8 on page 40.
- ▶ A CPC drawer can have more memory that is installed than what is enabled for customer use. The amount of memory that can be enabled by the customer is the total physically installed memory minus the 256 GB of HSA memory.
- ▶ A CPC drawer can have available unused memory, which can be ordered as a memory upgrade and enabled by LIC-CC concurrently without DIMM changes.
- ▶ DIMM changes require a disruptive power-on reset (POR) on IBM z16 A01 with a single CPC drawer. DIMM changes can be done concurrently on IBM z16 models with multiple CPC drawers using Enhanced Drawer Availability (EDA).
- ▶ CFG numbers from 32 to 35 are used on PDU machines only.
- ▶ BPA machines have an upper limit of CFG number 31.

DIMM plugging for the configurations in each CPC drawer do not have to be similar. Each memory 8-slot DIMM bank must have the same DIMM size; however, a drawer can have a mix of DIMM banks.

The support element View Hardware Configuration task can be used to determine the size and quantity of the memory plugged in each drawer. Figure 2-21 on page 42 shows an example of configuration number 27 from the previous tables, and displays the location and description of the installed memory modules.

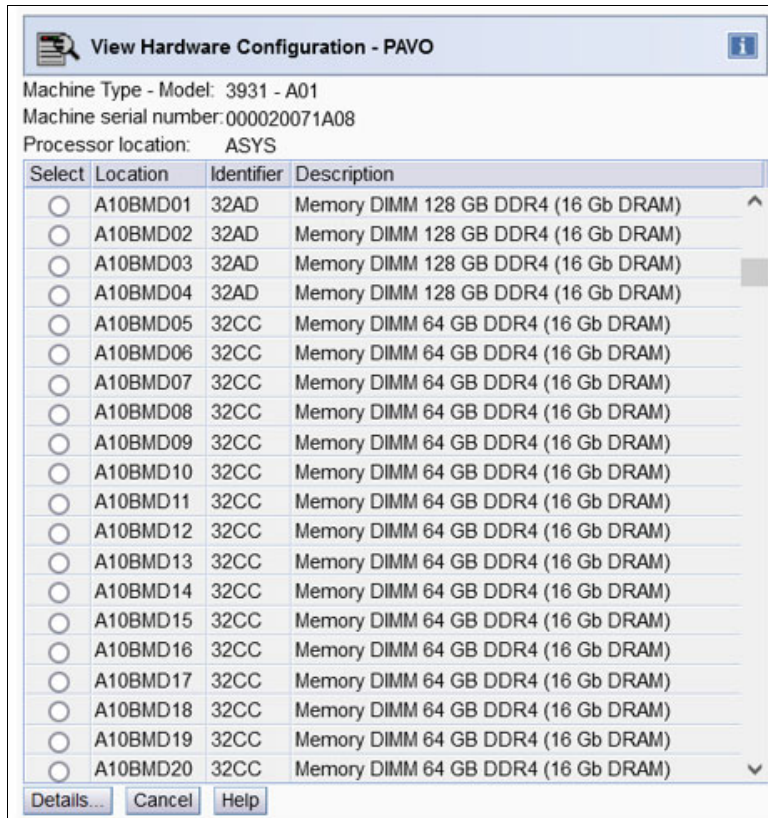


Figure 2-21 View Hardware Configuration task on the Support Element

Table 2-9 on page 43 lists the physical memory plugging configurations by feature code from manufacturing when the system is ordered. Consider the following points:

- ▶ The CPC drawer columns for the specific feature contain the Memory Plug Drawer Configuration number that is referenced in Table 2-8 on page 40 and the Population by DIMM Bank that is listed in Table 2-9 on page 43.
- ▶ Dial Max indicates the maximum memory that can be enabled by way of the LICC concurrent upgrade.

If more storage is ordered by using other feature codes, such as Virtual Flash Memory or Flexible Memory, the extra storage is installed and plugged as necessary.

For example, a customer orders FC 2857 that features 9472 GB customer memory and FC 0669 Max125 (3 CPC drawers). The drawer configurations include the following components:

- ▶ CPC0 (3584 GB), CPC2 (3584 GB) - Configuration #27 and CPC1 (3072 GB) - Configuration #26 (from Table 2-8 on page 40)
- ▶ Total 3584 + 3584 + 3072 - 256 HSA= 9984 GB (Dial Max)

Table 2-9 Memory features and physical plugging

Feature Code	Increments	Customer Memory Increments	Max39		Max82			Max125				Max168 / 200				
			Drawer CPC0	Dial Max	Drawer CPC0	Drawer CPC1	Dial Max	Drawer CPC0	Drawer CPC1	Drawer CPC2	Dial Max	Drawer CPC0	Drawer CPC1	Drawer CPC2	Drawer CPC3	Dial Max
2825	64	512	22	768	22	22	1792	22	22	22	2816	22	22	22	22	3840
2626		576	22	768	22	22	1792	22	22	22	2816	22	22	22	22	3840
2827		640	22	768	22	22	1792	22	22	22	2816	22	22	22	22	3840
2828		704	22	768	22	22	1792	22	22	22	2816	22	22	22	22	3840
2829		768	22	768	22	22	1792	22	22	22	2816	22	22	22	22	3840
2830	128	896	23	1280	22	22	1792	22	22	22	2816	22	22	22	22	3840
2831		1024	23	1280	22	22	1792	22	22	22	2816	22	22	22	22	3840
2832		1152	23	1280	22	22	1792	22	22	22	2816	22	22	22	22	3840
2833		1280	23	1280	22	22	1792	22	22	22	2816	22	22	22	22	3840
2834		1408	24	1792	22	22	1792	22	22	22	2816	22	22	22	22	3840
2835		1536	24	1792	22	22	1792	22	22	22	2816	22	22	22	22	3840
2836		1664	24	1792	22	22	1792	22	22	22	2816	22	22	22	22	3840
2837		1792	24	1792	22	22	1792	22	22	22	2816	22	22	22	22	3840
2838		1920	25	2816	23	23	2816	22	22	22	2816	22	22	22	22	3840
2839		2048	25	2816	23	23	2816	22	22	22	2816	22	22	22	22	3840
2840	256	2304	25	2816	23	23	2816	22	22	22	2816	22	22	22	22	3840
2841		2560	26	2816	23	23	2816	22	22	22	2816	22	22	22	22	3840
2842		2816	26	2816	23	23	2816	22	22	22	2816	22	22	22	22	3840
2843		3072	27	3328	24	24	3840	23	22	23	3840	22	22	22	22	3840
2844		3328	27	3328	24	24	3840	23	22	23	3840	22	22	22	22	3840
2845		3584	28	3840	24	24	3840	23	22	23	3840	22	22	22	22	3840
2846		3840	28	3840	24	24	3840	23	22	23	3840	22	22	22	22	3840

Feature Code	Increments	Customer Memory Increments	Max39		Max82			Max125				Max168 / 200				
			Drawer QPC0	Dial Max	Drawer QPC0	Drawer QPC1	Dial Max	Drawer QPC0	Drawer QPC1	Drawer QPC2	Dial Max	Drawer QPC0	Drawer QPC1	Drawer QPC2	Drawer QPC3	Dial Max
2847	512	4352	30	4864	25	25	4864	24	23	23	4864	23	23	22	23	5376
2848		4864	30	4864	25	25	4864	24	23	23	4864	23	23	22	23	5376
2849		5376	31	5888	26	26	5888	24	24	24	5888	23	23	22	23	5376
2850		5888	31	5888	26	26	5888	24	24	24	5888	24	23	23	24	6912
2851		6400	32	6912	27	27	6912	25	24	25	6912	24	23	23	24	6912
2852		6912	32	6912	27	27	6912	25	24	25	6912	24	23	23	24	6912
2853		7424	33	7936	28	28	7936	26	25	25	7936	25	24	24	24	8448
2854		7936	33	7936	28	28	7936	26	25	25	7936	25	24	24	24	8448
2855		8448	34	8960	29	29	8960	26	26	26	8960	25	24	24	24	8448
2856		8960	34	8960	29	29	8960	26	26	26	8960	25	25	25	25	9984
2857		9472	35	9984	30	30	9984	27	26	27	9984	25	25	25	25	9984
2858		9984	35	9984	30	30	9984	27	26	27	9984	25	25	25	25	9984
2859		10496			31	30	11008	28	27	27	11008	26	26	25	26	11520
2860		11008			31	30	11008	28	27	27	11008	26	26	25	26	11520
2861		11520			31	31	12032	28	28	28	12032	26	26	25	26	11520
2862		12032			31	31	12032	28	28	28	12032	27	26	26	27	13056
2863		12544			32	31	13056	29	28	29	13056	27	26	26	27	13056
2864		13056			32	31	13056	29	28	29	13056	27	26	26	27	13056
2865		13568			32	32	14080	30	29	29	14080	28	27	27	27	14592
2866		14080			32	32	14080	30	29	29	14080	28	27	27	27	14592
2867		14592			33	32	15104	30	30	30	15104	28	27	27	27	14592
2868		15104			33	32	15104	30	30	30	15104	28	28	28	28	16128
2869	15616			33	33	16128	31	30	30	16128	28	28	28	28	16128	
2870	16128			33	33	16128	31	30	30	16128	28	29	28	29	16128	
2871	16640			34	33	17152	31	30	31	17152	29	29	29	29	18176	
2872	17152			34	33	17152	31	30	31	17152	29	29	29	29	18176	

Feature Code	Increments	Customer Memory Increments	Max39		Max82			Max125				Max168 / 200					
			Drawer QPC0	Dial Max	Drawer QPC0	Drawer QPC1	Dial Max	Drawer QPC0	Drawer QPC1	Drawer QPC2	Dial Max	Drawer QPC0	Drawer QPC1	Drawer QPC2	Drawer QPC3	Dial Max	
2873	1024	18176			35	34	18176	32	31	31	19200	29	29	29	29	18176	
2874		19200			35	34	19200	32	31	31	19200	30	30	30	30	20224	
2875		20224			35	35	20224	32	32	32	21248	30	30	30	30	20224	
2876		21248						32	32	32	21248	31	30	30	31	22272	
2877		22272						33	32	33	23296	31	30	30	31	22272	
2878		23296						33	32	33	23296	31	31	31	31	24320	
2879		24320						34	33	33	25344	31	31	31	31	24320	
2880		25344						34	33	33	25344	32	31	31	32	26368	
2881		26368						34	34	34	27392	32	31	31	32	26368	
2882		27392						34	34	34	27392	32	32	32	32	28416	
2883		28416						35	34	35	29440	32	32	32	32	28416	
2884		29440						35	34	35	29440	33	32	32	33	30464	
2885		30464						35	35	35	30464	33	32	32	33	30464	
2886		31488										33	33	33	33	32512	
2887		32512										33	33	33	33	32512	
2888		2048	34560										34	34	34	34	36608
2889			36608										34	34	34	34	36608
2890	38656											35	35	35	35	40704	
2891	40704											35	35	35	35	40704	

2.5.4 Memory upgrades

Memory upgrades can be ordered and enabled by LIC, upgrading the DIMM cards, adding DIMM cards, or adding a CPC drawer.

For a model upgrade that results in the addition of a CPC drawer, the minimum memory increment is added to the system. Each CPC drawer has a minimum physical memory size of 1024 GB.

Memory allowed upgrades for Max200 models

Once a model Max200 is shipped, then the memory upgrades via MES are limited dependent on what configuration exists in the installed CPC drawers.

- ▶ If a CPC drawer is plugged with CFG numbers 22 to 33 (see Table 2-8 on page 40) then the max memory configuration for that CPC drawer is 33
- ▶ If a CPC drawer is plugged with CFG number 34, then the max memory configuration for that CPC drawer is 34
- ▶ If a CPC drawer is plugged with CFG number 35, then it's maxed out anyway.

Model Upgrades

During a model upgrade, adding a CPC drawer is a concurrent operation⁴. Adding physical memory to the added drawer is also concurrent. If all or part of the added memory is enabled for use, it might become available to an active LPAR if the partition includes defined reserved storage. (For more information, see 3.7.3, “Reserved storage” on page 128.) Alternatively, the added memory can be used by a defined LPAR that is activated after the memory is added.

Note: Memory downgrades within an IBM z16 are not supported. Feature downgrades (removal of a CPC quantity feature) are not supported.

2.5.5 Drawer replacement and memory

With EDA, which is supported for IBM z16 A01, sufficient resources must be available to accommodate resources that are rendered unavailable when a CPC drawer is removed for upgrade or repair.

For more information, see 2.7.1, “Redundant I/O interconnect” on page 53.

Removing a CPC drawer often results in removing active memory. With the flexible memory option, removing the affected memory and reallocating its use elsewhere in the system is possible. (For more information, see 2.5.7, “Flexible Memory Option” on page 47.) This process requires more available memory to compensate for the memory that becomes unavailable with the removal of the drawer.

2.5.6 Virtual Flash Memory

IBM Virtual Flash Memory (VFM) FC 0644 offers up to 6.0 TB of virtual flash memory in 512 GB (0.5 TB) increments (a maximum of 12 features for IBM z16 A01) for improved application availability and to handle paging workload spikes.

No application changes are required to change from IBM Flash Express to VFM. Consider the following points:

- ▶ Dialed memory + VFM = total hardware plugged
- ▶ Dialed memory + VFM + Flex memory option = total hardware plugged

VFM helps improve availability and handling of paging workload spikes when z/OS V2.1, V2.2, V2.3, V2.4, or V2.5 is run. With this support, z/OS helps improve system availability and responsiveness by using VFM across transitional workload events, such as market openings and diagnostic data collection. z/OS also helps improve processor performance by supporting middleware use of pageable large (1 MB) pages and to help eliminate delays that can occur when collecting diagnostic data.

VFM also can be used by coupling facility images to provide extended capacity and availability for workloads that use IBM WebSphere MQ Shared Queues structures.

VFM can help organizations meet their most demanding service level agreements and compete more effectively. VFM is easy to configure in the LPAR Image Profile and provides rapid time to value.

⁴ CPC 1 and CPC 2 can be added concurrently in the field if FC 2981 and FC 2982 are ordered with the initial configuration. The addition of a fourth CPC Drawer (CPC 3) is *not* supported. Four CPC drawer systems are factory-built only.

2.5.7 Flexible Memory Option

With the Flexible Memory Option, more physical memory is supplied to support the activation of the purchased memory entitlement in a single CPC drawer that is out of service during activation (POR), or in a scheduled concurrent drawer upgrade (memory add) or drawer maintenance (n+1 repair) with the use of enhanced drawer availability.

When you order memory, you can request extra flexible memory. The extra physical memory, (if required) is calculated by the configuration and priced accordingly.

The required memory DIMMs are installed before shipping and are based on a target capacity that is specified by the customer. These memory DIMMs are enabled by using a Licensed Internal Code Configuration Control (LICCC) order that is placed by the customer when they determine more memory capacity is needed.

The flexible memory sizes that are available for the IBM z16 A01 are listed in Table 2-10.

Table 2-10 Flexible memory offering

Feature Code	Increments	Customer Memory Increments	Max82			Max125				Max168 / 200				
			Drawer CPC0	Drawer CPC1	Dial Max	Drawer CPC0	Drawer CPC1	Drawer CPC2	Dial Max	Drawer CPC0	Drawer CPC1	Drawer CPC2	Drawer CPC3	Dial Max
2825	64	512	22	22	1792	22	22	22	2816	22	22	22	22	3840
2826		576	22	22	1792	22	22	22	2816	22	22	22	22	3840
2827		640	22	22	1792	22	22	22	2816	22	22	22	22	3840
2828		704	22	22	1792	22	22	22	2816	22	22	22	22	3840
2829		768	22	22	1792	22	22	22	2816	22	22	22	22	3840
2830	128	896	22	22	1792	22	22	22	2816	22	22	22	22	3840
2831		1024	23	23	2816	22	22	22	2816	22	22	22	22	3840
2832		1152	23	23	2816	22	22	22	2816	22	22	22	22	3840
2833		1280	23	23	2816	22	22	22	2816	22	22	22	22	3840
2834		1408	23	23	2816	22	22	22	2816	22	22	22	22	3840
2835		1536	24	24	3840	22	22	22	2816	22	22	22	22	3840
2836		1664	24	24	3840	22	22	22	2816	22	22	22	22	3840
2837		1792	24	24	3840	23	23	23	4352	22	22	22	22	3840
2838		1920	24	24	3840	23	23	23	4352	22	22	22	22	3840
2839		2048	25	25	4864	23	23	23	4352	22	22	22	22	3840
2840	256	2304	25	25	4864	23	23	23	4352	22	22	22	22	3840
2841		2560	26	26	5888	23	23	23	4352	22	22	22	22	3840
2842		2816	26	26	5888	23	23	23	4352	22	22	22	22	3840
2843		3072	27	27	6912	24	24	24	5888	23	23	23	23	5888
2844		3328	27	27	6912	24	24	24	5888	23	23	23	23	5888
2845		3584	28	28	7936	24	24	24	5888	23	23	23	23	5888
2846		3840	28	28	7936	24	24	24	5888	23	23	23	23	5888

Feature Code	Increments	Customer Memory Increments	Max82			Max125				Max168 / 200				
			Drawer CPC0	Drawer CPC1	Dial Max	Drawer CPC0	Drawer CPC1	Drawer CPC2	Dial Max	Drawer CPC0	Drawer CPC1	Drawer CPC2	Drawer CPC3	Dial Max
2847	512	4352	29	29	8960	25	25	25	7424	23	23	23	23	5888
2848		4864	30	30	9984	26	26	26	7424	24	24	24	24	7936
2849		5376	31	31	12032	26	26	26	8960	24	24	24	24	7936
2850		5888	31	31	12032	26	26	26	8960	24	24	24	24	7936
2851		6400	32	32	14080	27	27	27	10496	25	25	25	25	9984
2852		6912	32	32	14080	27	27	27	10496	25	25	25	25	9984
2853		7424	33	33	16128	28	28	28	12032	25	25	25	25	9984
2854		7936	33	33	16128	28	28	28	12032	26	26	26	26	12032
2855		8448	34	34	18176	29	29	29	13568	26	26	26	26	12032
2856		8960	34	34	18176	30	30	30	15104	26	26	26	26	12032
2857		9472	35	35	20224	30	30	30	15104	27	27	27	27	14080
2858		9984	35	35	20224	31	31	31	18176	27	27	27	27	14080
2859		10496				31	31	31	18176	27	27	27	27	14080
2860		11008				31	31	31	18176	28	28	28	28	16128
2861		11520				31	31	31	18176	28	28	28	28	16128
2862		12032				32	32	32	21248	28	28	28	28	16128
2863		12544				32	32	32	21248	29	29	29	29	18176
2864		13056				32	32	32	21248	29	29	29	29	18176
2865		13568				32	32	32	21248	29	29	29	29	18176
2866		14080				33	33	33	24320	30	30	30	30	20224
2867		14592				33	33	33	24320	30	30	30	30	20224
2868		15104				33	33	33	24320	30	30	30	30	20224
2869		15616				33	33	33	24320	31	31	31	31	24320
2870		16128				34	34	34	27392	31	31	31	31	24320
2871	16640				34	34	34	27392	31	31	31	31	24320	
2872	17152				34	34	34	27392	31	31	31	31	24320	

Feature Code	Increments	Customer Memory Increments	Max82			Max125				Max168 / 200				
			Drawer CPC0	Drawer CPC1	Dial Max	Drawer CPC0	Drawer CPC1	Drawer CPC2	Dial Max	Drawer CPC0	Drawer CPC1	Drawer CPC2	Drawer CPC3	Dial Max
2873	1024	18176				35	35	35	30464	31	31	31	31	24320
2874		19200				35	35	35	30464	32	32	32	32	28416
2875		20224								32	32	32	32	28416
2876		21248								32	32	32	32	28416
2877		22272								33	33	33	33	32512
2878		23296								33	33	33	33	32512
2879		24320								34	34	34	34	36608
2880		25344								34	34	34	34	36608
2881		26368								34	34	34	34	36608
2882		27392								34	34	34	34	36608
2883		28416								35	35	35	35	40704
2884		29440								35	35	35	35	40704

2.6 Reliability, availability, and serviceability

IBM Z servers continue to deliver enterprise class RAS with IBM z16. The main philosophy behind RAS is about preventing or tolerating (masking) outages. It is also about providing the necessary instrumentation (in hardware, LIC and microcode, and software) to capture or collect the relevant failure information to help identify an issue without requiring a re-creation of the event. These outages can be planned or unplanned, as shown in the following examples:

- ▶ An unplanned outage because of loss of cache coherency
- ▶ An unplanned outage because of a firmware problem
- ▶ A planned outage for a disruptive firmware upgrade
- ▶ A planned outage to add physical memory to a single CPC drawer configuration

The IBM Z hardware has decades of intense engineering behind it, which results in a robust and reliable platform. The hardware has many RAS features that are built into it.

For more information, see Chapter 9, “Reliability, availability, and serviceability” on page 383.

2.6.1 RAS in the CPC memory subsystem

The IBM z16 A01 server includes the following RAS features:

- ▶ Up to 48 DIMM per drawer in two rows (40 TB system maximum):
 - Organized in eight-card RAIM groups:
 - 50% reduced RAIM overhead (compared to IBM z15)
 - RAIM protection (similar to IBM z15)
 - Up to 3 chip marks + 1 channel mark

- DDR4 DRAM with on chip power regulation: N+1 voltage regulators
- Standard Open Memory Interface (OMI); up to 6 OMI per drawer:
 - CRC/Retry for soft errors
 - Degradate bus lanes 4 → 2 on hard error
 - No waiting for all eight cards (use first seven to respond)
- ▶ Concurrent service and upgrade by way of Concurrent Drawer Repair (CDR)

2.6.2 General IBM z16 A01 RAS features

The IBM z16 A01 server includes the following RAS features:

- ▶ The IBM z16 A01 server provides a true N+1 pumps and N+1 fans for the cooling function.
- ▶ The Power/Thermal Subsystem is continued from IBM z15 T01 to IBM z16 A01. It uses switchable, intelligent Power Distribution Units (PDUs), or Bulk Power Assemblies.
- ▶ Redundant (N+1), number of PDUs (up to four pairs, configuration dependent) or BPAs (also configuration-dependent - 2 or 4)
- ▶ CPC drawer is packaged to fit in the 19-inch frame. CPC drawer power and cooling includes the following components:
 - PSUs: AC to 12 V bulk/standby (N+1 redundant). The PSU FRU includes the fan. CPC drawers have three PSUs for BPA-based configurations or four PSUs for PDU-based configurations.
 - N+2 Voltage Regulation Module (VRM): On-point of load cards (POL) or voltage regulation sticks (VRS).
 - Power Processor Control Card: Power control card to control CPC fans (N+1 redundant) and are available in quantities of two.
 - Fans: Drawer has five fans and are N+1 redundant.
 - BMC/OSCs: Redundant (N+1).
- ▶ PU DCMs are all water-cooled.
- ▶ The PCIe+ I/O drawer power supplies for the IBM z16 also are based on the N+1 design. The second power supply can maintain operations and avoid an unplanned outage of the system.
- ▶ N+2 redundant environmental sensors (ambient temperature, relative humidity, and air density⁵).

The internal intelligent Power Distribution Unit (iPDU) provides the following capabilities:

- ▶ Individual outlet control by way of Ethernet:
 - Provide a System Reset capability
 - Power cycle an SE if a hang occurs
 - Verify a power cable at installation
- ▶ System Reset Function:
 - No physical EPO switch is available on the IBM z16, which provides a means for the service technician⁶ to put a server into a known state.
 - This function does not provide the option to power down and keep the power down to the system. The power must be unplugged or the customer-supplied power turned off at the panel.

⁵ The air density sensor measures air pressure and is used to control blower speed.

⁶ This function is available to IBM System Service Representatives (SSRs) only.

- ▶ Other characteristics:
 - PDU Firmware can be concurrently updated
 - Concurrently repairable
 - Power redundancy check
- ▶ Cable verification test by way of PDU:
 - By power cycling individual iPDU outlets, the system can verify proper cable connectivity
 - Power cable test runs during system Power On
 - Runs at system Installation and at every system Power On until the test passes
- ▶ PCIe service enhancements:
 - Mandatory end-to-end cyclic redundancy check (ECRC)
 - Customer operation code is separate from maintenance code
 - Native PCIe firmware stack that is running on the integrated firmware processor (IFP) to manage isolation and recovery

The power service and control network (PSCN) is used to control and monitor the elements in the system and include the following components:

- ▶ Ethernet Top of Rack (TOR) switches provide the internal PSCN connectivity:
 - Switches are redundant (N+1)
 - Concurrently maintainable
 - Each switch has one integrated power supply
 - BMCs are cross wired to the Ethernet switches
- ▶ Redundant SEs

Each SE has two power supplies (N+1) and input power is cross-coupled from the PDUs.
- ▶ Concurrent CPC upgrades

CPC1 to (CPC1 + CPC2) and (CPC1 + CPC2) to (CPC1+CPC2+CPC3) if CPC1 Reserve or CPC2 Reserve features are part of the initial system order (FC 2981 or FC 2982)
- ▶ All PCIe+ I/O drawer MESs are concurrent
- ▶ All LICC model changes are concurrent

System Recovery Boost

With IBM z16, System Recovery Boost feature (first introduced with IBM z15) enables the restoration of service from, and catch up after, planned and unplanned outages faster than on any previous IBM Z with no extra software cost. It also provides faster site switching changeover between systems active in different sites (in a GDPS configured environment).

Service restoration involves speeding up IPL and shutdown operations of an image (LPAR), and short-duration recovery process boosts for specific sysplex and operating system events. For more information see *Introducing IBM Z System Recovery Boost*, [REDP-5563](#).

Important: The base System Recovery Boost capability is built into IBM z16 firmware and does not require ordering of extra features. For IBM z16 A01, System Recovery Boost Upgrade (FC 9930 + FC 6804) is an optional, orderable feature that provides more temporary zIIP capacity for use during boost periods. Consider the following points:

- ▶ FC 9930 is *not* required to use the base System Recovery Boost capability.
- ▶ FC 9930 AND FC 6804 are needed *only* if more zIIP temporary capacity is required.

IBM z16 servers continue to deliver robust server designs through new technologies, hardening innovative and classic redundancy. For more information, see Chapter 9, “Reliability, availability, and serviceability” on page 383.

2.7 Connectivity

Connections to PCIe+ I/O drawers and Integrated Coupling Adapters are driven from the CPC drawer fan-out cards. These fan-outs are installed in the rear of the CPC drawer.

Figure 2-22 shows the location of the fan-out slots. Each slot is identified with a location code (label) of LGxx.

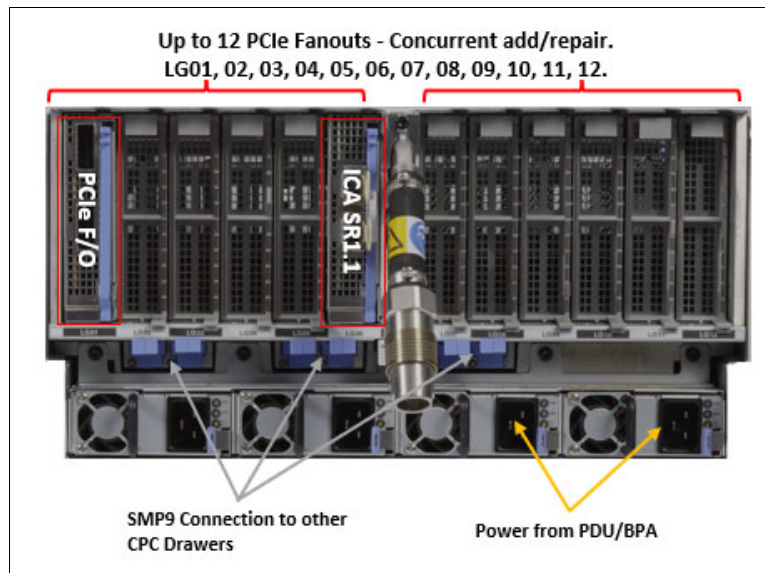


Figure 2-22 Fan out locations in the CPC drawer

Up to 12 PCIe fan-outs (LG01 - LG12) can be installed in each CPC drawer.

A fan-out can be repaired concurrently with the use of redundant I/O interconnect. For more information, see 2.7.1, “Redundant I/O interconnect” on page 53.

The following types of fan-outs are available:

- ▶ PCIe+ Generation 3 dual port fan-out card: This fan-out provides connectivity to the PCIe switch cards in the PCIe+ I/O drawer.
- ▶ Integrated Coupling Adapter (ICA SR1.1 and ICA SR): These adapters provide coupling connectivity to IBM z16, IBM z15, and IBM z14 servers.
- ▶ One, two, or three pairs of redundant SMP9 connectors provide connectivity to the other one, two, or three CPC drawers in the configuration.

When configured for availability, the channels and coupling links are balanced across CPC drawers. In a system that is configured for maximum availability, alternative paths maintain access to critical I/O devices, such as disks and networks. The CHPID Mapping Tool can be used to assist with configuring a system for high availability.

EDA allows a single CPC drawer in a multidrawer CPC to be removed and reinstalled (serviced) concurrently for an upgrade or a repair. Removing a CPC drawer means that the connectivity to the I/O devices that are connected to that CPC drawer is lost. To prevent connectivity loss, the redundant I/O interconnect feature allows you to maintain connection to critical I/O devices installed in PCIe+ I/O Drawers when a CPC drawer is removed. ICA SR1.1 (and ICA SR) can also be installed for coupling and timing links redundancy.

2.7.1 Redundant I/O interconnect

Redundancy is provided for PCIe I/O interconnects.

The PCIe+ I/O drawer supports up to 16 PCIe features, which are organized in two hardware domains (for each drawer). The infrastructure for the fan-out to I/O drawers and external coupling is shown in Figure 2-23.

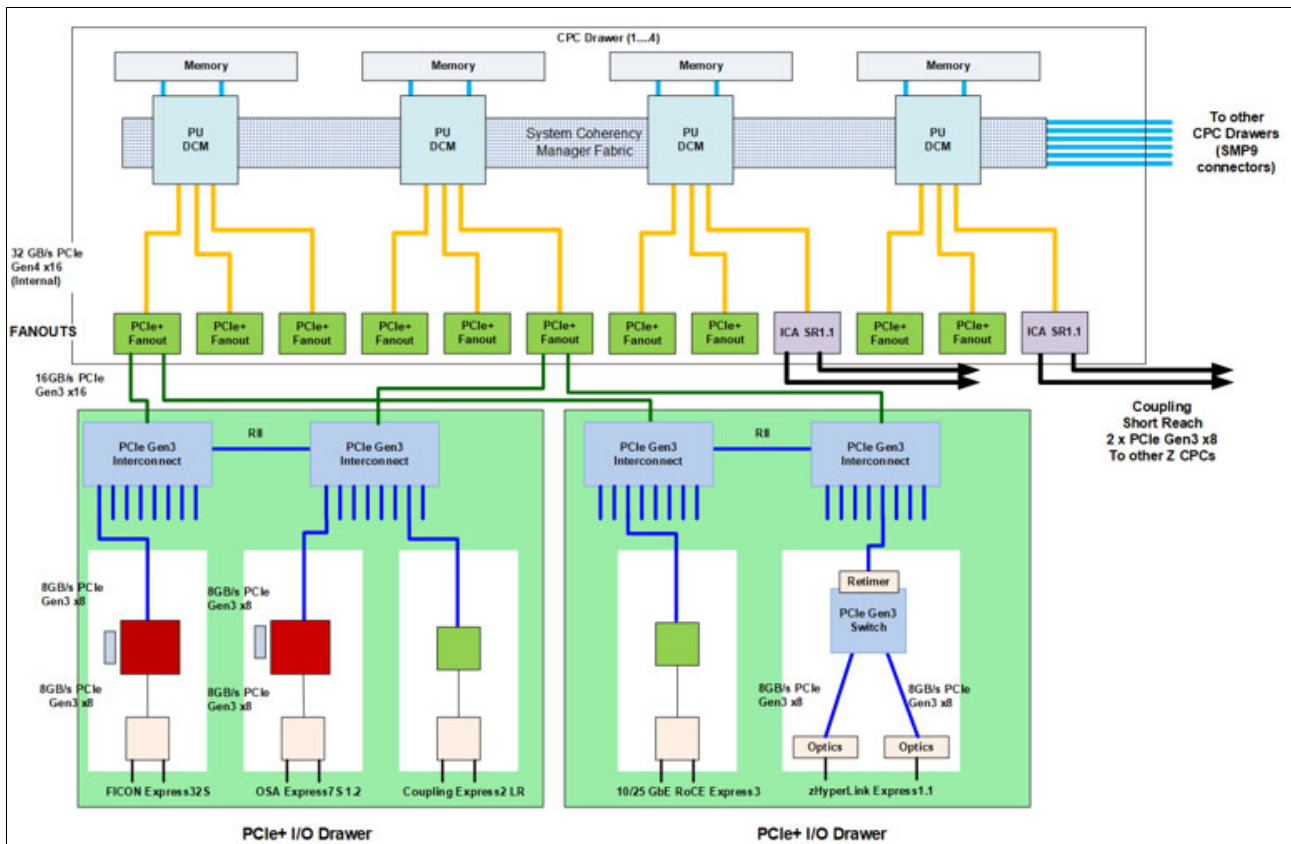


Figure 2-23 Infrastructure for PCIe+ I/O drawer (system with two PCIe+ I/O drawers)

The PCIe+ Gen3 fan-out cards are used to provide the connection from the PU DCM PCIe Bridge Unit (PBU), which uses split the PCIe Gen4 (@32GBps) processor busses into two PCIe Gen3 x16 (@16 GBps) interfaces to the PCIe switch card in the PCIe+ I/O drawer.

The PCIe switch card spreads the x16 PCIe bus to the PCIe I/O slots in the domain.

In the PCIe+ I/O drawer, the two PCIe switch cards (LG06 and LG16, see Figure 2-24) provide a backup path (Redundant I/O Interconnect [RII]) for each other through the passive connection in the PCIe+ I/O drawer backplane.

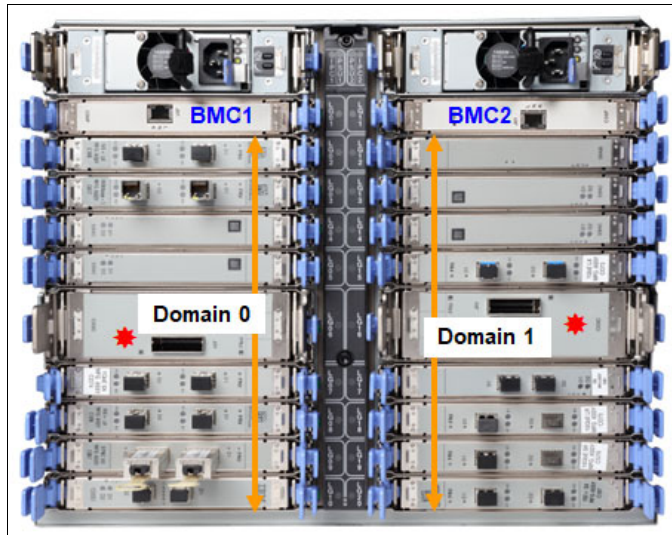


Figure 2-24 PCIe+ I/O drawer locations

During a CPC Drawer PCIe+ Gen3 fan-out or cable failure, all 16 PCIe cards in the two domains can be driven through a single PCIe switch card (see Figure 2-25).

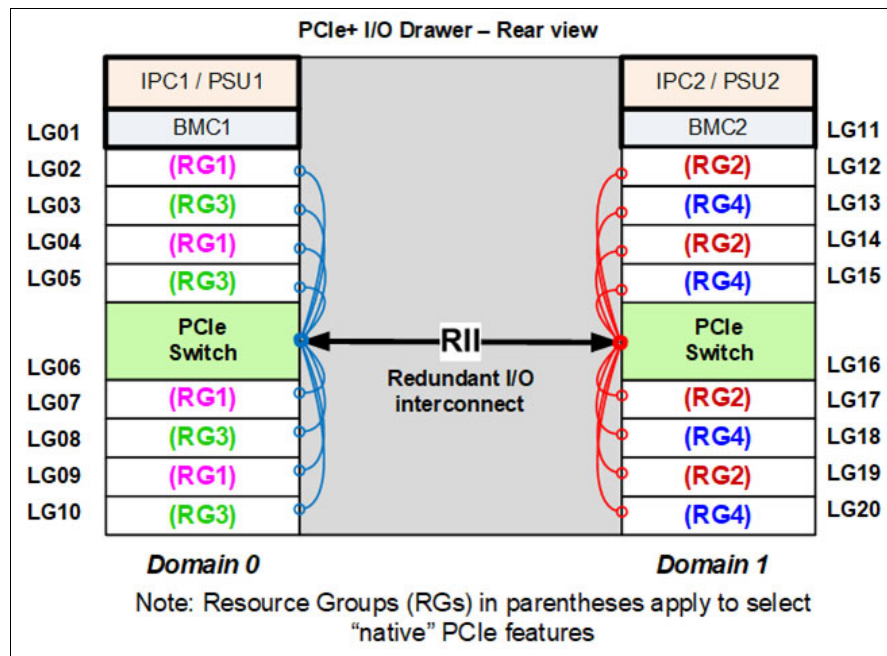


Figure 2-25 Redundant I/O Interconnect

To support RII between domain pair 0 and 1, the two interconnects to each pair must be driven from two different PCIe fan-outs. Normally, each PCIe interconnect in a pair supports the eight features in its domain. In backup operation mode, one PCIe interconnect supports all 16 features in the domain pair.

Note: The PCIe Interconnect (switch) adapter *must* be installed in the PCIe+ I/O drawer to maintain the interconnect across I/O domains. If the adapter is removed (for a service operation), the I/O cards in that domain (up to eight) become unavailable.

2.7.2 Enhanced drawer availability

With EDA, the effect of CPC drawer replacement is minimized. In a multiple CPC drawer system, a single CPC drawer can be concurrently removed and reinstalled for an upgrade or repair. Removing a CPC drawer without affecting the workload requires sufficient resources in the remaining CPC drawer.

Before removing the CPC drawer, the contents of the PUs and memory of the drawer must be relocated. PUs must be available on the remaining CPC drawers to replace the deactivated drawer. Also, sufficient redundant memory must be available if no degradation of applications is allowed.

To ensure that the CPC configuration supports removal of a CPC drawer with minimal effect on the workload, consider the flexible memory option. Any CPC drawer can be replaced, including the first CPC drawer that initially contains the HSA.

Removal of a CPC drawer also removes the CPC drawer connectivity to the PCIe I/O drawers, and coupling links. The effect of the removal of the CPC drawer on the system is limited by the use of redundant I/O interconnect. (For more information, see 2.7.1, “Redundant I/O interconnect” on page 53.) However, all ICA SR1.1 links that are installed in the removed CPC drawer must be configured offline.

If the enhanced drawer availability and flexible memory options are *not* used when a CPC drawer must be replaced, the memory in the failing drawer also is removed. This process might be necessary during an upgrade or a repair action.

Until the removed CPC drawer is replaced, a power-on reset of the system with the remaining CPC drawers is supported. The CPC drawer then can be replaced and added back into the configuration concurrently.

2.7.3 CPC drawer upgrade

All fan-outs that are used for I/O and coupling links are rebalanced concurrently as part of a CPC drawer addition to support better RAS characteristics.

2.8 Model configurations

When an IBM z16 is ordered, the PUs are characterized according to their intended usage. The PUs can be ordered as any of the following items:

CP	The processor is purchased and activated. PU supports running the z/OS, z/VSE, z/VM, z/TPF, and Linux on IBM Z ⁷ operating systems. It also can run Coupling Facility Control Code.
IFL	The Integrated Facility for Linux (IFL) is a processor that is purchased and activated for use by z/VM for Linux guests and Linux on IBM Z ⁷ operating systems.
Unassigned IFL	A processor that is purchased for future use as an IFL. It is offline and cannot be used until an upgrade for the IFL is installed. It does not affect software licenses or maintenance charges.
ICF	An internal coupling facility (ICF) processor that is purchased and activated for use by the Coupling Facility Control Code.
Unassigned ICF	A processor that is purchased for future use as an ICF. It is offline and cannot be used until an upgrade for the ICF is installed. It does not affect software licenses or maintenance charges.
zIIP	An “Off Load Processor” for workload that supports applications such as DB2 and z/OS Container Extensions. It also can be used for “System Recovery Boost” on page 51.
Unassigned zIIP	A processor that is purchased for future use as zIIP. It is offline and cannot be used until an upgrade for the zIIP is installed. It does not affect software licenses or maintenance charges.
Additional SAP	An optional processor that is purchased and activated for use as SAP (System Assist Processor).

A minimum of one PU that is characterized as a CP, IFL, or ICF is required per system. The maximum number of characterizable PUs is 200. The maximum number of zIIPs is up to twice the number of PUs that are characterized as CPs.

The following components are present in the IBM z16, but they are not part of the PUs that clients purchase and require no characterization:

- ▶ SAP to be used by the channel subsystem. The number of predefined SAPs depends on the IBM z16 model.
- ▶ Two IFPs, which are used in the support of designated features and functions, such as RoCE (all features), Coupling Express2 LR, zHyperLink Express 1.1, Internal Shared Memory (ISM) SMC-D, and other management functions.
- ▶ Two spare PUs, which can transparently assume any characterization during a permanent failure of another PU.

⁷ The KVM hypervisor is part of supported Linux on IBM Z distributions.

The IBM z16 uses features to define the number of PUs that are available for client use in each configuration. The models are listed in Table 2-11.

Table 2-11 IBM z16 processor configurations

Feature	CPC Drawers	PUs per drawer	Active PUs				zIIP	IFP	Opt SAPs	Base SAPs	Spares
			CPs	IFLs	ICFs	uIFLs					
Max39	1	48	0 - 39	0 - 39	0 - 39	0 - 38	0 - 25	2	0 - 8	5	2
Max82	2	48	0 - 82	0 - 82	0 - 82	0 - 81	0 - 54	2		10	2
Max125	3	48	0 - 125	0 - 125	0 - 125	0 - 124	0 - 82	2		15	2
Max168	4	48	0 - 168	0 - 168	0 - 168	0 - 167	0 - 110	2		20	2
Max200	4	57	0 - 200	0 - 200	0 - 200	0 - 199	0 - 132	2		24	2

- ▶ Not all PUs available on a model are required to be characterized with a feature code. Only the PUs purchased by a customer are identified with a feature code.
- ▶ zIIP maximum quantity for new build systems follows the 2:1 ratio. It might be greater if present during MES upgrades.
- ▶ All PU conversions can be performed concurrently.

A *capacity marker* identifies the number of CPs that were purchased. This number of purchased CPs is higher than or equal to the number of CPs that is actively used. The capacity marker marks the availability of purchased but unused capacity that is intended to be used as CPs in the future. This status often is present for software-charging reasons.

Unused CPs are not a factor when establishing the millions of service units (MSU) value that is used for charging monthly license charge (MLC) software, or when charged on a per-processor basis.

2.8.1 Upgrades

Concurrent upgrades of CPs, IFLs, ICFs, zIIPs, or SAPs are available for the IBM z16. However, concurrent PU upgrades require that more PUs are installed but not activated.

Spare PUs are used to replace defective PUs. Two spare PUs always are on an IBM z16 A01 server. In the rare event of a PU failure, a spare PU is activated concurrently and transparently and is assigned the characteristics of the failing PU.

If an upgrade request cannot be accomplished within the configuration, a hardware upgrade is required.

The following upgrade paths for the IBM z16 are shown in Figure 2-26:

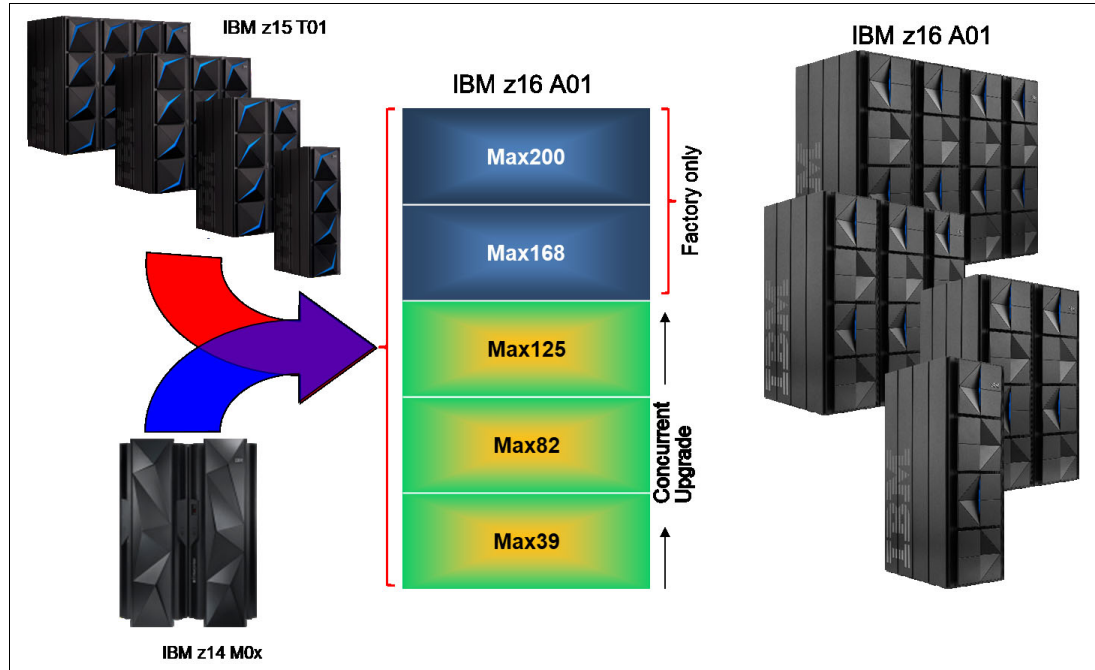


Figure 2-26 IBM z16 A01 system upgrade paths

- ▶ IBM z16 A01 to IBM z16 A01 upgrades:
 - Max39 - Max82, Max125 are concurrent (if FC 2981 or 2982 initially ordered)
 - No upgrade to Max168 or Max200 (these features are factory-built only)
 - More I/O drawers can be added based on available space in current frames or I/O expansion frames
- ▶ Any IBM z14 (M/T 3906) to IBM z16 A01:
 - Feature conversion of installed zAAPs to zIIPs (default) or another processor type
 - For installed On-Demand Records, change temporary zAAPs to zIIPs (stage the record)
- ▶ Any IBM z15 (M/T 8561) - IBM z16 A01
- ▶ IBM z16 (M/T 3931) - IBM z16 A01:
 - Model to model MAXxx upgrades cannot be performed if I/O drawers are populating the CPC drawer positions.
 - Supported model upgrade paths are listed in Table 2-12.

Table 2-12 Supported model MAXxx upgrade paths

	Max39	Max82	Max125	Max168	Max200
Max39	N	Y	Y	N	N
Max82	N	N	Y	N	N
Max125	N	N	N	N	N
Max168	N	N	N	N	N
Max200	N	N	N	N	N

2.8.2 Model capacity identifier

To recognize how many PUs are characterized as CPs, the Store System Information (STSI) instruction returns a Model Capacity Identifier (MCI). The MCI determines the number and speed of characterized CPs.

Characterization of a PU as an IFL, ICF, or zIIP is not reflected in the output of the STSI instruction because characterization has no effect on software charging. For more information about STSI output, see “Processor identification” on page 378.

The following distinct model capacity identifier ranges are recognized (one for full capacity and three for granular capacity):

- ▶ For full-capacity engines, model capacity identifiers 701 - 7K0 are used. They express capacity settings for 1 - 200 characterized CPs.
- ▶ Three model subcapacity identifier ranges offer a unique level of granular subcapacity engines at the low end. They are available for up to 39 characterized CPs. These three subcapacity settings are applied to up to 39 CPs, which combined offer 117 more capacity settings, as described next.

Granular capacity

The IBM z16 A01 server offers 117 capacity settings (granular capacity) for up to 39 CPs. When subcapacity settings are used, PUs beyond 39 can be characterized only as specialty engines. For models with more than 39 CPs, all CPs are running at full capacity (7xx).

The three defined ranges of subcapacity settings include model capacity identifiers numbered 401- 439, 501 - 539, and 601 - 639.

Consideration: All CPs have the same capacity identifier. Specialty engines (IFLs, zIIPs, and ICFs) operate at full speed.

List of model capacity identifiers

Regardless of the number of CPC drawers, a configuration with one characterized CP is possible, as listed in Table 2-13.

Table 2-13 Model capacity identifiers

Feature	Model capacity identifier
Max39	701 - 739, 601 - 639, 501 - 539, and 401 - 439
Max82	701 - 782, 601 - 639, 501 - 539, and 401 - 439
Max125	701 - 7C5, 601 - 639, 501 - 539, and 401 - 439
Max168	701 - 7G8, 601 - 639, 501 - 539, and 401 - 439
Max200	701 - 7K0, 601 - 639, 501 - 539, and 401 - 439

For more information about temporary capacity increases, see Chapter 8, “System upgrades” on page 331.

2.9 Power and cooling

The IBM z16 A01 power and cooling system is similar to IBM z15 T01 systems, which is packaged in an industry-standard, 19-inch form factor frame for all the internal system elements. The configuration can consist of 1 - 4 frames.

Consider the following points:

- ▶ The power subsystem is based on the following offerings:
 - Power Distribution Units (PDUs) that are mounted at the rear of the system in pairs
 - Bulk Power Assembly (BPA), as with previous systems
- ▶ The system uses 3-phase power:
 - Low voltage 4 wire “Delta”
 - High voltage 5 wire “Wye”
- ▶ No EPO (emergency power off) switch.
IBM z16 has a support element task to simulate the EPO function (used only when necessary to perform a System Reset Function).
- ▶ No DC input feature is available.
- ▶ The IBM z16 A01 system has a radiator unit (RU) with N+1 design for the pumps and blowers.
- ▶ The 19-inch frame is capable of top or bottom exit of power. All power cords are 4.26 meters (14 feet). Combined with the Top Exit I/O Cabling feature, more options are available when you are planning your computer room cabling.
- ▶ The new PSCN structure uses industry standard Ethernet switches (up to four).

2.9.1 PDU-based configurations

The IBM Z operate with redundant power infrastructure. The IBM z16 A01 is designed with a new power infrastructure that is based on intelligent PDUs that are mounted vertically on the rear side of the 19-inch racks and Power Supply Units for the internal components. The PDU configuration supports radiator-cooled systems only.

The PDUs are controlled by using an Ethernet port and support the following input:

- ▶ 3-phase 200 - 240 V AC (4-wire “Delta”)
- ▶ 3-phase 380 - 415 V AC (5-wire “Wye”)

The power supply units convert the AC power to DC power that is used as input for the Point of Loads (POLs) in the CPC drawer and the PCIe+ I/O drawers.

The power requirements depend on the number of CPC drawers (1 - 4), number of PCIe I/O drawers (0 - 12) and I/O features that are installed in the PCIe I/O drawers.

PDUs are installed and serviced from the rear of the frame. Unused power ports *never* should be used by any external device.

A schematic view of a maximum that is configured system with PDU-based power is shown in Figure 2-27.

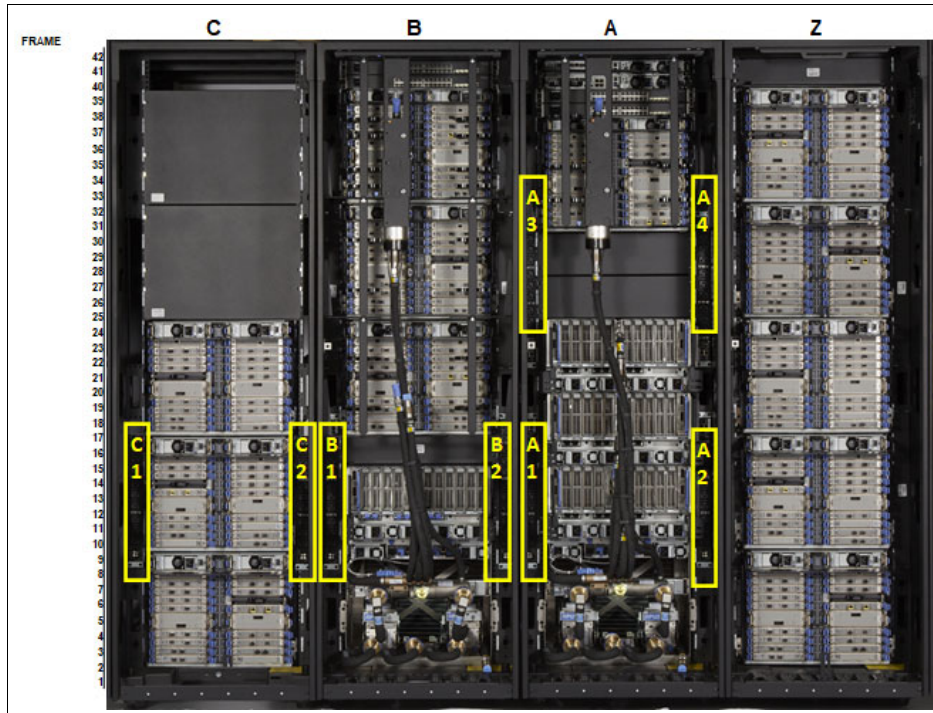


Figure 2-27 Rear view of maximum configured system PDU power

Each PDU installed requires a customer-supplied power feed. The number of power cords that are required depends on the system configuration.

Note: For initial installation, all power sources are required to run the system checkout diagnostics successfully.

PDUs are installed in pairs. A system can have 2, 4, 6, or 8 PDUs, depending on the configuration. Consider the following points:

- ▶ Paired PDUs are A1/A2, A3/A4, B1/B2, and C1/C2.
- ▶ From the rear of the system, the odd-numbered PDUs are on the left side of the rack; the even-numbered PDUs are on the right side of the rack.
- ▶ The total loss of one PDU in a pair does not affect the system operation.

Components that plug into the PDUs for redundancy (by using two power cords) include the following features:

- ▶ CPC Drawers, PCIe+ I/O drawers, Radiators, and Support Elements
- ▶ The redundancy for each component is achieved by plugging the power cables into the paired PDUs.

For example, the top Support Element (1), has one power supply plugged into PDU A1 and the second power supply plugged into the paired PDU A2 for redundancy.

Note: Customer power sources should always maintain redundancy across PDU pairs; that is, one power source or distribution panel supplies power for PDU A1 and the separate power source or distribution panel supplies power for PDU A2.

As a best practice, connect the odd-numbered PDUs (A1, B1, C1, and D1) to one power source or distribution panel, and the even-numbered PDUs (A2, B2, C2, and D2) to a separate power source or distribution panel.

The frame count rules (number of frames) for IBM z16 A01 are listed in Table 2-14.

Table 2-14 Frame count rules for IBM z16 A01

Frame Count	I/O drawers												
CPC drawers	0	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	1	2	2	2	2	2	3	3	3	3
2	1	1	1	2	2	2	2	2	3	3	3	3	3
3	1	1	2	2	2	2	2	3	3	3	3	3	N/A
4	2	2	2	2	2	3	3	3	3	3	4	4	4

The number of CPC drawers and I/O drawers determines the number of racks in the system and the number of PDUs in the system.

The PDU/line cord rules (number of PDU/Cord pairs) for IBM z16 A01 are listed in Table 2-15.

Table 2-15 PDU/line cord rules (# PDU/Cord pairs) for IBM z16 A01

PDU/Linecord	I/O drawers												
CPC drawers	0	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	1	2	2	2	2	2	3	3	3	3
2	2	2	2	2	2	2	2	2	3	3	3	3	3
3	2	2	2	2	2	2	2	3	3	3	3	3	N/A
4	3	3	3	3	3	3	3	3	3	4	4	4	4

2.9.2 Bulk Power Assembly-based configurations

The BPA configuration is the feature that allows customers to have truly redundant power cords with phase loss protection. Characteristics are similar to previous IBM Z, but BPA was redesigned to fit into the 19-inch frame.

No PDUs are installed in this configuration; instead, 1 or 2 pairs of BPAs are installed that house the bulk power distribution to all the components, and the Bulk Power Regulators (BPR).

With BPA-based configurations, 3-phase balanced power feature is supported. BPA-based systems support radiator-cooled systems.

The BPAs support 2- or 4-line cords with a single universal type of 3-phase 200 - 480 V AC.

The power supply units convert the regulated high-voltage DC power (supplied by BPA) to DC power that is used as input for the Points of Load (POLs) in the CPC drawer and the PCIe+ I/O drawers.

The power requirements depend on the number of CPC drawers (1 -4), number of PCIe I/O drawers (0 - 10), and I/O features that are installed in the PCIe+ I/O drawers.

A schematic view of a maximum configured system with BPA power is shown in Figure 2-28.

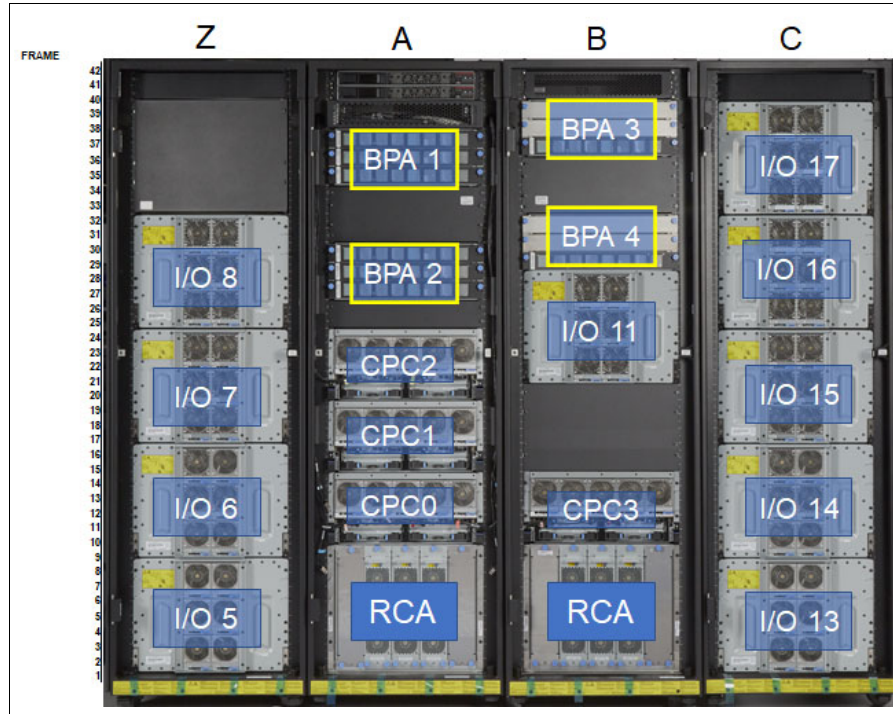


Figure 2-28 Rear view of maximum configured system BPA power

Each installed BPA requires a customer-supplied power feed. The number of power cords that are required depends on the system configuration. The total loss of one BPA does not affect system operation.

Note: For initial installation, all power sources are required to run the system checkout diagnostics successfully.

BPAs are installed in pairs (2 or 4), depending on the configuration. Consider the following points:

- ▶ BPA1 and BPA2 are always initially installed in Frame A.
- ▶ BPA3 and BPA4 are installed to support more components for larger configurations (CPC and I/O drawers).
- ▶ BPA1/BPA2 and BPA3/BPA4 for paired redundancy.
- ▶ From the rear of the system, the odd-numbered BPAs are above the even-numbered BPAs in both frames.
- ▶ The total loss of one BPA in a pair has no effect on system operation.

The following components plug into the BPAs X 2 for redundancy:

- ▶ CPC Drawers, I/O Drawers, Switches, Radiators, and Support Elements
- ▶ The redundancy for each component plugs into the paired BPAs

For example, for the top Support Element 1, one power supply plugs into BPA1 and the second power supply plugs into the paired BPA2 for redundancy.

Note: Customer power sources should always maintain redundancy across BPA pairs; that is, one power source or distribution panel supplies power for BPA1 and the separate power source or distribution panel supplies power for BPA2.

As a best practice, connect the odd-numbered BPAs (BPA1 and BPA3) to one power source or distribution panel, and the even-numbered BPAs (BPA2 and BPA4) to a separate power source or distribution panel.

2.9.3 Power estimation tool

The power estimation tool for the IBM z16 allows you to enter your precise server configuration to obtain an *estimate* of power consumption by using the following process:

1. Log in to the Resource link with your user ID.
2. Click **Planning** → **Tools** → **Power Estimation Tools**.
3. Specify the quantity for the features that are installed in your system.

This tool estimates the power consumption for the specified configuration. The tool does *not* verify that the specified configuration can be physically built.

Tip: The exact power consumption for your system varies. The object of the tool is to estimate the power requirements to aid you in planning for your system installation. Actual power consumption after installation can be confirmed by using the HMC Monitors Dashboard task.

2.9.4 Cooling

The PU DCMs for IBM z16 A01 are cooled by a cold plate that is connected to the internal water-cooling loop. In an air-cooled system, the radiator unit dissipates the heat from the internal water loop with air. The radiator unit provides improved availability with N+ 1 pumps and blowers.

For all IBM z16 A01 servers, the CPC drawer components (except for PU DCMs) and the PCIe+ I/O drawers are air cooled by redundant fans. Airflow of the system is directed from front (cool air) to the back of the system (hot air).

Radiator-cooled (air-cooled) models (FC 4040, FC 4041)

The IBM z16 A01 PU DCMs in the CPC drawers are cooled by closed loop water. The internal closed water loop removes heat from PU DCMs by circulating water between the radiator heat exchanger and the cold plate that is mounted on the PU DCMs.

For more information, see 2.9.5, “Radiator Cooling Unit” on page 65.

Although the PU DCMs are cooled by water, the heat is exhausted into the room from the radiator heat exchanger by forced air with blowers. At the system level, these IBM z16 A01 are still air-cooled systems.

2.9.5 Radiator Cooling Unit

A total of 1 - 2 Radiator Cooling Units (RCUs) are used in the system: One in Frame A and one in Frame B in support of water cooling of the PU DCMs within the CPC drawers. The unit includes N+1 pumps and N+1 fans. Water loops to each drawer are directly delivered by way of hoses to each drawer from manifolds.

The RCU discharges heat from the internal frame water loop to the customer's data center.

Each RCU provides cooling to PU DCMs with closed loop water within the respective frame. No connection to an external chilled water supply is required. For the IBM z16 A01 server, the internal circulating water is conditioned water (BTA) that is added to the radiator unit during system installation with the Fill and Drain Tool (FC 3393).

Fill and Drain Tool

The Fill and Drain Tool (FDT) is a new design and is included with new IBM z16 servers. The FDT (FC 3393) is *not* compatible with IBM z14 and previous systems. The FDT is used to provide the internal water at the installation and for maintenance, and to remove it at discontinuance.

The new design uses a pump for filling the system and FRUs, and a compressor for draining FRUs and discontinuance. The process is faster and more effective. The FDT is shown in Figure 2-29.

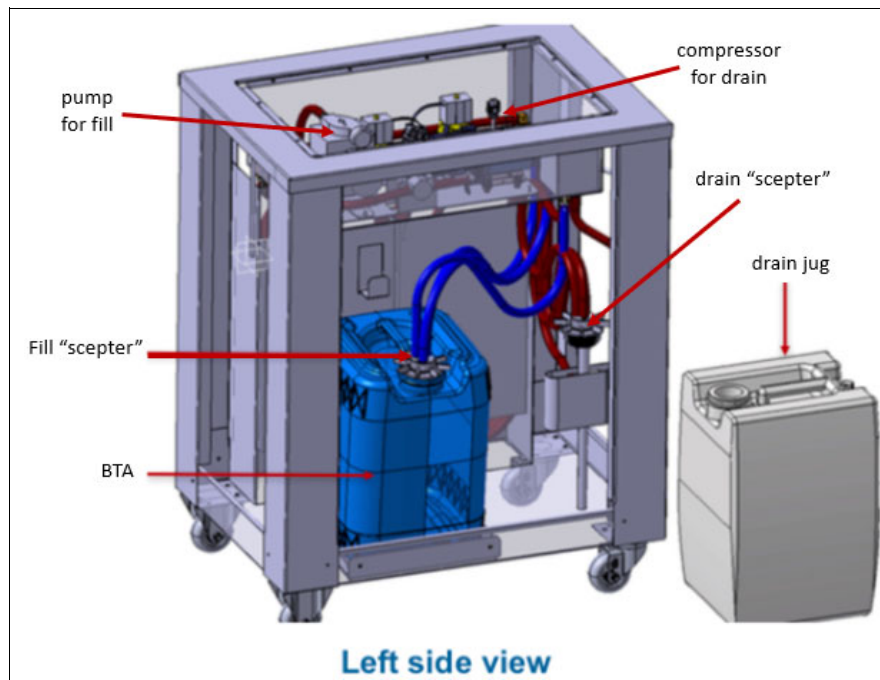


Figure 2-29 Fill Drain Tool

The RCU contains two independent pump FRUs. Because the cooling capability is a redundant N+1 design, a single working pump and blower can support the entire load. The replacement of one pump or blower can be done concurrently and does not affect performance.

Each RCU contains up to four independent fan assemblies that can be concurrently serviced. The number of fans present depends on the number of CPC drawers that are installed in the frame.

The water pumps, manifold assembly, radiator assembly (which includes the heat exchanger), and fan assemblies are the main components of the IBM z16 RCU, as shown in Figure 2-30.

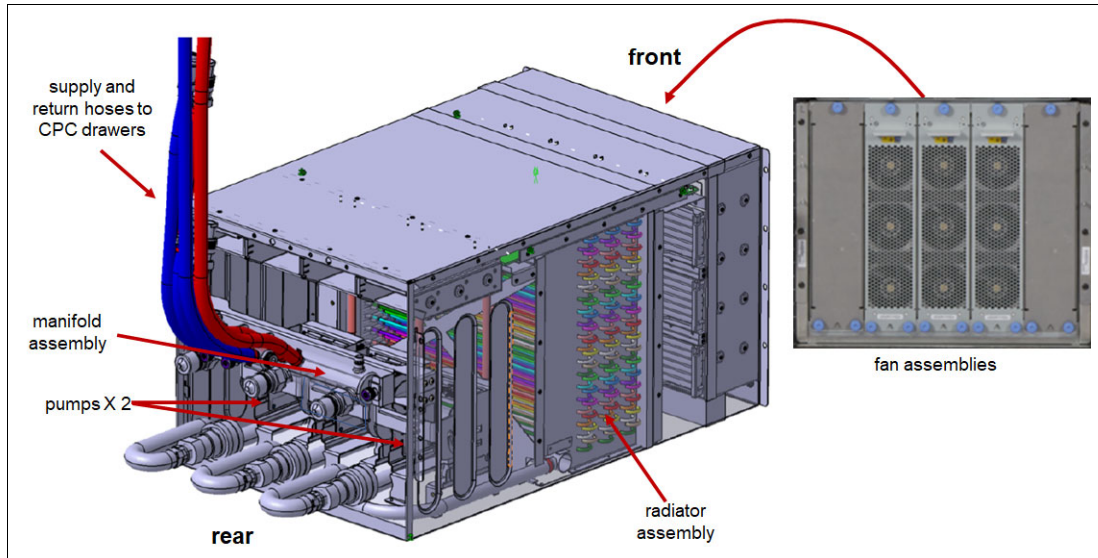


Figure 2-30 Radiator Cooling Unit

The closed water loop in the radiator unit is shown in Figure 2-31. The warm water that is exiting from the PU DCMs cold plates enters pumps through a common manifold and is pumped through a heat exchanger where heat is extracted by the air flowing across the heat exchanger fins. The cooled water is then recirculated back into the PU DCMs cold plates.

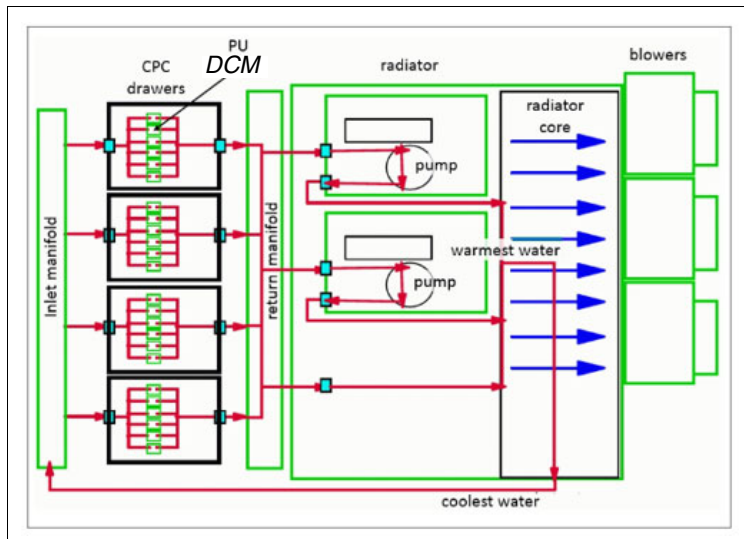


Figure 2-31 Radiator cooling system

2.10 Summary

All aspects of the IBM z16 A01 structure are listed in Table 2-16

Table 2-16 System structure summary

Description	Max39	Max82	Max125	Max168	Max200
Maximum number of characterized PUs	39	82	125	168	200
Number of CPs	0 - 39	0 - 82	0 - 125	0 - 168	0 - 200
Number of IFLs	0 - 39	0 - 82	0 - 125	0 - 168	0 - 200
Number of unassigned IFLs	0 - 38	0 - 81	0 - 124	0 - 167	0 - 199
Number of ICFs	0 - 39	0 - 82	0 - 125	0 - 168	0 - 200
Number of unassigned ICFs	0 - 38	0 - 81	0 - 124	0 - 167	0 - 199
Number of zIIPs	0 - 25	0 - 54	0 - 82	0 - 110	0 - 132
Number of unassigned zIIPs	0 - 25	0 - 54	0 - 82	0 - 110	0 - 132
Standard SAPs	5	10	15	20	24
Other SAPs	0 - 8	0 - 8	0 - 8	0 - 8	0 - 8
Number of IFP	2	2	2	2	2
Standard spare PUs	2	2	2	2	2
Enabled Memory ^a sizes GB	512 - 9984	512 - 20224	512 - 30464	512 - 40704	512 - 40704
Flexible memory ^a sizes GB	N/A	512 - 9984	512 - 20224	512 - 30464	512 - 30464
L1 cache per PU (I/D)	128/128 KB	128/128 KB	128/128 KB	128/128 KB	128/128 KB
L2 private unified cache per core	32 MB	32 MB	32 MB	32 MB	32 MB
L3 virtual cache on PU chip	32 x 8 = 256 MB	32 x 8 = 256 MB	32 x 8 = 256 MB	32 x 8 = 256 MB	32 x 8 = 256 MB
L4 virtual cache on chips in drawer	32 x 8 x 8 = 2 GB	32 x 8 x 8 = 2 GB	32 x 8 x 8 = 2 GB	32 x 8 x 8 = 2 GB	32 x 8 x 8 = 2 GB
Cycle time (ns)	0.192	0.192	0.192	0.192	0.192
Clock frequency	5.2 GHz	5.2 GHz	5.2 GHz	5.2 GHz	5.2 GHz
Maximum number of PCIe fan-outs	12	24	36	48	60
PCIe bandwidth	16 GBps	16 GBps	16 GBps	16 GBps	16 GBps
Number of support elements	2	2	2	2	2
External AC power	3-phase	3-phase	3-phase	3-phase	3-phase

a. For BPA systems, only 5 TB of memory can be configured per CPC drawer.



Central processor complex design

This chapter describes the design of the IBM z16 processor unit. By understanding this design, users become familiar with the functions that make the IBM z16 a system that accommodates a broad mix of workloads for large enterprises.

Note: The IBM z16 Model A01, Machine Type (M/T) 3931 (M/T 3931), is further identified in this document as IBM z16, unless otherwise specified.

For more information about the processor unit, see *z/Architecture Principles of Operation*, SA22-7832.

This chapter includes the following topics:

- ▶ 3.1, “Overview” on page 70
- ▶ 3.2, “Design highlights” on page 71
- ▶ 3.3, “CPC drawer design” on page 73
- ▶ 3.4, “Processor unit design” on page 79
- ▶ 3.5, “Processor unit functions” on page 100
- ▶ 3.6, “Memory design” on page 115
- ▶ 3.7, “Logical partitioning” on page 119
- ▶ 3.8, “Intelligent Resource Director” on page 130
- ▶ 3.9, “Clustering technology” on page 132
- ▶ 3.10, “Virtual Flash Memory” on page 142
- ▶ 3.11, “IBM Secure Service Container” on page 143

3.1 Overview

The IBM z16 symmetric multiprocessor (SMP) system is the next step in an evolutionary trajectory that began with the introduction of the IBM System/360 in 1964. Over time, the design was adapted to the changing requirements that were dictated by the shift toward new types of applications on which clients depend.

IBM Z servers offer high levels of reliability, availability, serviceability (RAS), resilience, and security. The IBM z16 fits into the IBM strategy in which mainframes play a central role in creating an infrastructure for cloud, artificial intelligence, and analytics, which is underpinned by security. The IBM z16 server is designed so that everything around it, such as operating systems, middleware, storage, security, and network technologies that support open standards, helps you achieve your business goals.

The IBM z16 extends the platform's capabilities and adds value with breakthrough technologies, such as the following examples:

- ▶ On-chip Artificial Intelligence (AI) at speed and scale that is designed to leave no transaction behind.
- ▶ An industry-first system that uses quantum-safe technologies, cryptographic discovery tools, and end-to-end data encryption to protect against future attacks now.
- ▶ A continuous compliance solution to help keep up with changing regulations, which reduces cost and risk.
- ▶ A consistent cloud experience to enable accelerated modernization, rapid delivery of new services, and end-to-end automation.
- ▶ New options in flexible and responsible consumption to manage system resources across geographical locations, with sustainability that is built in across its lifecycle.

The modular CPC drawer design aims to reduce (or in some cases even eliminate) planned and unplanned outages. The design does so by offering concurrent repair, replace, and upgrade functions for processors, memory, and I/O.

For more information about the IBM z16 RAS features, see Chapter 9, "Reliability, availability, and serviceability" on page 383.

IBM z16 A01 servers include the following features:

- ▶ Ultra-high frequency, large, high-speed buffers (caches) and memory
- ▶ Superscalar processor design
- ▶ Improved out-of-order core execution
- ▶ Simultaneous multithreading (SMT)
- ▶ Single-instruction multiple-data (SIMD)
- ▶ On-core integrated accelerator for Z SORT, one per PU core
- ▶ On-chip integrated accelerator for IBM zEnterprise® Data Compression (zEDC), one per PU chip
- ▶ On-chip integrated accelerator for AI (AI unit or AIU), one per PU chip
- ▶ Quantum-safe cryptography support
- ▶ Flexible configuration options

It is the next implementation of IBM Z servers to address the ever-changing IT environment.

For more information about frames and configurations, see Chapter 2, “Central processor complex hardware components” on page 15, and Appendix E, “Frame configurations Power Distribution Units and Bulk Power Assembly-based systems” on page 533.

3.2 Design highlights

The physical packaging of IBM z16 servers CPC drawer is a continuation and evolution of the previous generations of IBM z Systems. Its modular CPC drawer and new dual chip module (DCM) design address the augmenting costs that are related to building systems with ever-increasing capacities.

The modular CPC drawer design is flexible and expandable. It offers unprecedented capacity and security features to meet consolidation needs.

IBM z16 servers CPC continues the line of mainframe processors that are compatible with an earlier version. The IBM z16 brings the following processor design enhancements:

- ▶ 7 nm silicon lithography
- ▶ Eight cores per PU chip design with 22.5 billion transistors per PU chip
- ▶ Redesigned cache structure that is implemented in dense SRAM
- ▶ Four PU Dual Chip Modules per CPC Drawer
- ▶ Each PU chip features two PCIe Generation 4 ports (x16 @ 32 GBps)
- ▶ Optimized pipeline
- ▶ Improved SMT and SIMD
- ▶ Improved branch prediction
- ▶ Improved co-processor functions (CPACF)
- ▶ IBM integrated accelerator for zEnterprise Data Compression (zEDC) (on-chip compression accelerator)
- ▶ IBM integrated accelerator for Z Sort (on-core sort accelerator)
- ▶ IBM integrated accelerator for AI (on-chip AI accelerator)
- ▶ Transparent memory encryption.

It uses 24-, 31-, and 64-bit addressing modes, multiple arithmetic formats, and multiple address spaces for robust interprocess security.

The IBM z16 system design features the following main objectives:

- ▶ Offer a data-centric approach to information (data) security that is simple, transparent, and consumable (extensive data encryption from inception to archive, in-flight, and at-rest).
- ▶ Offer a flexible infrastructure to concurrently accommodate a wide range of operating systems and applications, from the traditional systems (for example, z/OS and z/VM) to the world of Linux, cloud, analytics, and mobile computing.
- ▶ Offer state-of-the-art integration capability for server consolidation by using virtualization capabilities in a highly secure environment:
 - Logical partitioning, which allows up to 85 independent logical servers.
 - z/VM, which can virtualize hundreds to thousands of servers as independently running virtual machines (guests).

- HiperSockets, which implement virtual LANs between logical partitions (LPARs) within the system.
- Efficient data transfer that uses direct memory access (SMC-D), Remote Direct Memory Access (SMC-R), and reduced storage access latency for transactional environments.
- The IBM Z Processor Resource/System Manager (PR/SM) is designed for Common Criteria Evaluation Assurance Level 5+ (EAL 5+) certification for security; therefore, an application that is running on one partition (LPAR) cannot access another application on a different partition, which provides essentially the same security as an air-gapped system.
- The Secure Execution feature, which securely separates second-level guest operating systems that are running under KVM for Z from each other and securely separates access to second-level guests from the hypervisor.

This configuration allows for a logical and virtual server coexistence and maximizes system utilization and efficiency by sharing hardware resources.

- ▶ Offer high-performance computing to achieve the outstanding response times that are required by new workload-type applications. This performance is achieved by high-frequency, enhanced superscalar processor technology, out-of-order core execution, large high-speed buffers (cache) and memory, an architecture with multiple complex instructions, and high-bandwidth channels.
- ▶ Offer the high capacity and scalability that are required by the most demanding applications, from the single-system and clustered-systems points of view.
- ▶ Offer the capability of concurrent upgrades for processors, memory, and I/O connectivity, which prevents system outages in planned situations.
- ▶ Implement a system with high availability and reliability. These goals are achieved with redundancy of critical elements and sparing components of a single system, and the clustering technology of the Parallel Sysplex environment.
- ▶ Have internal and external connectivity offerings, supporting open standards, such as Gigabit Ethernet (GbE) and Fibre Channel Protocol (FCP).
- ▶ Provide leading cryptographic performance. Every processor unit (PU) includes a dedicated and optimized CP Assist for Cryptographic Function (CPACF). Optional Crypto Express features with cryptographic coprocessors provide the highest standardized security certification.¹ These optional features also can be configured as Cryptographic Accelerators to enhance the performance of Secure Sockets Layer/Transport Layer Security (SSL/TLS) transactions.
- ▶ Provide on-chip compression. Every PU chip design incorporates a compression unit, which is the IBM Integrated Accelerator for z Enterprise Data Compression (zEDC). This configuration is different from the CMPSC (Compression Coprocessor) that is implemented in each core.
- ▶ Provide a new dedicated on-chip integrated AI Accelerator for high-speed inference to enable real-time AI embedded directly in transactional workloads, and improvements for performance, security, and availability.
- ▶ Be self-managing and self-optimizing, adjusting itself when the workload changes to achieve the best system throughput. This process can be done by using the Intelligent Resource Director or the Workload Manager functions, which are assisted by HiperDispatch.

¹ Federal Information Processing Standard (FIPS) 140-2 Security Requirements for Cryptographic Modules.

- ▶ Have a balanced system design with pervasive encryption, which provides large data rate bandwidths for high-performance connectivity along with processor and system capacity, while protecting every byte that enters and exits the IBM z16.

The remaining sections in this chapter describe the IBM z16 system structure. It shows a logical representation of the data flow from PUs, caches, memory cards, and various interconnect capabilities.

3.3 CPC drawer design

An IBM z16 A01 system can have up to four CPC drawers in a full configuration, with up to 200 PUs that can be characterized for customer use, and up to 40 TB of customer usable memory.

Note: An IBM z16 server with Bulk Power Assembly (BPA) power option is limited to 5 TB per processor drawer (up to 20 TB maximum in a full configuration with four CPC drawers).

The following types of CPC drawer configurations are available for IBM z16 A01:

- ▶ One drawer: Max39
- ▶ Two drawers: Max82
- ▶ Three drawers: Max125
- ▶ Four drawers: Max168
- ▶ Four drawers: Max200

Note: Max168 and Max200 are factory-build only. It is not possible to upgrade in the field to Max168 or Max200.

The IBM z16 A01 has up to 24 memory controller units (MCUs) for a Max200 feature (one MCU per PU chip, and up to six MCUs populated per CPC drawer). The MCU configuration uses eight channels Reed-Solomon redundant array of independent memory (RAIM).

The RAIM design is new compared to the IBM z15 T01, moving from a 4+1 DIMM structure that is based on 5-channel RAIM design on IBM z15 to an 8-channel R-S RAIM design on the IBM z16. The new memory architecture provides approximately 15% DRAM reduction for a similar RAS, but a higher memory bandwidth at drawer level.

The DIMM sizes (32, 64, 128, or 256 GB) include RAIM overhead. An IBM z16 CPC drawer can have up to 48 memory DDR4 DIMMs (populated with 32, 40, or 48 DIMMs).

The IBM z16 microprocessor chip (called IBM Telum) integrates a new cache hierarchy design with only two levels of physical cache (L1 and L2). The cache hierarchy (L1, L2) is implemented with dense static random access memory (SRAM).

Unlike the IBM z15, eDRAM is no longer used in the IBM Telum processor. On an IBM z16, L2 cache (32 MB) is semi-private with 16 MB dedicated to the associated core, and 16 MB shared with the system (the 50/50 split is adjustable). Level 3 (L3) and Level 4 (L4) caches are now virtual caches and are allocated on L2.

Two processor chips (up to eight active cores per PU chip) are combined in a Dual Chip Module (DCM) and four DCMs are assembled in a CPC drawer (eight PU chips). An IBM z16 can have from one CPC drawer (Max39) up to four (Max200).

Figure 3-1 shows the new IBM Telum processor.

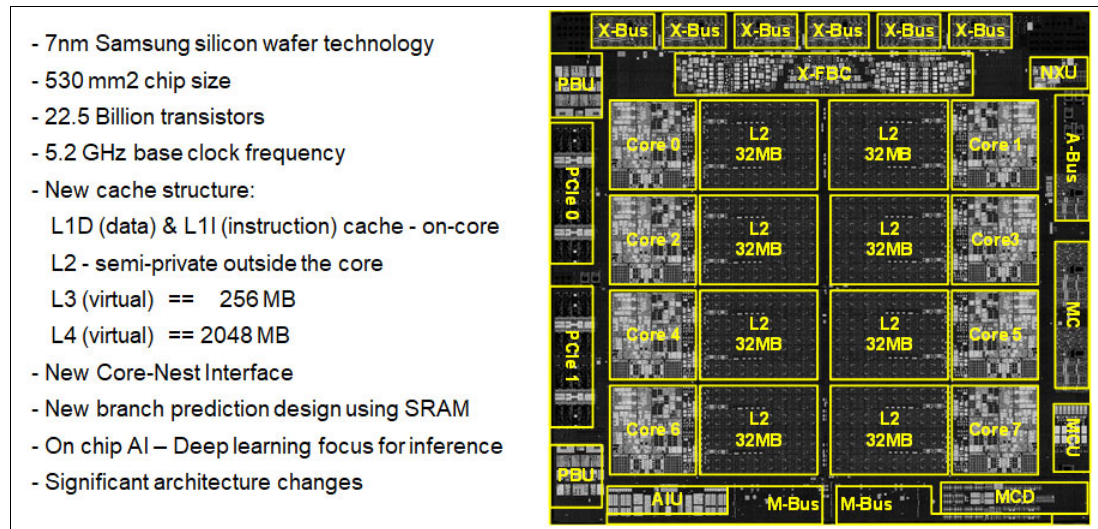


Figure 3-1 IBM Telum processor

The new IBM z16 Dual Chip Module (DCM) is shown in Figure 3-2.

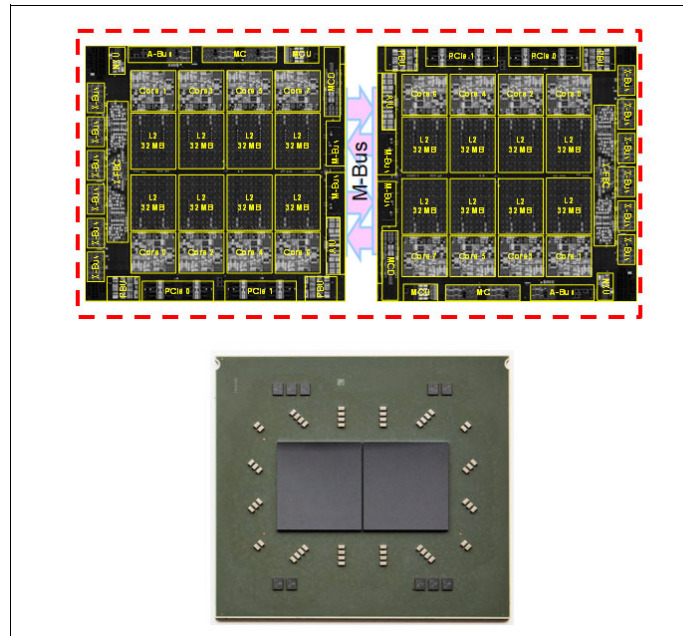


Figure 3-2 IBM z16 Dual Chip Module

Concurrent maintenance allows dynamic central processing complex (CPAC) drawer add and repair.²

IBM z16 processors use 7 nm extreme ultraviolet (EUV) lithography chip technology with advanced low latency pipeline design, which creates high-speed yet power-efficient circuit designs. The PU DCM has a dense packaging, which allows closed water loop cooling. The heat from the closed loop is dissipated into the air by a radiator unit (RU).

² For configurations with two or more CPC drawers installed.

The external water-cooling option is no longer available on the IBM z16. For more information, see 2.9, “Power and cooling” on page 60.

3.3.1 Cache levels and memory structure

The IBM z16 includes a new optimized memory subsystem design that focuses on keeping data “closer” to the PU core. With the current processor configuration, all on-chip cache levels increased.

The IBM z16 A01 cache hierarchy is shown in Figure 3-3.

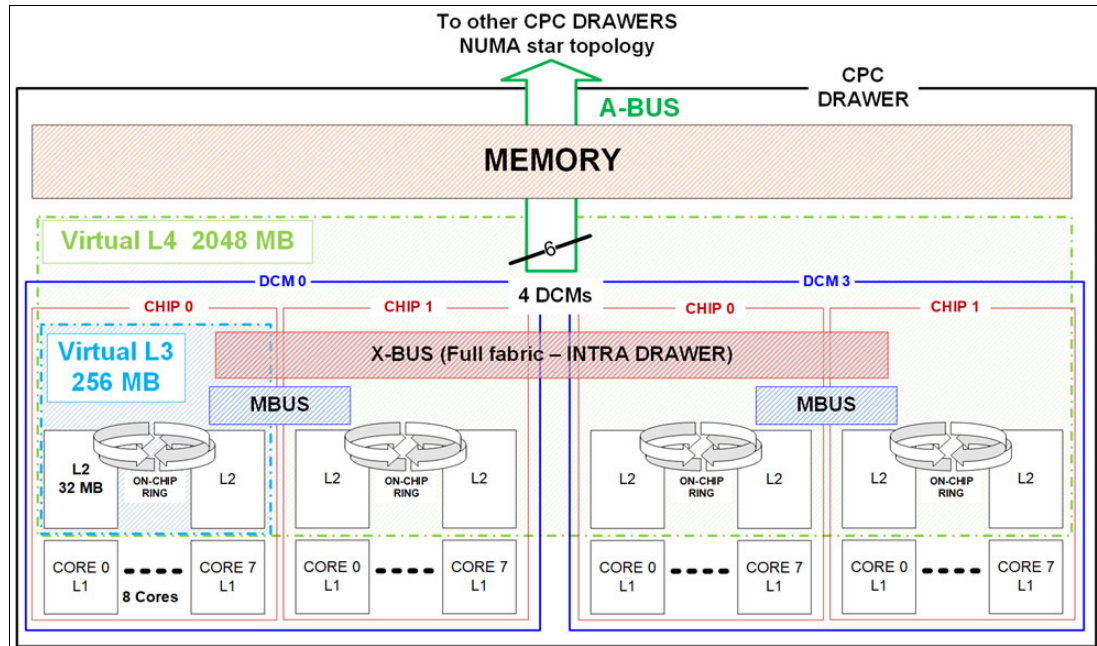


Figure 3-3 IBM z16 cache levels and memory hierarchy

On IBM z16, L1 and L2 caches are implemented on the PU chip, and L3 and L4 caches are now implemented as virtual caches and dynamically allocated on the shared part of the L2 semi-private cache.

The cache structure of the IBM z16 features the following characteristics:

- ▶ Large L1, L2 caches (more data closer to the core).
- ▶ L1 cache is implemented by using SRAM technology and has the same size than on IBM z15 (128 KB for instructions and 128 KB for data).
- ▶ L2 cache (32 MB in total) uses SRAM technology, and is semi-private to each PU core with 16 MB dedicated to the associated core, and 16 MB shared with the system (the 50/50 split is adjustable).
- ▶ L3 cache (up to 256 LB) now becomes a virtual cache and can be allocated on any of the share part of a L2 cache.
- ▶ L4 cache (up to 2048 MB) is also a virtual cache and can be allocated on any of the share part of a L2 cache.

Figure 3-4 shows the new cache structure that is implemented in an IBM z16 CPC drawer.

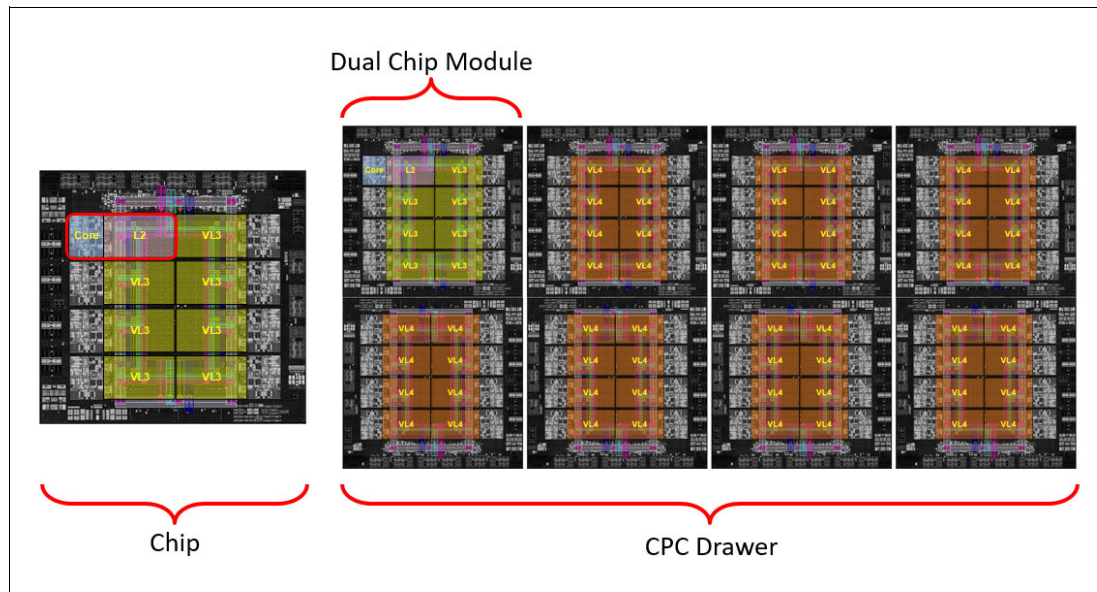


Figure 3-4 IBM z16 cache structure at CPC drawer level

Main storage has up to 10 TB addressable memory per CPC drawer, which uses up to 48 DDR4 DIMMs. A system with four CPC drawers can have up to 40 TB of main storage.

Considerations

Cache sizes are limited by ever-diminishing cycle times because they must respond quickly without creating bottlenecks. Access to large caches costs more cycles. Instruction and data cache (L1) sizes must be limited because larger distances must be traveled to reach long cache lines. This L1 access time generally occurs in one cycle, which prevents increased latency.

Also, the distance to remote caches as seen from the microprocessor becomes a significant factor. For example, on an IBM z15 server, access to L4 physical cache (on the SC chip and which might not even be in the same CPC drawer) requires several cycles to travel the distance to the cache. On an IBM z16, having an L4 virtual, physically allocated on the shared L2 requires fewer processor cycles in many instances.

Although large caches mean increased access latency, the new technology 7 nm EUV chip lithography and the lower cycle time allows IBM z16 servers to increase the size of L2 cache level within the PU chip.

To overcome the inherent delays of the SMP CPC drawer design and save cycles to access the remote virtual L4 content, the system keeps instructions and data as close to the processors as possible. This configuration can be managed by directing as much work of a specific LPAR workload to the processors in the same CPC drawer as the L4 virtual cache.

This configuration is achieved by having the IBM Processor Resource/Systems Manager (PR/SM) scheduler and the z/OS WLM and dispatcher work together. Have them keep as much work as possible within the boundaries of as few processors and L4 virtual cache space (which is best within a CPC drawer boundary) without affecting throughput and response times.

The cache structures of IBM z16 A01 systems are compared with the previous generation of IBM Z (IBM z15 T01) in Figure 3-5.

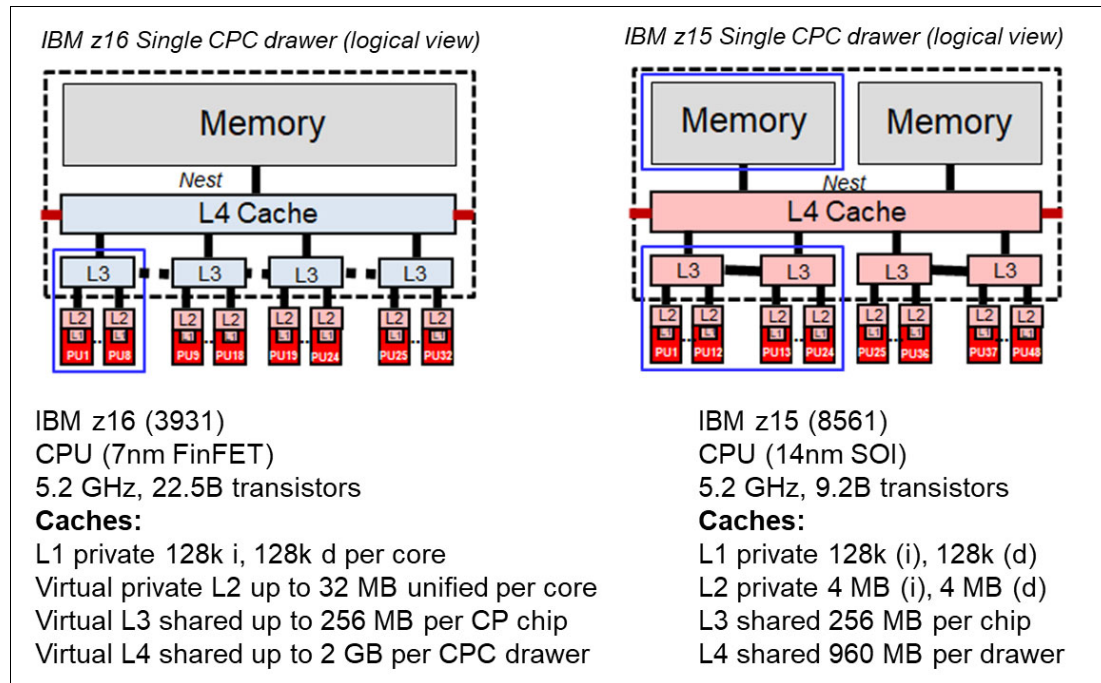


Figure 3-5 IBM z16 and IBM z15 cache level comparison

Compared to IBM z15, the IBM z16 cache design has larger L2 cache size. Cache L3 and L4 are now virtual caches in the IBM z16. More affinity exists between the memory of a partition, the L4 virtual cache in a drawer, and the cores in the PU chips. As in IBM z15, the IBM z16 cache level structure is focused on keeping more data closer to the PU. This design can improve system performance on many production workloads.

HiperDispatch

To help avoid latency in a high-frequency processor design, PR/SM and the dispatcher must be prevented from scheduling and dispatching a workload on *any* processor available, which keeps the workload in as small a portion of the system as possible. The cooperation between z/OS and PR/SM is bundled in a function that is called *HiperDispatch*. HiperDispatch uses the IBM z16 cache topology, which features reduced cross-cluster “help” and better locality for multi-task address spaces.

PR/SM can use dynamic PU reassignment to move processors (CPs, ZIIPs, IFLs, ICFs, SAPs, and spares) to a different chip and drawer to improve the reuse of shared caches by processors of the same partition. It can use dynamic memory relocation (DMR) to move a running partition’s memory to different physical memory to improve the affinity and reduce the distance between the memory of a partition and the processors of the partition.

For more information about HiperDispatch, see 3.7, “Logical partitioning” on page 119.

3.3.2 CPC drawer interconnect topology

CPC drawers are interconnected in a point-to-point topology that allows a CPC drawer to communicate with every CPC drawer. Data transfer does not always have to go through another CPC drawer to address the requested data or control information.

The IBM z16 A01 inter-CPC drawer communication structure is shown in Figure 3-6.

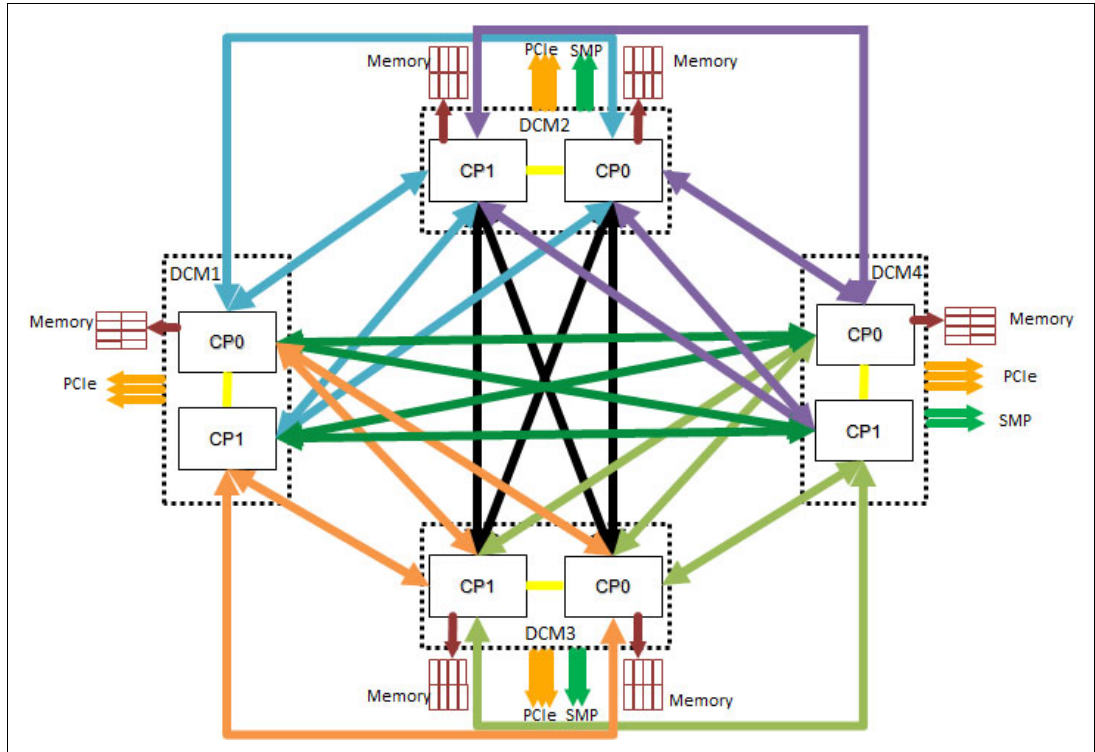


Figure 3-6 IBM z16 CPC drawer communication topology

A simplified topology of a four-CPC drawer system is shown in Figure 3-7.

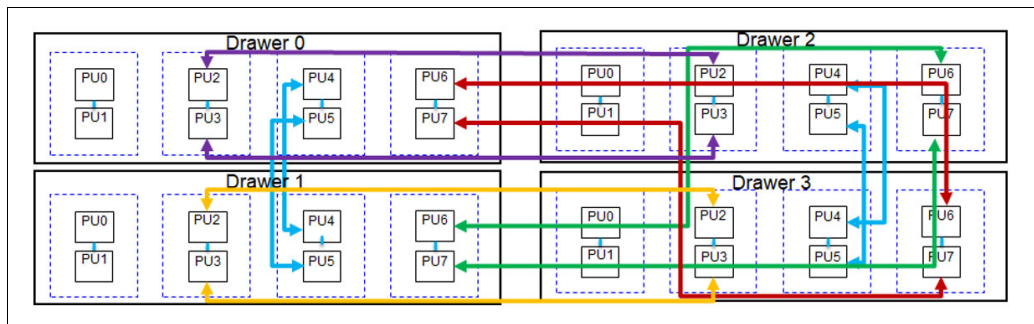


Figure 3-7 Point-to-point topology with four CPC drawers

Inter-CPC drawer communication occurs at the Level 4 virtual cache level, which is implemented on the semi-private part of one of the Level 2 caches in a chip module. The Level 4 cache function regulates coherent drawer-to-drawer traffic.

3.4 Processor unit design

Processor cycle time is especially important for processor-intensive applications. Current systems design is driven by processor cycle time, although improved cycle time does not automatically mean that the performance characteristics of the system improve.

IBM z16 A01 core frequency is 5.2 GHz (same as IBM z15 T01), but with increased number of processors that share larger caches to have shorter access times and improved capacity and performance.

Through innovative processor design (significant architecture changes, new cache structure, new Core-Nest interface, new branch prediction design that uses dense SRAM, and new on-chip AI accelerator for inference), the IBM Z processor performance continues to evolve.

Enhancements were made on the processor unit design, including the following examples:

- ▶ Cache structure
- ▶ Branch prediction mechanism
- ▶ Floating point unit
- ▶ Divide engine scheduler
- ▶ Load/Store Unit and Operand Store Compare (OSC)
- ▶ Simultaneous multi-threading
- ▶ Relative nest intensity (RNI) redesigns

For more information about RNI, see 12.4, “Relative Nest Intensity” on page 483.

The processing performance was enhanced through the following changes to the IBM z16 processor design:

- ▶ Core optimization to enable performance and capacity growth.
- ▶ New cache structure design, including a larger cache Level 2 (SRAM) and virtual Level 3 and Level 4 cache to reduce latency.
- ▶ On-chip IBM Integrated Accelerator for zEnterprise Data Compression (Nest compression accelerator, or NXU. For more information, see Figure 2-14 on page 31.)
- ▶ Enhancement of nest-core staging.
- ▶ On-chip IBM Integrated Accelerator for AI. For more information, see Chapter 2, “Central processor complex hardware components” on page 15, and Appendix B, “IBM Z Integrated Accelerator for AI” on page 507.

Because of these enhancements, the IBM z16 processor full speed z/OS single-thread performance is on average 1.11 times faster than the IBM z15 at equal N-way. For more information about performance, see Chapter 12, “Performance and capacity planning” on page 477.

z13 servers introduced architectural extensions with instructions that reduce processor quiesce effects, cache misses, and pipeline disruption, and increase parallelism with instructions that process several operands in a single instruction (SIMD). The processor architecture was further developed for IBM z14 and IBM z15.

IBM z16 includes the following enhancements:

- ▶ Optimized third-generation SMT
- ▶ Improved Out-of-Order core execution
- ▶ Improvements in branch prediction and handling
- ▶ Pipeline optimization
- ▶ Secure Execution³
- ▶ Co-processor compression enhancements

the IBM z16 enhanced Instruction Set Architecture (ISA) includes a set of instructions that are added to improve compiled code efficiency. These instructions optimize PUs to meet the demands of various business and analytics workload types without compromising the performance characteristics of traditional workloads.

3.4.1 Simultaneous multithreading

Aligned with industry directions, IBM z16 servers can process up to two simultaneous threads in a single core while sharing certain resources of the processor, such as execution units, translation lookaside buffers (TLBs), and caches. When one thread in the core is waiting for other hardware resources, the second thread in the core can use the shared resources rather than remaining idle. This capability is known as *simultaneous multithreading* (SMT).

An operating system with SMT support can be configured to dispatch work to a thread on a zIIP (for eligible workloads in z/OS) or an IFL (for z/VM and Linux on IBM Z) core in single thread or SMT mode so that HiperDispatch cache optimization can be considered. For more information about operating system support, see Chapter 7, “Operating system support” on page 251.

SMT technology allows instructions from more than one thread to run in any pipeline stage at a time. SMT can handle up to four pending translations.

Each thread has its own unique state information, such as Program Status Word (PSW) and registers. The simultaneous threads cannot necessarily run instructions instantly and must at times compete to use certain core resources that are shared between the threads. In some cases, threads can use shared resources that are not experiencing competition.

³ Secure execution requires operating system support.

Two threads (A and B) that are running on the same processor core on different pipeline stages and sharing the core resources is shown in Figure 3-8.

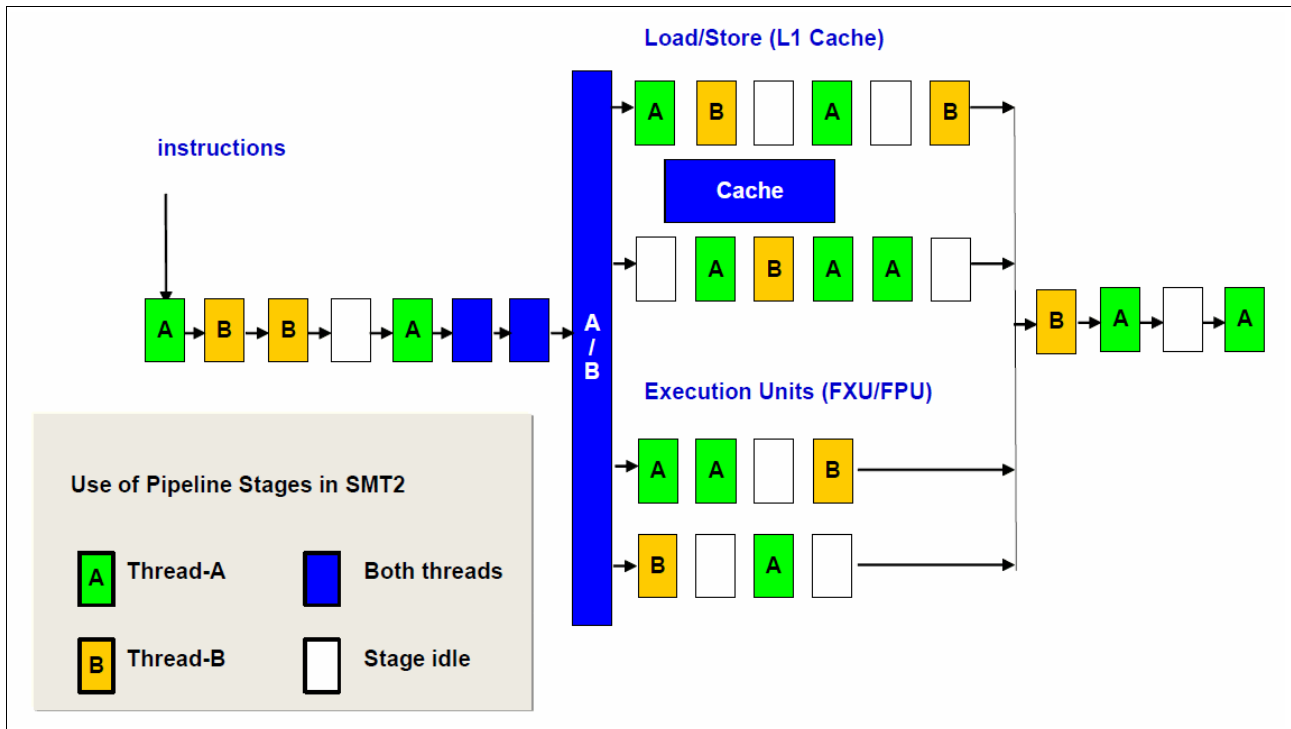


Figure 3-8 Two threads running simultaneously on the same processor core

The use of SMT provides more efficient use of the processors' resources and helps address memory latency, which results in overall throughput gains. The active thread shares core resources in space, such as data and instruction caches, TLBs, branch history tables, and, in time, pipeline slots, execution units, and address translators.

Although SMT increases the processing capacity, the performance in some cases might be superior if a single thread is used. Enhanced hardware monitoring supports measurement through CPUMF for thread usage and capacity.

For workloads that need maximum thread speed, the partition's SMT mode can be turned off. For workloads that need more throughput to decrease the dispatch queue size, the partition's SMT mode can be turned on.

SMT use is functionally transparent to middleware and applications, and no changes are required to run them in an SMT-enabled partition.

3.4.2 Single-instruction multiple-data

The IBM z16 superscalar processor has 32 vector registers and an instruction set architecture that includes a subset of instructions (known as SIMD) that were added to improve the efficiency of complex mathematical models and vector processing. These new instructions allow a larger number of operands to be processed with a single instruction. The SIMD instructions use the superscalar core to process operands in parallel.

SIMD provides the next phase of enhancements of IBM Z analytics capability. The set of SIMD instructions is a type of data parallel computing and vector processing that can decrease the amount of code and accelerate code that handles integer, string, character, and floating point data types. The SIMD instructions improve performance of complex mathematical models and allow integration of business transactions and analytic workloads on IBM Z servers.

The 32 vector registers feature 128 bits. The instructions include string operations, vector integer, and vector floating point operations. Each register contains multiple data elements of a fixed size. The following instructions code specifies which data format to use and the size of the elements:

- ▶ Byte (16 8-bit operands)
- ▶ Halfword (eight 16-bit operands)
- ▶ Word (four 32-bit operands)
- ▶ Doubleword (two 64-bit operands)
- ▶ Quadword (one 128-bit operand)

The collection of elements in a register is called a *vector*. A single instruction operates on all of the elements in the register. Instructions include a nondestructive operand encoding that allows the addition of the register vector A and register vector B and stores the result in the register vector A ($A = A + B$).

A schematic representation of a SIMD instruction with 16-byte size elements in each vector operand is shown in Figure 3-9.

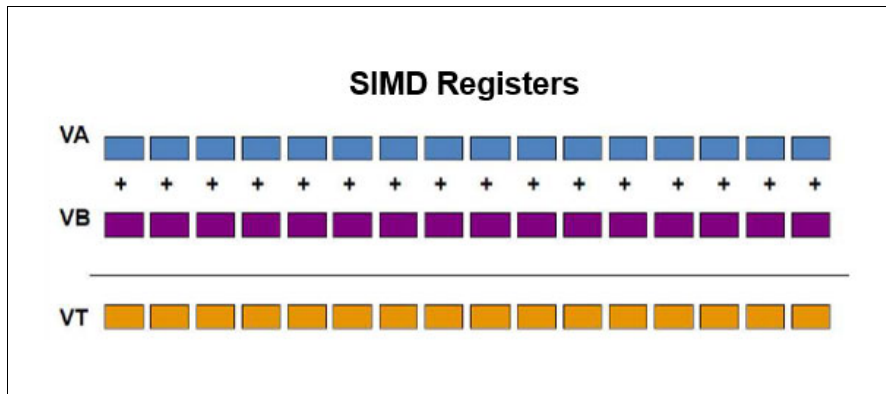


Figure 3-9 SIMD operation logic

The vector register file overlays the floating-point registers (FPRs), as shown in Figure 3-10. The FPRs use the first 64 bits of the first 16 vector registers, which saves hardware area and power, and makes it easier to mix scalar and SIMD codes. Effectively, the core gets 64 FPRs, which can further improve FP code efficiency.

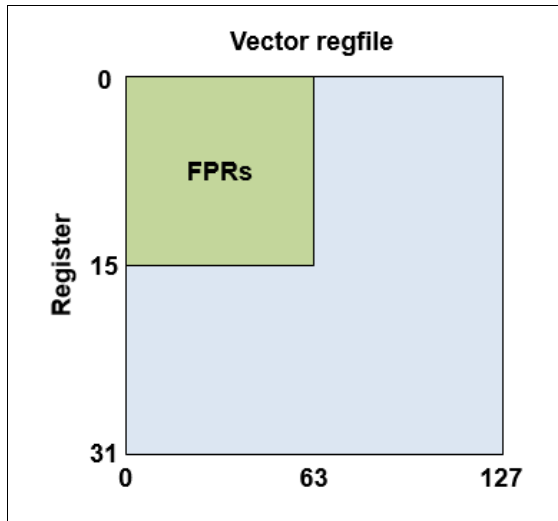


Figure 3-10 Floating point registers overlaid by vector registers

SIMD instructions include the following examples:

- ▶ Integer byte to quadword add, sub, and compare
- ▶ Integer byte to doubleword min, max, and average
- ▶ Integer byte to word multiply
- ▶ String find 8-bit, 16-bit, and 32-bit
- ▶ String range compare
- ▶ String find any equal
- ▶ String load to block boundaries and load/store with length

For most operations, the condition code is not set. A summary condition code is used only for a few instructions.

3.4.3 Out-of-Order execution

IBM z16 servers have an Out-of-Order core, much like the IBM z15 and IBM z14. This optimized Out-of-Order feature yields significant performance benefits for compute-intensive applications. It does so by reordering instruction execution, which allows later (younger) instructions to be run ahead of a stalled instruction, and reordering storage accesses and parallel storage accesses. Out-of-Order maintains good performance growth for traditional applications.

Out-of-Order execution can improve performance in the following ways:

- ▶ Reordering instruction execution

Instructions stall in a pipeline because they are waiting for results from a previous instruction or the execution resource that they require is busy. In an in-order core, this stalled instruction stalls all later instructions in the code stream. In an out-of-order core, later instructions are allowed to run ahead of the stalled instruction.

- ▶ Reordering storage accesses

Instructions that access storage can stall because they are waiting on results that are needed to compute the storage address. In an in-order core, later instructions are stalled. In an out-of-order core, later storage-accessing instructions that can compute their storage address are allowed to run.

- ▶ Hiding storage access latency

Many instructions access data from storage. Storage accesses can miss the L1 and require 7 - 50 more clock cycles to retrieve the storage data. In an in-order core, later instructions in the code stream are stalled. In an out-of-order core, later instructions that are not dependent on this storage data are allowed to run.

The IBM z16 processor includes pipeline enhancements that benefit Out-of-Order execution. The processor design features advanced micro-architectural innovations that provide the following benefits:

- ▶ Maximized instruction-level parallelism (ILP) for a better cycles per instruction (CPI) design.
- ▶ Maximized performance per watt.
- ▶ Enhanced instruction dispatch and grouping efficiency.
- ▶ Increased Out-of-Order resources, such as Global Completion Table entries, physical GPR entries, and physical FPR entries.
- ▶ Improved completion rate.
- ▶ Reduced cache/TLB miss penalty.
- ▶ Improved execution of D-Cache store and reload and new Fixed-point divide.
- ▶ New Operand Store Compare (OSC) (load-hit-store conflict) avoidance scheme.
- ▶ Enhanced branch prediction structure and sequential instruction fetching.

Program results

The Out-of-Order execution does not change any program results. Execution can occur out of (program) order, but all program dependencies are accepted, and the same results are seen as in-order (program) execution. The design was optimized by increasing the Global Completion Table (GCT) from 48x3 to 60x3, which increased the issue queue size from 2x30 to 2x36 and designed a new Mapper.

This implementation requires special circuitry to make execution and memory accesses display in order to the software. The logical diagram of an IBM z16 core is shown in Figure 3-11 on page 85.

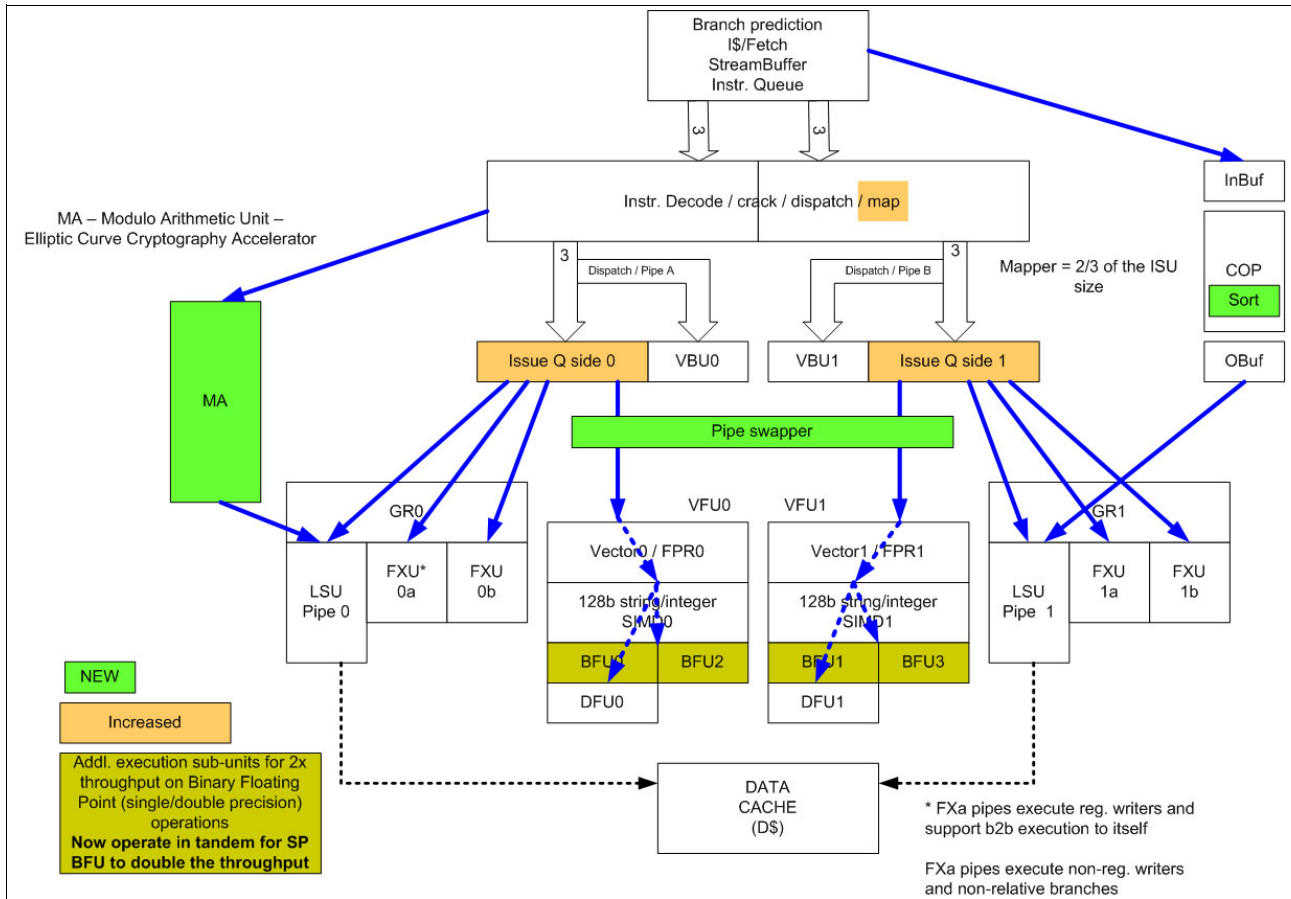


Figure 3-11 IBM z16 PU core logical diagram

Memory address generation and memory accesses can occur out of (program) order. This capability can provide a greater use of the IBM z16 superscalar core, and improve system performance.

The IBM z16 A01 processor unit core is a superscalar, out-of-order, SMT processor with eight execution units. Up to six instructions can be decoded per cycle, and up to 12 instructions or operations can be started to run per clock cycle (0.192 ns). The execution of the instructions can occur out of program order and memory address generation and memory accesses can also occur out of program order. Each core includes special circuitry to display execution and memory accesses in order to the software.

The IBM z16 superscalar PU core can have up to 10 instructions or operations that are running per cycle. This technology results in shorter workload runtime.

Enhanced branch prediction

If the branch prediction logic of the microprocessor makes the wrong prediction, all instructions in the parallel pipelines are removed. The wrong branch prediction is expensive in a high-frequency processor design. Therefore, the branch prediction techniques that are used are important to prevent as many wrong branches as possible.

For this reason, various history-based branch prediction mechanisms are used, as shown in the in-order part of the IBM z16 PU core logical diagram in Figure 3-11. The branch target buffer (BTB) runs ahead of instruction cache prefetches to prevent branch misses in an early stage. Furthermore, a branch history table (BHT) offers a high branch prediction success rate in combination with a pattern history table (PHT) and the use of tagged multi-target prediction technology branch prediction.

Branch prediction is now implemented as a two level BTB, BTB1 (“small” and “fast”), and BTB2 (large, dense-SRAM). Now, BTB1 and BTB2 feature dynamic (variable) capacity:

- ▶ BTB1: First Level Branch Target Buffer, smaller than IBM z15, dynamic director, variable capacity:
 - Minimum total branches in all parents (all *large* branches) = 8 K
 - Maximum total branches in all parents (all *medium* branches) = 12 K
- ▶ BTB2: Second Level Branch Target Buffer, also variable capacity (variable directory), up to 260 k branches

Branch prediction also implements auxiliary predictors for:

- ▶ Direction:
 - Two table TAGE⁴ Pattern History Table (PHT): A two-level table (with different history lengths). Branch direction is predicted based on history.
 - Perceptron: Called a Perceptron because this is a neural network algorithm that learns to correlate branch history over time and predicts direction of branches that the other mechanisms cannot catch with sufficient accuracy
- ▶ Target:
 - Two table TAGE Changing Target Buffer (CTB): A two-level table (with different history lengths). Branches are remembered that have different targets depending on history.
 - Return Address Table Call/Return Stack (RAT CRS): Multi-level CRS that is implemented as a table lookup

3.4.4 Superscalar processor

A *scalar processor* is a processor that is based on a single-issue architecture, which means that only a single instruction is run at a time. A *superscalar processor* allows concurrent (parallel) execution of instructions by adding resources to the microprocessor in multiple pipelines, each working on its own set of instructions to create parallelism.

A superscalar processor is based on a multi-issue architecture. However, when multiple instructions can be run during each cycle, the level of complexity is increased because an operation in one pipeline stage might depend on data in another pipeline stage. Therefore, a superscalar design demands careful consideration of which instruction sequences can successfully operate in a long pipeline environment.

IBM z16 is a superscalar processor. Each processor unit, or core, is a superscalar and out-of-order processor that supports 10 concurrent issues to execution units in a single CPU cycle:

- ▶ Fixed-point unit (FXU): The FXU handles fixed-point arithmetic.
- ▶ Load-store unit (LSU): The LSU contains the data cache. It is responsible for handling all types of operand accesses of all lengths, modes, and formats as defined in the z/Architecture.

⁴ TAgged GEometric predictor.

- ▶ Instruction fetch and branch (IFB) (prediction) and Instruction cache and merge (ICM). These two sub units (IFB and ICM) contain the instruction cache, branch prediction logic, instruction fetching controls, and buffers. Its relative size is the result of the elaborate branch prediction.
- ▶ L1 data and L1 instruction are incorporated into the LSU and ICM, respectively.

COBOL enhancements

IBM z16 core implements new instructions for the compiler to accelerate numeric formatting, and hardware support for new numeric conversion instructions (exponents and arithmetic common in financial applications).

3.4.5 On-chip coprocessors and accelerators

This section introduces the CPACF enhancements for IBM z16 and the IBM Integrated Accelerator for zEnterprise Data Compression (zEDC).

IBM integrated Accelerator for zEDC (on-chip)

Introduced in IBM z15, the On-Chip data compression accelerator (Nest Accelerator Unit - NXU, see Figure 3-12 on page 88) provides real value for existing and new data compression use cases.

IBM z16 Compression/Decompression accelerator is implemented in the Nest Accelerator Unit (NXU) on each processor chip of the IBM Telum microprocessor. IBM z16 On-Chip Compression delivers industry-leading throughput and replaces the zEDC Express PCIe adapter available on the IBM z14 and earlier servers.

One Nest Accelerator Unit (NXU) is used per processor chip, which is shared by all cores on the chip and features the following benefits:

- ▶ Brand new concept of sharing and operating an accelerator function in the nest
- ▶ Supports DEFLATE compliant compression/decompression and GZIP CRC/ZLIB Adler
- ▶ Low latency
- ▶ High bandwidth
- ▶ Problem state execution
- ▶ Hardware/Firmware interlocks to ensure system responsiveness
- ▶ Designed instruction
- ▶ Run in millicode

The On-Chip Compression Accelerator removes this virtualization constraint because it is shared by all PUs on the processors chip; therefore, it is available to all LPARs and guests.

Moving the compression function from the I/O drawer to the processor chip means that compression can operate directly on L2 cache and data does not need to be passed by using I/O.

Data compression is running in one of the two execution modes available: Synchronous mode or Asynchronous mode:

- ▶ Synchronous execution occurs in problem states where the user application starts the instruction in its virtual address space.
- ▶ Asynchronous execution is optimized for Large Operations under z/OS for authorized applications (for example, BSAM/QSAM) and issues I/O by using EADMF for asynchronous execution.

Asynchronous execution maintains the current user experience and provides a transparent implementation for existing authorized users of zEDC.

The On-Chip data compression implements compression as defined by RFC1951 (DEFLATE).

Figure 3-12 shows the nest compression accelerator (NXU) for On-Chip Compression acceleration.

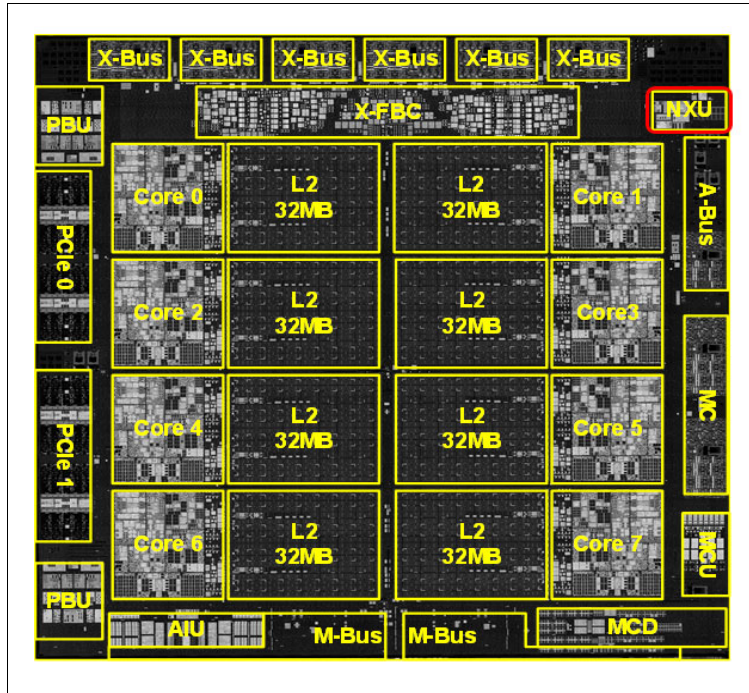


Figure 3-12 Integrated Accelerator for zEDC (NXU) on the IBM z16 PU chip

For more information about sizing, migration considerations, and software support, see Appendix C, “IBM Integrated Accelerator for zEnterprise Data Compression” on page 511.

Coprocessor units (on-core)

A data compression coprocessor and a cryptography coprocessor unit is available on *each core* in the IBM Telum chip.

The compression engine uses static dictionary compression and expansion that is based on CMPSC instruction. The compression dictionary uses the level 1 (L1) cache (instruction cache).

The cryptography coprocessor is used for CPACF, which offers a set of symmetric cryptographic functions for encrypting and decrypting of clear key operations.

The compression and cryptography coprocessors feature the following characteristics:

- ▶ Each core has an independent compression and cryptographic engine.
- ▶ The coprocessor was redesigned to support SMT operation and for throughput increase.
- ▶ It is available to any processor type (regardless of the processor characterization).
- ▶ The owning processor is busy when its coprocessor is busy.

The location of the coprocessor on the IBM z16 chip is shown in Figure 3-13.

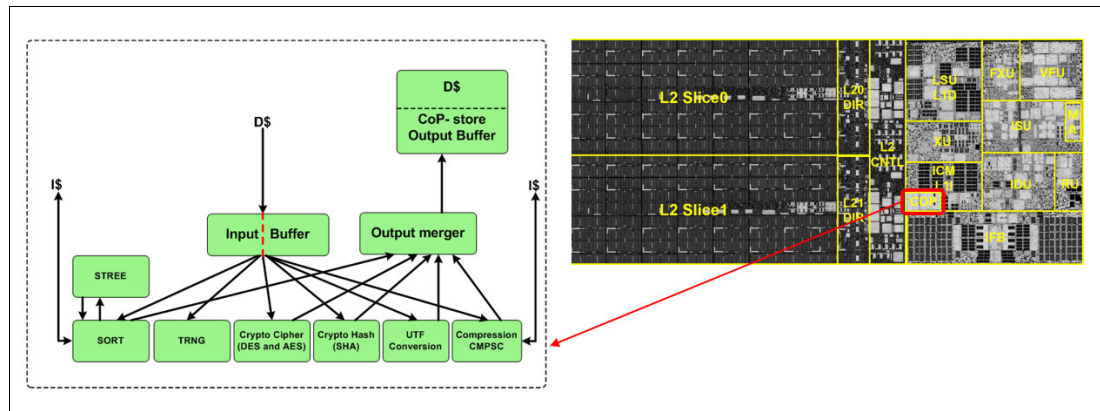


Figure 3-13 IBM z16 Core co-processor

On-core compression (CMPSC) on IBM z16

The compression coprocessor on IBM z16 provides the same functions that are available on IBM z15.

On-core cryptography coprocessor (CPACF)

CPACF accelerates the encrypting and decrypting of SSL/TLS transactions, virtual private network (VPN)-encrypted data transfers, and data-storing applications that do not require FIPS 140-2 level 4 security. The assist function uses a special instruction set for symmetrical clear key cryptographic encryption and decryption, and for hash operations. This group of instructions is known as the *Message-Security Assist* (MSA).

For more information about these instructions, see *z/Architecture Principles of Operation*, SA22-7832.

Crypto functions enhancements

The IBM z16 microprocessor structure was optimized and aligned to the new cache hierarchy. Co-processor results (data) are stored by way of level 1 (L1) cache.

The crypto/hashing/UTF-conversion/compression engines were redesigned for increased throughput.

CPACF accelerator that is built into every core supports Pervasive Encryption by providing fast synchronous cryptographic services:

- ▶ Encryption (DES, TDES, and AES)
- ▶ Hashing (SHA-1, SHA-2, SHA-3, and SHAKE)
- ▶ Random Number Generation (PRNG, DRNG, and TRNG)
- ▶ Elliptic Curve supported operations:
 - ECDH[E]:
 - P256, P384, and P521
 - X25519 and X448
 - ECDSA:
 - Keygen, sign, and verify
 - P256, P384, and P521

- EdDSA:
 - Keygen, sign, and verify
 - Ed25519 and Ed448

For more information about cryptographic functions on IBM z16 servers, see Chapter 6, “Cryptographic features” on page 213.

IBM Integrated Accelerator for Z Sort (on-core)

Sorting data is a significant part of IBM Z workloads including batch workloads, database query processing, and utility processing. The amount of data that is stored and processed on IBM Z continues to grow at a high rate, which drives an ever-increasing sort workload.

Introduced on IBM z15 was the sort accelerator that is known as the IBM Integrated Accelerator for Z Sort (see Figure 3-13 on page 89). The SORTL hardware instruction that is implemented on each core is used by DFSORT and the Db2 utilities for z/OS Suite to allow the use of a hardware-accelerated approach to sorting.

The IBM Integrated Accelerator for Z Sort feature termed as “ZSORT” helps to reduce the CPU costs and improve the elapsed time for eligible workloads. One of the primary requirements for ZSORT is providing enough virtual, real, and auxiliary storage.

Sort jobs that run in memory-constrained environments in which the amount of memory that is available to be used by DFSORT jobs is restricted might not achieve optimal performance results or might not be able to use ZSORT.

The 64-bit memory objects (above-the-bar-storage) can use the ZSORT accelerator for sort workloads for optimal results. Because ZSORT is part of the CPU and memory latency is much less than disk latency, sorting in memory is more efficient than sorting with memory and disk workspace. By allowing ZSORT to process the input completely in memory, it can achieve the best results in elapsed time and CPU time.

Because the goal of ZSORT is to reduce CPU time and elapsed time, it can require more storage than a DFSORT application that does not use ZSORT.

Note: Not all sorts are eligible to use ZSORT. IBM’s zBNA tool provides modeling support for identifying potential ZSORT-eligible candidate jobs and estimates the benefits of ZSORT. The tool uses information in the SMF type 16 records.

The following restrictions disable ZSORT and revert to the use of traditional sorting technique:

- ▶ SORTL facility is not enabled/unavailable on the processor
- ▶ ZSORT is not enabled
- ▶ OPTION COPY or SORT FIELDS=COPY is specified
- ▶ Use of:
 - INREC
 - JOINKEYS
 - MERGE FIELDS
 - MODS(EXIT) statements
 - OUTREC
 - OUTFIL
 - SUM FIELDS
- ▶ Program started sorts
- ▶ Memory objects cannot be created

- ▶ Insufficient memory object storage available (required more than currently available)
- ▶ Unsupported sort fields specified (examples Unicode, Locale, and ALTSEQ)
- ▶ Unknown file size or file size=0.
- ▶ SIZE/FILSZ=Uxxxxxx is specified
- ▶ SORTIN/SORTOUT is a VSAM Cluster
- ▶ Sort control field positions are beyond 4092 and VLSHRT is specified
- ▶ Use of EXCP access method was requested
- ▶ Insufficient storage (for example, above or below the line)
- ▶ Sorting key greater than 4088 bytes or greater than 4080 bytes if EQUALS is specified
- ▶ For variable records, the record length (LRECL) must be greater than 24
- ▶ zHPF is unavailable for a sort that cannot be performed entirely in memory
- ▶ Insufficient amount of sort workspace

3.4.6 IBM Integrated Accelerator for Artificial Intelligence (on-chip)

The IBM Z processor chip was enhanced from one generation to another. This enhancement enables various data manipulations (such as compression, sorting, cryptography) directly in hardware, on the processor chip by way of purpose-built accelerators. It also provides eligible workloads with low latency time, high performance, and high throughput.

The new IBM z16 microprocessor chip, also called the *IBM Telum processor*, integrates a new AI accelerator. This innovation brings incredible value to applications and workloads that are running on IBM Z platform.

Customers can benefit from the integrated AI accelerator by adding AI operations that are used to perform fraud prevention and fraud detection, customer behavior predictions, and supply chain operations. All of these operations are done in real time and fully integrated in transactional workloads. As a result, valuable insights are gained from their data instantly.

The integrated accelerator for AI delivers AI inference in real time, at large scale, and high throughput rate, with no transaction left behind. The AI capability applies directly to the running transaction. It shifts the traditional paradigm of applying AI to the transactions that were completed. This innovative technology also can be used for intelligent IT workloads placement algorithms, which contributes to the better overall system performance.

The Telum processor also integrates powerful mechanisms of data prefetch, fast and high capacity level 1 (L1) and level 2 (L2) caches, enhanced branch prediction, and other improvements and innovations that streamlines the data processing by the AI accelerator. The hardware, firmware, and software are vertically integrated to deliver the new AI for inference functions seamless to the applications.

The location of the integrated accelerator for AI on the Telum chip is shown in Figure 3-14.

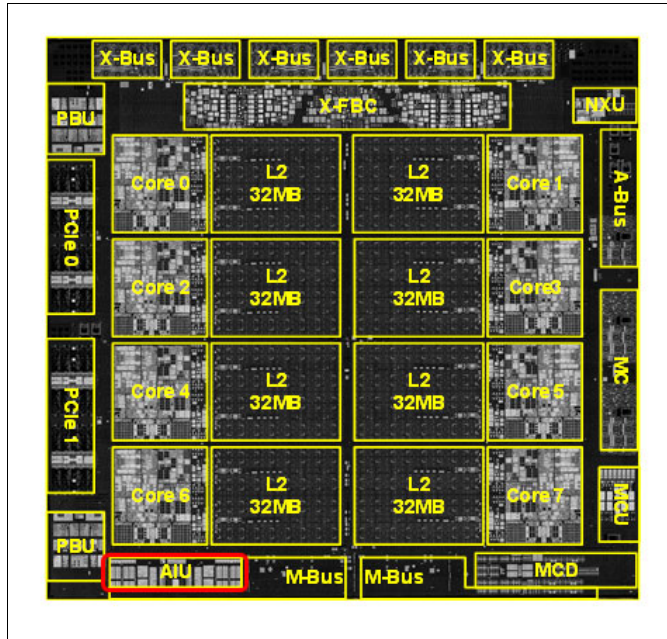


Figure 3-14 Integrated Accelerator for AI on the IBM Telum processor

The AI accelerator is driven by the new Neural Networks Processing Assist (NNPA) instruction.

NNPA is a new nonprivileged Complex Instruction Set Computer (CISC) memory-to-memory instruction that operates on tensor objects that are in user program's memory. AI functions and macros are abstracted by NNPA.

Figure 3-15 shows the AI accelerator and its components:

- ▶ Data movers surround the compute arrays that consist of the Processor Tiles (PT)
- ▶ Processing Elements (PE)
- ▶ Special Function Processors (SFP)

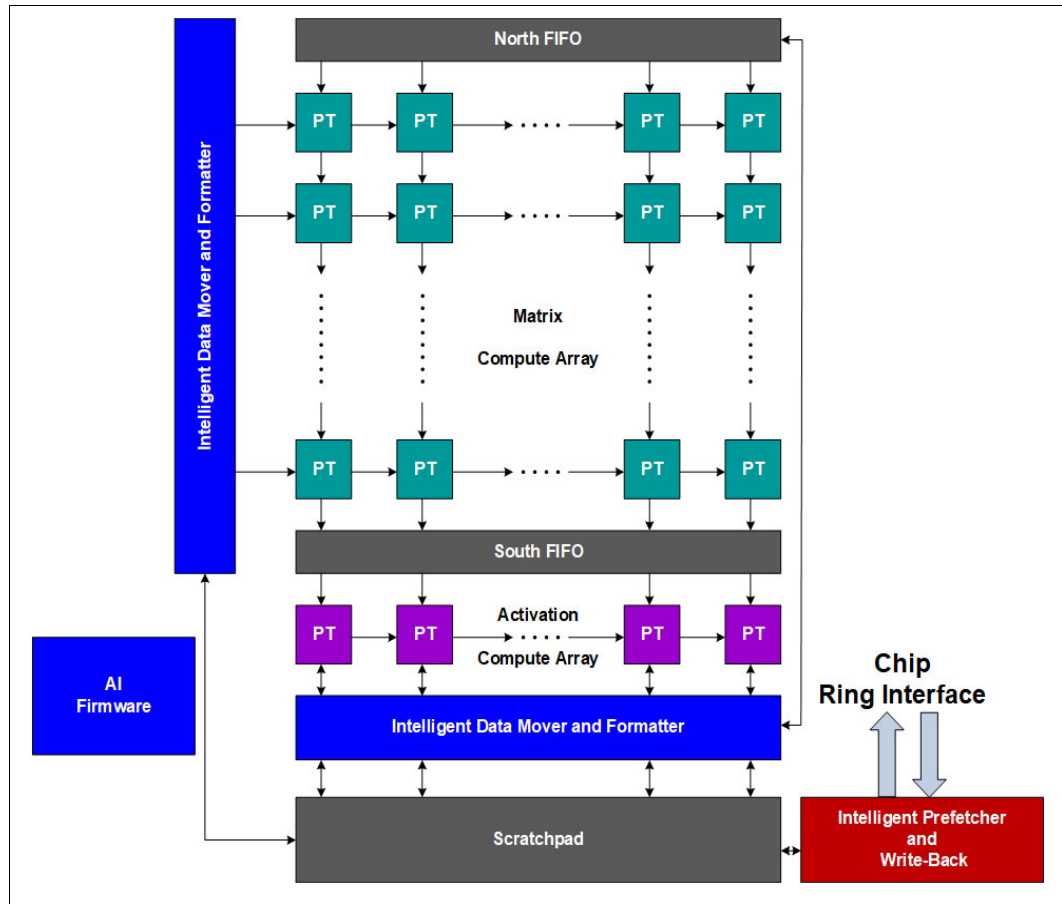


Figure 3-15 IBM z16 Integrated accelerator for AI logical diagram

Intelligent data movers and prefetchers are connected to the chip by way of ring interface for high-speed, low-latency, read/write cache operations at 200+ GBps read/store bandwidth, and 600+ GBps bandwidth between engines.

Compute Arrays consist of 128 processor tiles with 8-way FP-16 FMA SIMD, which are optimized for matrix multiplication and convolution, and 32 processor tiles with 8-way FP-16/FP-32 SIMD, which are optimized for activation functions and complex functions.

The integrated AI accelerator delivers more than 6 TFLOPs per chip and over 200 TFLOPs in fully configured IBM z16 system with the 32 chips. The AI accelerator is shared by all cores on the chip. The firmware, running on the cores and accelerator, orchestrates and synchronizes the execution on the accelerator.

Using IBM Z Integrated AI Accelerator in your enterprise

Figure 3-16 shows the software ecosystem and high-level integration of the AI accelerator into enterprise AI/Machine Learning solution stack. Great flexibility and interoperability are available for training and building models.

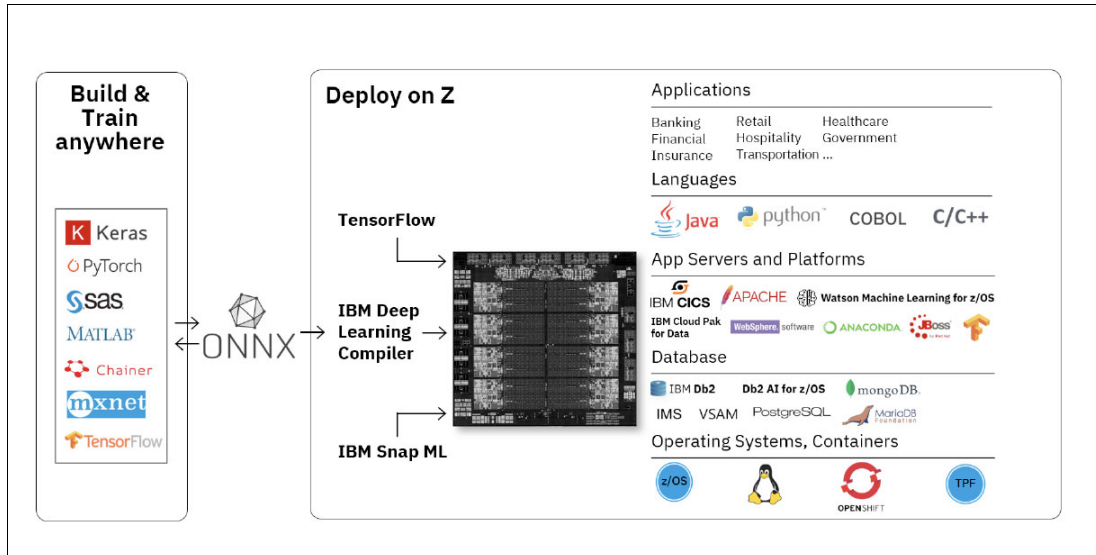


Figure 3-16 Software ecosystem for the AI accelerator

Acknowledging the diverse AI training frameworks, customers can train their models on platforms of their choice, including IBM Z (on-premises and in hybrid cloud) and then, deploy it efficiently on IBM Z in colocation with the transactional workloads. No other development effort is needed to enable this strategy.

IBM has invested into Open Neural Network Exchange (ONNX), which is a standard format for representing AI models that allows a data scientist to build and train a model in the framework of choice without worrying about the downstream inference implications.

To enable deployment of ONNX models, IBM provides an ONNX model compiler that is optimized for IBM Z. IBM also optimized key Open Source frameworks, such as TensorFlow and TensorFlow Serving, for use on IBM Z platform.

IBM open-sourced zDNN library provides common APIs for the functions that allow to convert tensor format to the accelerator required one. Customers can run zDNN under z/OS (in zCX) and Linux on IBM Z.

A Deep Learning Compiler (DLC) for z/OS and for Linux on IBM Z provides the AI functions to the applications.

3.4.7 Decimal floating point accelerator

The decimal floating point (DFP) accelerator function is on each of the microprocessors (cores) on the 8-core chip. Its implementation meets business application requirements for better performance, precision, and function.

Base 10 arithmetic is used for most business and financial computation. Floating point computation that is used for work that is typically done in decimal arithmetic involves frequent data conversions and approximation to represent decimal numbers. This process makes floating point arithmetic complex and error-prone for programmers who use it for applications in which the data is typically decimal.

Hardware DFP computational instructions provide the following features:

- ▶ Data formats of 4, 8, and 16 bytes
- ▶ An encoded decimal (base 10) representation for data
- ▶ Instructions for running decimal floating point computations
- ▶ An instruction that runs data conversions to and from the decimal floating point representation

Benefits of the DFP accelerator

The DFP accelerator offers the following benefits:

- ▶ Avoids rounding issues, such as those issues that occur with binary-to-decimal conversions.
- ▶ Controls binary-coded decimal (BCD) operations better.
- ▶ Follows the standardization of the dominant decimal data and decimal operations in commercial computing, which supports the industry standardization (IEEE 745R) of decimal floating point operations. Instructions are added in support of the Draft Standard for Floating-Point Arithmetic - IEEE 754-2008, which is intended to supersede the ANSI/IEEE Standard 754-1985.
- ▶ Allows COBOL programs that use zoned-decimal operations to take advantage of the z/Architecture DFP instructions.

IBM z16 servers have two DFP accelerator units per core, which improve the decimal floating point execution bandwidth. The floating point instructions operate on newly designed vector registers (32 new 128-bit registers).

IBM z16 servers include decimal floating point packed conversion facility support with the following benefits:

- ▶ Reduces code path length because extra instructions to format conversion are no longer needed.
- ▶ Packed data is operated in memory by all decimal instructions without general-purpose registers, which were required only to prepare for decimal floating point packed conversion instruction.
- ▶ Converting from packed can now force the input packed value to positive instead of requiring a separate OI, OILL, or load positive instruction.
- ▶ Converting to packed can now force a positive zero result instead of requiring ZAP instruction.

Cobol and PL/I compilers were updated to support the new IBM z16 enhancements:

- ▶ BCD to HFP conversions
- ▶ Numeric editing operation
- ▶ Zoned decimal operations

Software support

DFP is supported in the following programming languages and products:

- ▶ Release 4 and later of the High Level Assembler
- ▶ C/C++, which requires supported z/OS version
- ▶ Enterprise PL/I Release 3.7 and Debug Tool Release 8.1 or later
- ▶ Java Applications that use the BigDecimal Class Library
- ▶ SQL support as of Db2 Version 9 and later

3.4.8 IEEE floating point

Binary and hexadecimal floating-point instructions are implemented in IBM z16 servers. They incorporate IEEE standards into the system.

The IBM z16 core implements two other execution subunits for 2x throughput on BFP (single/double precision) operations (see Figure 3-11 on page 85).

The key point is that Java and C/C++ applications tend to use IEEE BFP operations more frequently than earlier applications. Therefore, the better the hardware implementation of this set of instructions, the better the performance of applications.

3.4.9 Processor error detection and recovery

The PU uses a process called *transient recovery* as an error recovery mechanism. When an error is detected, the instruction unit tries the instruction the instruction again, and attempts to recover the error. If the second attempt is unsuccessful (that is, a permanent fault exists), a relocation process is started that restores the full capacity by moving work to another PU.

Relocation under hardware control is possible because the R-unit has the full designed state in its buffer. PU error detection and recovery are shown in Figure 3-17.

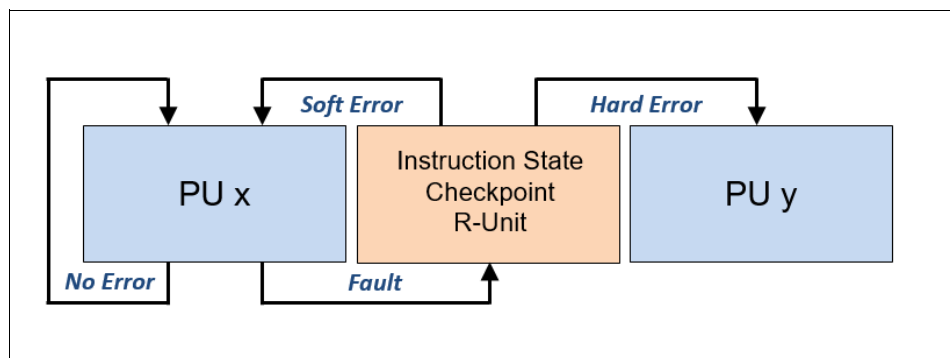


Figure 3-17 PU error detection and recovery

3.4.10 Branch prediction

Because of the ultra-high frequency of the PUs, the penalty for a wrongly predicted branch is high. Therefore, a multi-pronged strategy for branch prediction is implemented on each core based on gathered branch history that is combined with other prediction mechanisms.

The BHT (Branch History Table) implementation on processors provides a large performance improvement. Originally introduced on the IBM ES/9000 9021 in 1990, the BHT is continuously improved.

It offers significant branch performance benefits. The BHT allows each PU to take instruction branches that are based on a stored BHT, which improves processing times for calculation routines.

In addition to the BHT, IBM z16 servers use the following techniques to improve the prediction of the correct branch to be run:

- ▶ BTB
- ▶ PHT
- ▶ CTB

The success rate of branch prediction contributes significantly to the superscalar aspects of IBM z16 processor. This success is because the architecture rules prescribe that the correctly predicted result of the branch is essential for successful parallel execution of an instruction stream.

IBM z16 integrates a new branch prediction design that uses SRAM and supports the following enhancements over IBM z15:

- ▶ BTB1: 8 K - 12 K
- ▶ BTB2: up to 260 K
- ▶ TAGE PHT: 4 k x 2
- ▶ TAGE CTB: 1 k x 2

3.4.11 Wild branch

When a bad pointer is used or when code overlays a data area that contains a pointer to code, a random branch is the result. This process causes a 0C1 or 0C4 abend. Random branches are difficult to diagnose because clues about how the system got to that point are not evident.

With the wild branch hardware facility, the last address from which a successful branch instruction was run is kept. z/OS uses this information with debugging aids, such as the **SLIP** command, to determine from where a wild branch came.

It also can collect data from that storage location. This approach decreases the number of debugging steps that are necessary when you want to know from where the branch came.

3.4.12 Translation lookaside buffer

The TLB in the instruction and data L1 caches use a secondary TLB to enhance performance.

The size of the TLB is kept as small as possible because of its short access time requirements and hardware space limitations. Because memory sizes recently increased significantly as a result of the introduction of 64-bit addressing, a smaller working set is represented by the TLB.

To increase the working set representation in the TLB without enlarging the TLB, large (1 MB) page and giant page (2 GB) support is available and can be used when suitable. For more information, see “Large page support” on page 116.

With the enhanced DAT-2 (EDAT-2) improvements, the IBM Z servers support 2 GB page frames.

IBM z16 TLB

IBM z16 switches to a logical-tagged L1 directory and inline TLB2. Each L1 cache directory entry contains the virtual address and Address Space Control Element (ASCE) because it no longer must access TLB for L1 cache hit. TLB2 is accessed in parallel to L2, which saves significant latency compared to TLB1-miss.

The new translation engine allows up to four translations pending concurrently. Each translation step is ~2x faster, which helps second level guests.

3.4.13 Instruction fetching, decoding, and grouping

The superscalar design of the microprocessor allows for the decoding of up to six instructions per cycle and the execution of up to 12 instructions per cycle. Both execution and storage accesses for instruction and operand fetching can occur out of sequence.

Instruction fetching

Instruction fetching normally tries to get as far ahead of instruction decoding and execution as possible because of the relatively large instruction buffers that are available. In the microprocessor, smaller instruction buffers are used. The operation code is fetched from the l-cache and put in instruction buffers that hold prefetched data that is awaiting decoding.

Instruction decoding

The processor can decode up to six instructions per cycle. The result of the decoding process is queued and later used to form a group.

Instruction grouping

From the instruction queue, up to 12 instructions can be completed on every cycle. A complete description of the rules is beyond the scope of this publication.

The compilers and JVMs are responsible for selecting instructions that best fit with the superscalar microprocessor. They abide by the rules to create code that best uses the superscalar implementation. All IBM Z compilers and JVMs are constantly updated to benefit from new instructions and advances in microprocessor designs.

3.4.14 Extended Translation Facility

The z/Architecture instruction set includes instructions in support of the Extended Translation Facility. They are used in data conversion operations for Unicode data, which causes applications that are enabled for Unicode or globalization to be more efficient. These data-encoding formats are used in web services, grid, and on-demand environments in which XML and SOAP technologies are used. The High Level Assembler supports the Extended Translation Facility instructions.

3.4.15 Instruction set extensions

Thirty new instructions were added to the IBM z16 processor. The following new IBM z16 mnemonics were added to the IBM Z/Architecture:

- ▶ LBEAR, LFI, LLGFI, and LPSWEY
- ▶ NNPA
- ▶ QPACI
- ▶ RDP
- ▶ SLLHH, SLLHL, SLLLH, SRLHH, SRLHL, SROLLH, and STBEAR
- ▶ VCFN, VCLFNH, VCLFNL, VCLZDP, VCNF, VCRNF, VCSPH, VPKZR, VSCHDP, VSCHP, VSCHSP, VSCHXP, VSCSHP, VSRPR, VUPKZH, and VUPKZL

A new procedure is available to run against customer macros in assembler libraries to verify that no conflicts exist between some older IBM Macro names and new IBM z16 (M/T 3931) hardware instruction mnemonics.

3.4.16 Transactional Execution

The Transactional Execution (TX) capability, which is known in the industry as *hardware transactional memory*, runs a group of instructions atomically; that is, all of their results are committed or no result is committed. The execution is optimistic. The instructions are run, but previous state values are saved in a transactional memory. If the transaction succeeds, the saved values are discarded; otherwise, they are used to restore the original values.

The Transaction Execution Facility provides instructions, including declaring the beginning and end of a transaction, and canceling the transaction. TX is expected to provide significant performance benefits and scalability by avoiding most locks. This benefit is especially important for heavily threaded applications, such as Java.

Removal of support of the transactional execution and constrained transactional execution facility^a: In a future IBM Z hardware system family, the transactional execution and constrained transactional execution facility will no longer be supported. Users of the facility on current servers should always check the facility indications before use.

- a. Statements by IBM regarding its plans, directions, and intent are subject to change or withdrawal without notice at the sole discretion of IBM. Information regarding potential future products is intended to outline general product direction and should not be relied on in making a purchasing decision.

3.4.17 Runtime Instrumentation

Runtime Instrumentation (RI) is a hardware facility for managed run times, such as the Java Runtime Environment (JRE). RI allows dynamic optimization of code generation as it is being run. It requires fewer system resources than the current software-only profiling, and provides information about hardware and program characteristics. RI also enhances JRE in making the correct decision by providing real-time feedback.

3.5 Processor unit functions

The PU functions are described in this section.

3.5.1 Overview

All PUs on an IBM z16 are physically identical. When the system is initialized, two integrated firmware processors (IFP) are allocated from the pool of PUs that is available for the entire system. The other PUs can be characterized to specific functions (CP, IFL, ICF, zIIP, or SAP).

The function that is assigned to a PU is set by the Licensed Internal Code (LIC). The LIC is loaded when the system is initialized at power-on reset (POR) and the PUs are *characterized*.

Only characterized PUs include a designated function. Non-characterized PUs are considered spares. You must order at least one CP, IFL, or ICF on an IBM z16.

This design brings outstanding flexibility to IBM z16 servers because any PU can assume any available characterization. The design also plays an essential role in system availability because PU characterization can be done dynamically, with no system outage.

For more information about software level support of functions and features, see Chapter 7, “Operating system support” on page 251.

Concurrent upgrades

For all IBM z16 A01 features that have more processor units (PUs) installed (non-characterized) than activated, concurrent upgrades can be done by using LIC activation. This activation assigns a PU function to a previously non-characterized PU. No hardware changes are required.

The upgrade can be done concurrently through the following facilities:

- ▶ Customer Initiated Upgrade (CIU) for permanent upgrades
- ▶ On/Off Capacity on Demand (On/Off CoD) for temporary upgrades
- ▶ Capacity BackUp (CBU) for temporary upgrades
- ▶ Capacity for Planned Event (CPE) for temporary upgrades (available only if the CPE feature code was carried forward from a previous IBM z14 or IBM z15 machine)
- ▶ System Recovery Boost upgrades
- ▶ Flexible Capacity for Cyber Resilience upgrades

If the PU chips in the installed CPC drawers have no available remaining PUs, an upgrade results in a feature upgrade and the installation of an extra CPC drawer. Field add (MES) of a CPC drawer is possible for IBM z16 Model A01 features Max39 and Max82 only. These features can be upgraded to a Max125 provided initial order for the CPC Reserve features FC 2981 or FC 2982. CPC drawer installation is nondisruptive, but takes more time than a simple LIC upgrade. Features Max68 and Max200 are factory build only.

For more information about Capacity on Demand, see Chapter 8, “System upgrades” on page 331.

PU sparing

If a PU failure occurs, the failed PU's characterization is dynamically and transparently reassigned to a spare PU. IBM z16 servers have two spare PUs. PUs that are not characterized on a CPC configuration also can be used as extra spare PUs.

For more information about PU sparing, see 3.5.10, “Sparing rules” on page 113.

PU pools

PUs that are defined as CPs, IFLs, ICFs, and zIIPs are grouped in their own pools from where they can be managed separately. This configuration significantly simplifies capacity planning and management for LPARs. The separation also affects weight management because CP and zIIP weights can be managed separately.

For more information, see “[PU weighting](#)” on page 101.

All assigned PUs are grouped in the PU pool. These PUs are dispatched to online logical PUs. For example, consider an IBM z16 with 10 CPs, 2 IFLs, 5 zIIPs, and 1 ICF. This system has a PU pool of 18 PUs, called the *pool width*. Subdivision defines the following pools:

- ▶ A CP pool of 10 CPs
- ▶ An ICF pool of one ICF
- ▶ An IFL pool of two IFLs
- ▶ A zIIP pool of five zIIPs

PUs are placed in the pools in the following circumstances:

- ▶ When the system is POREd
- ▶ At the time of a concurrent upgrade
- ▶ As a result of adding PUs during a CBU
- ▶ Following a capacity on-demand upgrade through On/Off CoD or CIU.

PUs are removed from their pools when a concurrent downgrade occurs as the result of the removal of a CBU. They also are removed through the On/Off CoD process and the conversion of a PU. When a dedicated LPAR is activated, its PUs are taken from the correct pools. This process also is the case when an LPAR logically configures a PU as on, if the width of the pool allows for it.

For an LPAR, logical PUs are dispatched from the supporting pool only. The logical CPs are dispatched from the CP pool, logical zIIPs from the zIIP pool, logical IFLs from the IFL pool, and the logical ICFs from the ICF pool.

PU weighting

Because CPs, zIIPs, IFLs, and ICFs have their own pools from where they are dispatched, they can be given their own weights. For more information about PU pools and processing weights, see the *Processor Resource/Systems Manager Planning Guide*, SB10-7178.

3.5.2 Central processors

A central processor (CP) is a PU that uses the full z/Architecture instruction set. It can run z/Architecture-based operating systems (z/OS, z/VM, TPF, z/TPF, z/VSE, and Linux on IBM Z) and the Coupling Facility Control Code (CFCC). Up to 200 PUs can be characterized as CPs, depending on the configuration.

The IBM z16 can be initialized in LPAR (PR/SM) mode or in Dynamic Partition Manger (DPM) mode.

CPs are defined as dedicated or shared. Reserved CPs can be defined to an LPAR to allow for nondisruptive image upgrades. If the operating system in the LPAR supports the logical processor add function, reserved processors are no longer needed. Regardless of the installed model, an LPAR can have up to 200 logical CPs that are defined (the sum of active and reserved logical CPs). In practice, define no more CPs than the operating system supports.

All PUs that are characterized as CPs within a configuration are grouped into the CP pool. The CP pool can be seen on the Hardware Management Console (HMC) workplace. Any z/Architecture operating systems and CFCCs can run on CPs that are assigned from the CP pool.

The IBM z16 A01 server recognizes four distinct capacity settings for CPs. Full-capacity CPs are identified as CP7. In addition to full-capacity CPs, three subcapacity settings (CP6, CP5, and CP4), each for up to 39 PUs, are offered.

The following capacity settings appear in hardware descriptions:

- ▶ CP4 Feature Code 1955 (up to 39 PUs)
- ▶ CP5 Feature Code 1956 (up to 39 PUs)
- ▶ CP6 Feature Code 1957 (up to 39 PUs)
- ▶ CP7 Feature Code 1958 (up to 200 PUs)

Granular capacity adds 117 subcapacity settings to the 200 capacity settings that are available with full capacity CPs (CP7). Each of the 117 subcapacity settings applies to up to 39 CPs only, independent of the model installed.

Note: Information about CPs in the remainder of this chapter applies to all CP capacity settings, unless indicated otherwise. For more information about granular capacity, see 2.3.3, “PU characterization” on page 33.

3.5.3 Integrated Facility for Linux (FC 1959)

An IFL is a PU that can be used to run Linux, Linux guests on z/VM operating systems, and an IBM Secure Service Container (SSC). Up to 200 PUs can be characterized as IFLs, depending on the configuration.

Note: IFLs can be dedicated to a Linux, a z/VM, or an SSC LPAR, or can be shared by multiple Linux guests, z/VM LPARs, or SSC that are running on the same IBM z16 server. Only z/VM, Linux on IBM Z operating systems, SSC, and designated software products can run on IFLs. IFLs are orderable by using FC 1959.

IFL pool

All PUs that are characterized as IFLs within a configuration are grouped into the IFL pool. The IFL pool can be seen on the HMC workplace.

IFLs do not change the model capacity identifier of the IBM z16. Software product license charges that are based on the model capacity identifier are not affected by the addition of IFLs.

Unassigned IFLs

An IFL that is purchased but not activated is registered as an unassigned IFL (FC 1962). When the system is later upgraded with another IFL, the system recognizes that an IFL was purchased and is present.

The allowable number of IFLs and Unassigned IFLs per feature is listed in Table 3-1.

Table 3-1 IFLs and Unassigned IFLs per feature

Features	Max39	Max82	Max125	Max168	Max200
Maximum of IFLs FC 1959	39	82	125	168	200
Maximum of Unassigned IFLs FC 1962	38	81	124	167	199

3.5.4 Internal Coupling Facility (FC 1960)

An Internal Coupling Facility (ICF) is a PU that is used to run the CFCC for Parallel Sysplex environments. Within the sum of all unassigned PUs in up to four CPC drawers, up to 200 ICFs can be characterized, depending on the model. However, the maximum number of ICFs that can be defined on a coupling facility LPAR is limited to 16. ICFs are orderable by using FC 1960.

Unassigned ICFs

New on IBM z16, an ICF that is purchased but not activated is registered as an unassigned ICF (FC 1974). When the system is later upgraded with another ICF, the system recognizes that an ICF was purchased and is present.

The allowable number of ICFs and Unassigned ICFs for each model is listed in Table 3-2.

Table 3-2 ICFs and Unassigned ICFs per feature

Features	Max39	Max82	Max125	Max168	Max200
Maximum of ICFs FC 1960	39	82	125	168	200
Maximum of Unassigned ICFs FC 1974	38	81	124	167	199

ICFs exclusively run CFCC. ICFs do not change the model capacity identifier of the IBM z16 system. Software product license charges that are based on the model capacity identifier are not affected by the addition of ICFs.

All ICFs within a configuration are grouped into the ICF pool. The ICF pool can be seen on the HMC workplace.

The ICFs can be used by coupling facility LPARs only. ICFs are dedicated or shared. ICFs can be dedicated to a CF LPAR, or shared by multiple CF LPARs that run on the same system. However, having an LPAR with dedicated and shared ICFs at the same time is not possible.

Coupling Thin Interrupts

With the introduction of Driver 15F (zEC12 and zBC12), the IBM z/Architecture provides a thin interrupt class called *Coupling Thin Interrupts*⁵. The capabilities that are provided by hardware, firmware, and software support the generation of coupling-related “Thin Interrupts” when the following situations occur:

- ▶ On the coupling facility (CF) side:
 - A CF command or a CF signal (arrival of a CF-to-CF duplexing signal) is received by a shared-engine CF image.
 - The completion of a CF signal that was previously sent by the CF occurs (completion of a CF-to-CF duplexing signal).
- ▶ On the z/OS side:
 - CF signal is received by a shared-engine z/OS image (arrival of a List Notification signal).
 - An asynchronous CF operation completes.

The interrupt causes the receiving partition to be dispatched by an LPAR if it is not dispatched. This process allows the request, signal, or request completion to be recognized and processed in a more timely manner.

After the image is dispatched, “poll for work” logic in CFCC and z/OS can be used largely as-is to locate and process the work. The new interrupt expedites the redispaching of the partition.

LPAR presents these Coupling Thin Interrupts to the guest partition, so CFCC and z/OS both require interrupt handler support that can deal with them. CFCC also changes to relinquish control of the processor when all available pending work is exhausted, or when the LPAR undispatches it off the shared processor, whichever comes first.

CF processor combinations

A CF image can have one of the following combinations that are defined in the image profile:

- ▶ Dedicated ICFs
- ▶ Shared ICFs
- ▶ Dedicated CPs
- ▶ Shared CPs

Shared ICFs add flexibility. However, running only with shared coupling facility PUs (ICFs or CPs) is not a preferable production configuration. It is preferable for a production CF to operate by using dedicated ICFs.

⁵ It is the only option for shared processors in a CF image (whether they be ICFs or CPs) on IBM z16.

In Figure 3-18, the CPC on the left has two environments that are defined (production and test), and each has one z/OS and one coupling facility image. The coupling facility images share an ICF.

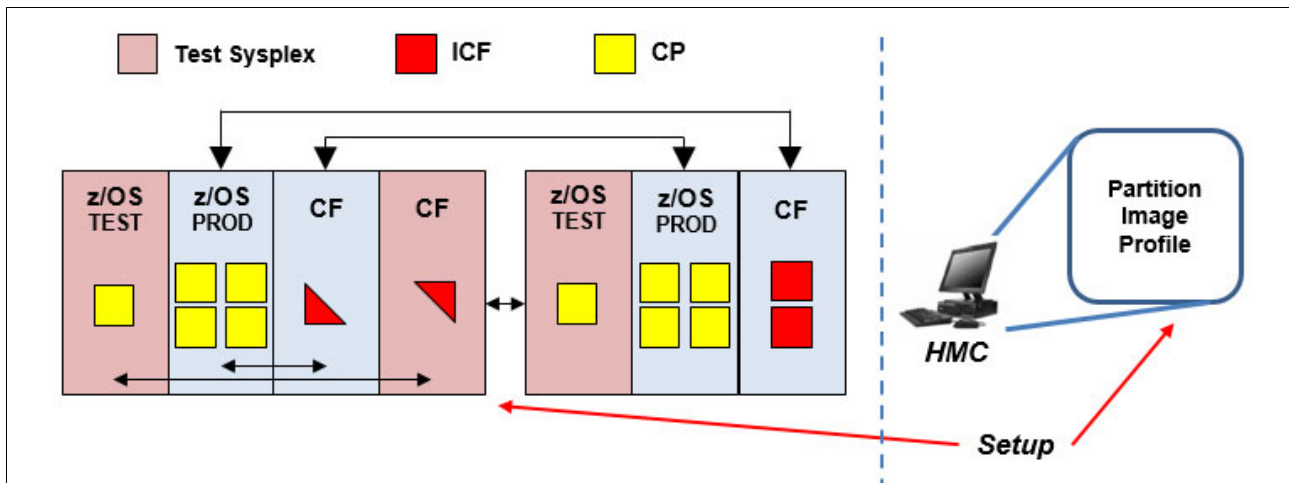


Figure 3-18 ICF options - shared ICFs

The LPAR processing weights are used to define how much processor capacity each CF image can include. The capped option also can be set for a test CF image to protect the production environment.

Connections between these z/OS and CF images can use internal coupling links to avoid the use of real (external) coupling links, and get the best link bandwidth available.

Dynamic CF dispatching

The *dynamic coupling facility dispatching* (DYNDISP) function features a dispatching algorithm that you can use to define a backup CF in an LPAR on the system. When this LPAR is in backup mode, it uses few processor resources.

DYNDISP allows more environments with multiple CF images to coexist in a server, and to share CF engines with reasonable performance. DYNDISP THIN is the only option for CF images that use shared processors on IBM z16. For more information, see 3.9.3, “Dynamic CF dispatching” on page 141.

Coupling Facility Processor scalability

CF work management and dispatcher changed to improve efficiency as processors are added to scale up the capacity of a CF image.

CF images support up to 16 processors. To obtain sufficient CF capacity, customers might be forced to split the CF workload across more CF images. However, this change brings more configuration complexity and granularity (more, smaller CF images, more coupling links, and logical CHPIDs to define and manage for connectivity, and so on).

To improve CF processor scaling for the customer’s CF images and to make effective use of more processors as the sysplex workload increases, CF work management and dispatcher provide the following improvements IBM z16:

- ▶ IBM z16 provides improved CF processor scalability for CF images.
- ▶ Increased number of CF tasks
- ▶ ICA SR latency improvements that improve coupling efficiency in a parallel sysplex.

Coupling Facility Enhancements with CFCC level 25

CFCC level 25 is available on IBM z16 with driver 51. For more information about CFCC Level 25 enhancements, see “CFCC Level 25” on page 134.

3.5.5 IBM Z Integrated Information Processor (FC 1961)

A zIIP⁶ reduces the standard processor (CP) capacity requirements for z/OS Java, XML system services applications, and a portion of work of z/OS Communications Server and Db2 UDB for z/OS Version 8 or later, which frees up capacity for other workload requirements.

A zIIP enables eligible z/OS workloads to have a portion of them directed for execution to a processor that is characterized as a zIIP. Because the zIIPs do not increase the MSU value of the processor, they do not affect the IBM software license changes.

IBM z16 is the fourth generation of IBM Z processors to support SMT. IBM z16 servers implement two threads per core on IFLs and zIIPs. SMT must be enabled at the LPAR level and supported by the z/OS operating system. SMT was enhanced for IBM z16 and it is enabled for SAPs by default (no customer intervention required).

Introduced in z/OS V2R4, the z/OS Container Extensions⁷ allows deployment of Linux on IBM Z software components, such as Docker Containers in a z/OS system, in direct support of z/OS workloads without requiring a separately provisioned Linux server. It also maintains overall solution operational control within z/OS and with z/OS qualities of service. Workload deployed in z/OS Container Extensions is zIIP eligible.

How zIIPs work

zIIPs are designed for supporting designated z/OS workloads. One of the workloads is Java code execution. When Java code must be run (for example, under control of IBM WebSphere), the z/OS JVM calls the function of the zIIP. The z/OS dispatcher then suspends the JVM task on the CP that it is running on and dispatches it on an available zIIP. After the Java application code execution is finished, z/OS redispaches the JVM task on an available CP. After this process occurs, normal processing is resumed.

This process reduces the CP time that is needed to run Java WebSphere applications, which frees that capacity for other workloads.

⁶ IBM z Systems Application Assist Processors (zAAPs) are not available since IBM z14 servers. A zAAP workload is dispatched to available zIIPs (zAAP on zIIP capability).

⁷ z/OS Container Extensions that are running on IBM z16 require IBM Container Hosting Foundation for z/OS software product (5655-HZ1).

The logical flow of Java code that is running on an IBM z16 that has a zIIP available is shown in Figure 3-19. When JVM starts the execution of a Java program, it passes control to the z/OS dispatcher that verifies the availability of a zIIP.

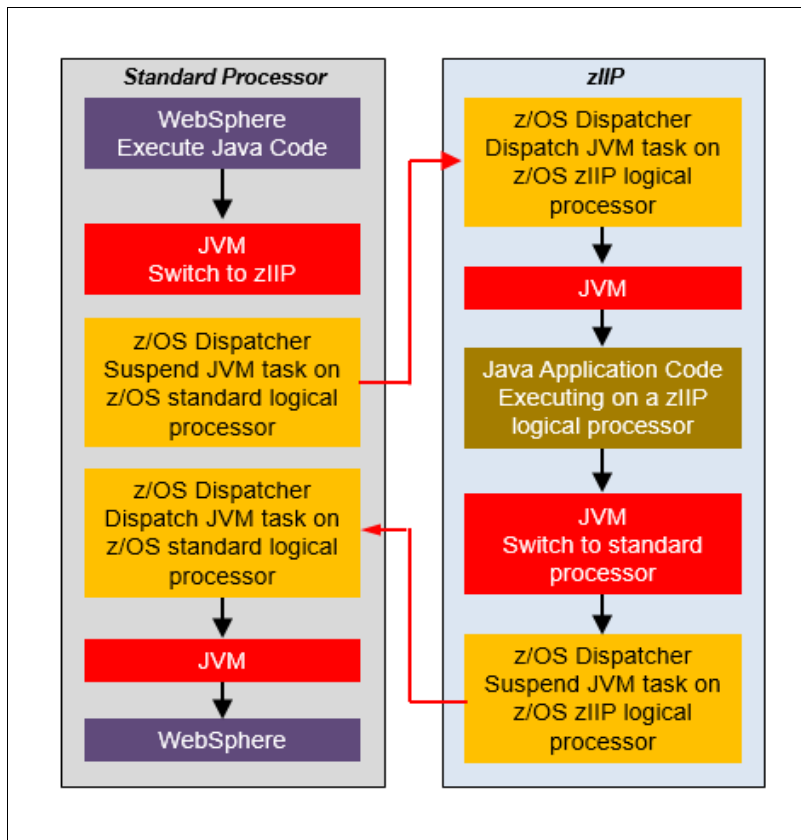


Figure 3-19 Logical flow of Java code execution on a zIIP

The availability is treated in the following manner:

- ▶ If a zIIP is available (not busy), the dispatcher suspends the JVM task on the CP and assigns the Java task to the zIIP. When the task returns control to the JVM, it passes control back to the dispatcher. The dispatcher then reassigns the JVM code execution to a CP.
- ▶ If no zIIP is available (all busy), the z/OS dispatcher allows the Java task to run on a standard CP. This process depends on the option that is used in the OPT statement in the IEAOPTxx member of SYS1.PARMLIB.

A zIIP runs IBM authorized code only. This IBM authorized code includes the z/OS JVM in association with parts of system code, such as the z/OS dispatcher and supervisor services. A zIIP cannot process I/O or clock comparator interruptions. It also does not support operator controls, such as IPL.

Java application code can run on a CP or a zIIP. The installation can manage the use of CPs so that Java application code runs only on CPs or zIIPs, or on both.

The following execution options for zIIP-eligible code execution are available and supported for z/OS⁸. These options are user-specified in IEAOPTxx and can be dynamically altered by using the **SET OPT** command:

► Option 1: Java dispatching by priority (IIPHONORPRIORITY=YES)

This option is the default option and specifies that CPs must not automatically consider zIIP-eligible work for dispatching on them. The zIIP-eligible work is dispatched on the zIIP engines until Workload Manager (WLM) determines that the zIIPs are overcommitted.

WLM then requests help from the CPs. When help is requested, the CPs consider dispatching zIIP-eligible work on the CPs based on the dispatching priority relative to other workloads. When the zIIP engines are no longer overcommitted, the CPs stop considering zIIP-eligible work for dispatch.

This option runs as much zIIP-eligible work on zIIPs as possible. It also allows it to spill over onto the CPs only when the zIIPs are overcommitted.

► Option 2: Java dispatching by priority (IIPHONORPRIORITY=NO)

zIIP-eligible work runs on zIIPs only while at least one zIIP engine is online. zIIP-eligible work is not normally dispatched on a CP, even if the zIIPs are overcommitted and CPs are unused. The exception is that zIIP-eligible work can sometimes run on a CP to resolve resource conflicts.

Therefore, zIIP-eligible work does not affect the CP utilization that is used for reporting through the subcapacity reporting tool (SCRT), no matter how busy the zIIPs are.

If zIIPs are defined to the LPAR but are not online, the zIIP-eligible work units are processed by CPs in order of priority. The system ignores the IIPHONORPRIORITY parameter in this case and handles the work as though it had no eligibility to zIIPs.

zIIPs provide the following benefits:

- Potential software cost savings.
- Simplification of infrastructure as a result of the colocation and integration of new applications with their associated database systems and transaction middleware, such as Db2, IMS, or CICS. Simplification can happen, for example, by introducing a uniform security environment, and by reducing the number of TCP/IP programming stacks and system interconnect links.
- Prevention of processing latencies that occur if Java application servers and their database servers are deployed on separate server platforms.

The following Db2 UDB for z/OS V8 or later workloads can run in Service Request Block (SRB) mode:

- Query processing of network-connected applications that access the Db2 database over a TCP/IP connection by using IBM Distributed Relational Database Architecture (DRDA).

DRDA enables relational data to be distributed among multiple systems. It is native to Db2 for z/OS, which reduces the need for more gateway products that can affect performance and availability. The application uses the DRDA requester or server to access a remote database. IBM Db2 Connect is an example of a DRDA application requester.

- Star schema query processing, which is mostly used in business intelligence work.

A *star schema* is a relational database schema for representing multidimensional data. It stores data in a central fact table and is surrounded by more dimension tables that hold information about each perspective of the data. For example, a star schema query joins various dimensions of a star schema data set.

⁸ z/OS V2R2 and later (older z/OS versions are out of support)

- ▶ Db2 utilities that are used for index maintenance, such as LOAD, REORG, and REBUILD. Indexes allow quick access to table rows. However, the databases become less efficient over time and must be maintained as data in large databases is manipulated.

The zIIP runs portions of eligible database workloads, which helps to free computer capacity and lower software costs. Not all Db2 workloads are eligible for zIIP processing. Db2 UDB for z/OS V8 and later gives z/OS the information to direct portions of the work to the zIIP. The result is that in every user situation, different variables determine how much work is redirected to the zIIP.

On an IBM z16, the following workloads also can benefit from zIIPs:

- ▶ z/OS Communications Server uses the zIIP for eligible Internet Protocol Security (IPSec) network encryption workloads. Portions of IPSec processing take advantage of the zIIPs, specifically end-to-end encryption with IPSec. The IPSec function moves a portion of the processing from the general-purpose processors to the zIIPs. In addition, to run the encryption processing, the zIIP also handles the cryptographic validation of message integrity and IPSec header processing.
- ▶ z/OS Global Mirror, formerly known as *Extended Remote Copy* (XRC), also uses the zIIP. Most z/OS Data Facility Storage Management Subsystem (DFSMS) system data mover (SDM) processing that is associated with z/OS Global Mirror can run on the zIIP.
- ▶ The first IBM user of z/OS XML system services is Db2 V9. For Db2 V9 before the z/OS XML System Services enhancement, z/OS XML System Services non-validating parsing was partially directed to zIIPs when used as part of a distributed Db2 request through DRDA. This enhancement benefits Db2 by making all z/OS XML System Services non-validating parsing eligible to zIIPs. This configuration is possible when processing is used as part of any workload that is running in enclave SRB mode.
- ▶ z/OS Communications Server also allows the HiperSockets Multiple Write operation for outbound large messages (originating from z/OS) to be run by a zIIP. Application workloads that are based on XML, HTTP, SOAP, and Java, and traditional file transfer can benefit.
- ▶ During the SRB boost period, ANY work in a boosting image is eligible to run on a zIIP processor associated with the image (LPAR).

Many more workloads and software can use zIIP processors, such as the following examples:

- ▶ IBM z/OS Container Extensions (zCX)
- ▶ IBM z/OS CIM monitoring
- ▶ IBM z/OS Management Facility (z/OSMF)
- ▶ System Display and Search Facility (SDSF)
- ▶ IBM z/OS Connect EE components
- ▶ IBM Sterling™ Connect:Direct®
- ▶ IBM Z System Automation:
- ▶ Java components of IBM Z SMS and SAS
- ▶ IBM Z NetView RESTful API server
- ▶ IBM Z Workload Scheduler & Dynamic Workload Console (under WebSphere Liberty)
- ▶ IMS workloads (DRDA, SOAP, MSC, ISC)
- ▶ Db2 for z/OS Data Gate
- ▶ Db2 Sort for z/OS
- ▶ Db2 Analytics Accelerator Loader for z/OS
- ▶ Db2 Utilities Suite for z/OS
- ▶ Db2 Log Analysis Tool for z/OS
- ▶ Data Virtualization Manager for z/OS (DVM)
- ▶ IzODA (Apache Spark workloads)
- ▶ Watson Machine Learning for z/OS (WMLz) for MLeap and Spark workloads

- ▶ IBM Z Common Data Provider (CDP)
- ▶ IBM Omegamon Portfolio components
- ▶ IBM RMF (Monitor III work)
- ▶ IBM Developer for z/OS Enterprise Edition components.

For more information about zIIP and eligible workloads, see [the IBM zIIP web page](#).

zIIP installation

One CP must be installed with or before any zIIP is installed. In IBM z16 A01, the zIIP-to-CP ratio is 2:1⁹, which means that up to 132 zIIPs on feature Max200 can be characterized.

Unassigned zIIPs

New on IBM z16, an ICF that is purchased but not activated is registered as an unassigned ICF (FC 1974). When the system is later upgraded with another ICF, the system recognizes that an ICF was purchased and is present.

The allowable number of zIIPs for each model is listed in Table 3-3.

Table 3-3 zIIPs and Unassigned zIIPs per feature

Features	Max39	Max82	Max125	Max168	Max200
Maximum of zIIPs FC 1961	25	54	82	110	132
Maximum of Unassigned zIIPs FC 1975	24	53	81	109	131

zIIPs are orderable by using FC 1961. Up to two zIIPs can be ordered for each CP or marked CP configured in the system. If the installed CPC drawer has no remaining unassigned PUs, the assignment of the next zIIP might require the installation of another CPC drawer.

PUs that are characterized as zIIPs within a configuration are grouped into the zIIP pool. This configuration allows zIIPs to have their own processing weights, independent of the weight of parent CPs. The zIIP pool can be seen on the hardware console.

The number of permanent zIIPs plus temporary zIIPs cannot exceed twice the number of purchased CPs plus temporary CPs. Also, the number of temporary zIIPs cannot exceed the number of permanent zIIPs.

zIIPs and logical partition definitions

zIIPs are dedicated or shared, depending on whether they are part of an LPAR with dedicated or shared CPs. In an LPAR, at least one CP must be defined before zIIPs for that partition can be defined. The number of zIIPs that are available in the system is the number of zIIPs that can be defined to an LPAR.

LPAR: In an LPAR, as many zIIPs as are available can be defined together with at least one CP.

⁹ The 2:1 ratio can be exceeded (during boost periods) if System Recovery Boost Upgrade (FC 9930 and FC 6802) is used for activating temporary zIIP capacity.

3.5.6 System assist processors

A system assist processor (SAP) is a PU that runs the channel subsystem LIC to control I/O operations. All SAPs run I/O operations for all LPARs. As with IBM z14 and IBM z15 servers, in IBM z16 SMT is enabled¹⁰ for SAPs. All features include standard SAPs configured. The number of standard SAPs depends on the IBM z16 feature, as listed in Table 3-4.

Table 3-4 SAPs per feature

Features	Max39	Max82	Max125	Max168	Max200
Standard SAPs	5	10	15	20	24

SAP configuration

A standard SAP configuration provides a well-balanced system for most environments. However, some application environments feature high I/O rates, typically Transaction Processing Facility (TPF) environments. In this case, more SAPs can be ordered.

Assigning more SAPs can increase the capability of the channel subsystem to run I/O operations. In IBM z16 systems, the number of SAPs plus the number of optional SAPs cannot exceed firmware limit of 128 threads.

Optional other orderable SAPs (FC 1963)

The option to order more SAPs is available on all models (FC 1963). These extra SAPs increase the capacity of the channel subsystem to run I/O operations, which is suggested for TPF environments. The maximum number of optional extra orderable SAPs depends on the configuration and the number of available uncharacterized PUs. The number of SAPs is listed in Table 3-5.

Table 3-5 Optional SAPs per feature

Features	Max39	Max82	Max125	Max168	Max200
Optional SAPs	0 - 8	0 - 8	0 - 8	0 - 8	0 - 8

3.5.7 Reserved processors

Reserved processors are defined by PR/SM to allow for a nondisruptive capacity upgrade. Reserved processors are similar to spare logical processors and can be shared or dedicated. Reserved CPs can be defined to an LPAR dynamically to allow for nondisruptive image upgrades.

Reserved processors can be dynamically configured online by an operating system that supports this function if enough unassigned PUs are available to satisfy the request. The PR/SM rules that govern logical processor activation remain unchanged.

By using reserved processors, you can define more logical processors than the number of available CPs, IFLs, ICFs, and zIIPs in the configuration to an LPAR. This process makes it possible to nondisruptively configure online more logical processors after more CPs, IFLs, ICFs, and zIIPs are made available concurrently. They can be made available with one of the capacity on-demand options.

¹⁰ Enabled by default, cannot be changed or altered by user.

The maximum number of reserved processors that can be defined to an LPAR depends on the number of logical processors that are defined. A maximum of 300 logical processors plus reserved processors can be used. If the operating system in the LPAR supports the logical processor add function, reserved processors are no longer needed.

Do not define more active and reserved processors than the operating system for the LPAR can support. For more information about logical processors and reserved processors and their definitions, see 3.7, “Logical partitioning” on page 119.

3.5.8 Integrated firmware processors

Integrated Firmware Processors (IFP) are allocated from the pool of PUs and are available for the entire system. Unlike other characterized PUs, IFPs are standard on all IBM z16 models and not defined by the client.

The two PUs that are characterized as IFP are dedicated to supporting firmware functions that are implemented in Licensed Internal Code (LIC); for example, the resource groups (RGs) that are used for managing the following *native* Peripheral Component Interconnect Express (PCIe) features:

- ▶ 10GbE and 25GbE RoCE Express3 Short Reach (SR) and Long Reach (LR)
- ▶ 10GbE and 25GbE RoCE Express2
- ▶ 10GbE and 25GbE RoCE Express2.1
- ▶ Coupling Express2 Long Reach

IFPs also are initialized at POR. They support Resource Group (RG) LIC¹¹ to provide native PCIe I/O feature management and virtualization functions.

3.5.9 Processor unit assignment

The processor unit assignment of characterized PUs is done at POR time when the system is initialized. The initial assignment rules keep PUs of the same characterization type grouped as much as possible in relation to PU chips and CPC drawer boundaries to optimize shared cache usage.

The IBM z16 A01 PU assignment is based on CPC drawer plug order (*not* “ordering”). Feature upgrade provides more processor (CPC) drawers. Max125 cannot be upgraded because the supposed targeted features (Max168 and Max200) are factory built only.

The CPC drawers are populated from the bottom up. This process defines the low-order and the high-order CPC drawers:

- ▶ CPC drawer 1 (CPC 0 at position A10): Plug order 1 (low-order CPC drawer)
- ▶ CPC drawer 2 (CPC 1 at position A15): Plug order 2
- ▶ CPC drawer 3 (CPC 2 at position A20): Plug order 3 (high-order CPC drawer)

The assignment rules comply with the following order:

- ▶ SAPs: Spread across CPC drawers and high PU chips. Each CPC drawer includes at least five standard SAPs. Start with the highest PU chip high core, then the next highest PU chip high core.
- ▶ CPs and zIIPs: Assign CPs and zIIPs to cores on chips in lower CPC drawers working upward.

¹¹ IBM zHyperLink Express1.1 and IBM zHyperLink Express are not managed by Resource Groups LIC.

- ▶ IFLs and ICFs: Assign IFLs and ICFs to cores on chips in higher CPC drawers working downward.
- ▶ IFP: Two IFPs are assigned to CPC drawer 0¹² for a Max39; CPC drawer 1 for Max82 and Max125 and CPC drawer 2 for Max168 and Max200.
- ▶ Spares: Two spares are assigned per model. On z16 there are no specific rules to place them. Any “unassigned PU” in any drawer can be assigned as spare. For additional information about spare PUs use, refer to 3.5.10, “Sparing rules”.

These rules are intended to isolate processors that are used by different operating systems as much as possible on different CPC drawers and even on different PU chips. This configuration ensures that different operating systems do not use the same shared caches. For example, CPs and zIIPs are all used by z/OS, and can benefit by using the same shared caches. However, IFLs are used by z/VM and Linux, and ICFs are used by CFCC.

This initial PU assignment, which is done at POR, can be dynamically rearranged by an LPAR by swapping an active core to a core in a different PU chip in a different CPC drawer to improve system performance. For more information, see “LPAR dynamic PU reassignment” on page 124.

When a CPC drawer is added concurrently after POR and new LPARs are activated, or processor capacity for active partitions is dynamically expanded, the extra PU capacity can be assigned from the new CPC drawer. The processor unit assignment rules consider the newly installed CPC drawer dynamically.

3.5.10 Sparing rules

On an IBM z16 A01 system, two PUs are reserved as spares. The spare PUs are available to replace any two characterized PUs, whether they are CP, IFL, ICF, zIIP, SAP, or IFP.

Systems with a failed PU for which no spare is available *call home* for a replacement. A system with a failed PU that is spared and requires a DCM to be replaced (referred to as a *pending repair*) can still be upgraded when sufficient PUs are available.

Transparent CP, IFL, ICF, zIIP, SAP, and IFP sparing

Depending on the model, sparing of CP, IFL, ICF, zIIP, SAP, and IFP is transparent and does not require operating system or operator intervention.

With *transparent sparing*, the status of the application that was running on the failed processor is preserved. The application continues processing on a newly assigned CP, IFL, ICF, zIIP, SAP, or IFP (allocated to one of the spare PUs) without client intervention.

Application preservation

If no spare PU is available, *application preservation* (z/OS only) is started. The state of the failing processor is passed to another active processor that is used by the operating system. Through operating system recovery services, the task is resumed successfully (in most cases, without client intervention).

¹² For a layout of CPC drawers’ locations, refer to 3.5.11, “CPC drawer numbering” on page 114

Dynamic SAP and IFP sparing and reassignment

Dynamic recovery is provided if a failure of the SAP or IFP occurs. If the SAP or IFP fails, and if a spare PU is available, the spare PU is dynamically assigned as a new SAP or IFP. If no spare PU is available, and more than one CP is characterized, a characterized CP is reassigned as an SAP or IFP. In either case, client intervention is not required. This capability eliminates an unplanned outage and allows a service action to be deferred to a more convenient time.

3.5.11 CPC drawer numbering

IBM z16 A01 CPC drawer numbering starts with CPC 0, the first installed CPC drawer. It is in frame A at A10. The second one, in the same frame, at A15. The third one, in the same frame at A20. The fourth CPC drawer is in frame B (location B10).

Figure 3-20 shows CPC drawer numbering.

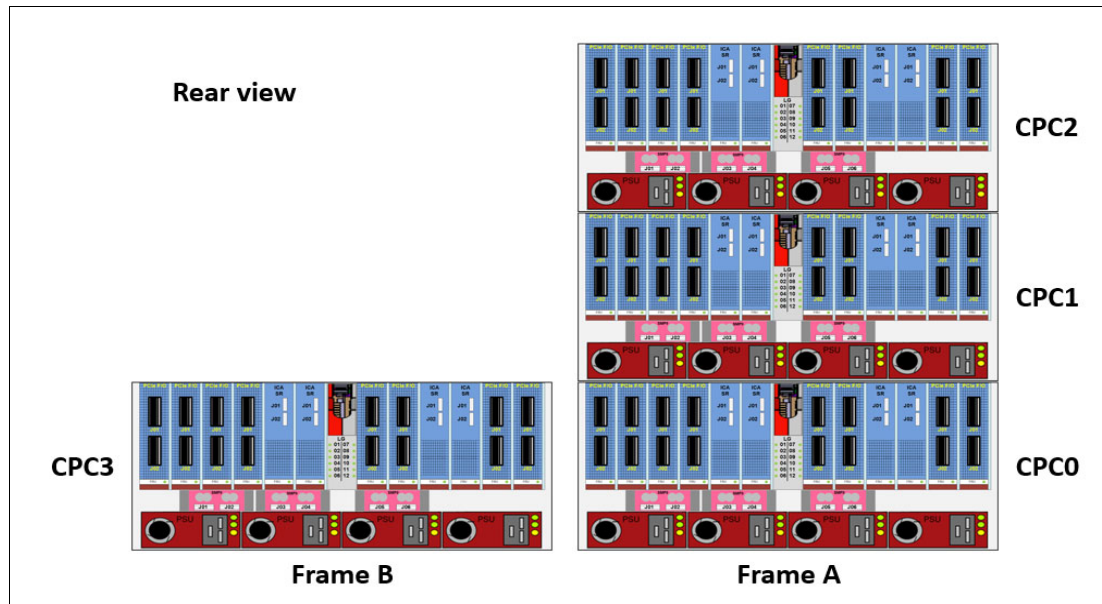


Figure 3-20 CPC drawer numbering

3.6 Memory design

Various considerations of the IBM z16 memory design are described in this section.

3.6.1 Overview

the IBM z16 A01 memory design also provides flexibility, high availability, and the following upgrades:

- ▶ Concurrent memory upgrades if the physically installed capacity is not yet reached
IBM z16 servers can have more physically installed memory than the initial available capacity. Memory upgrades within the physically installed capacity can be done concurrently by LIC, and no hardware changes are required. However, memory upgrades *cannot* be done through CBU or On/Off CoD.
- ▶ Concurrent memory upgrades if the physically installed capacity is reached
Physical memory upgrades require a processor drawer to be removed and reinstalled after replacing the memory cards in the processor drawer. Except for the feature Max39, the combination of enhanced drawer availability and the flexible memory option allows you to concurrently add memory to the system. For more information, see 2.5.5, “Drawer replacement and memory” on page 46, and 2.5.7, “Flexible Memory Option” on page 47.

When the total capacity that is installed has more usable memory than required for a configuration, the Licensed Internal Code Configuration Control (LICCC) determines how much memory is used from each processor drawer. The sum of the LICCC provided memory from each CPC drawer is the amount that is available for use in the system.

Memory allocation

When the system is activated by using a POR, PR/SM determines the total installed memory and the customer enabled memory. Later in the process, during LPAR activation, PR/SM assigns and allocates each partition memory according to their image profile.

PR/SM controls all physical memory, and can make physical memory available to the configuration when a CPC drawer is added.

In older IBM Z processors, memory allocation was striped across the available CPC drawers because relatively fast connectivity (that is, relatively fast to the processor clock frequency) existed between the drawers. Splitting the work between all of the memory controllers allowed a smooth performance variability.

The memory allocation algorithm changed starting with IBM z13®. For IBM z16, PR/SM tries to allocate memory into a single CPC drawer. If memory does not fit into a single drawer, PR/SM tries to allocate the memory into the CPC drawer with the most processor entitlement.

The PR/SM memory and logical processor resources allocation goal is to place all partition resources on a single CPC drawer, if possible. The resources, such as memory and logical processors, are assigned to the logical partitions at the time of their activation. Later on, when all partitions are activated, PR/SM can move memory between CPC drawers to benefit the performance of each LPAR, without operating system knowledge. This process was done on the previous families of IBM Z servers only for PUs that use PR/SM dynamic PU reallocation.

With IBM z16 servers, this process occurs whenever the configuration changes, such as in the following circumstances:

- ▶ Activating or deactivating an LPAR
- ▶ Changing the LPARs processing weights
- ▶ Upgrading the system through a temporary or permanent record
- ▶ Downgrading the system through deactivation of a temporary record

PR/SM schedules a global reoptimization of the resources in use. It does so by reviewing all the partitions that are active and prioritizing them based on their processing entitlement and weights, which creates a high- and low-priority rank. Then, the resources, such as logical processors and memory, can be moved from one CPC drawer to another to address the priority ranks that were created.

When partitions are activated, PR/SM tries to find a home assignment CPC drawer, home assignment node, and home assignment chip for the logical processors that are defined to them. The PR/SM goal is to allocate all the partition logical processors and memory to a single CPC drawer (the home drawer for that partition).

If all logical processors can be assigned to a home drawer and the partition-defined memory is greater than what is available in that drawer, the exceeding memory amount is allocated on another CPC drawer. If all the logical processors cannot fit in one CPC drawer, the remaining logical processors spill to another CPC drawer. When that overlap occurs, PR/SM stripes the memory (if possible) across the CPC drawers where the logical processors are assigned.

The process of reallocating memory is based on the *memory copy/reassign* function, which is used to allow enhanced drawer availability (EDA) and concurrent drawer replacement (CDR)¹³. This process was enhanced starting with z13 and IBM z13s® to provide more efficiency and speed to the process without affecting system performance.

IBM z16 A01 implements a faster dynamic memory reallocation mechanism, which is especially useful during service operations (EDA and CDR). PR/SM controls the reassignment of the content of a specific physical memory array in one CPC drawer to a physical memory array in another CPC drawer. To accomplish this task, PR/SM uses all the available physical memory in the system. This memory includes the memory that is not in use by the system that is available but not purchased by the client, and the planned memory options, if installed.

Because of the memory allocation algorithm, systems that undergo many miscellaneous equipment specification (MES) upgrades for memory can have different memory mixes and quantities in all processor drawers of the system. If the memory fails, it is technically feasible to run a POR of the system with the remaining working memory resources. After the POR completes, the memory distribution across the processor drawers is different, as is the total amount of available memory.

Large page support

By default, page frames are allocated with a 4 KB size. IBM z16 servers also support large page sizes of 1 MB or 2 GB. The first z/OS release that supports 1 MB pages is z/OS V1R9. Linux on IBM Z 1 MB pages support is available in SUSE Linux Enterprise Server 10 SP2 and Red Hat Enterprise Linux (RHEL) 5.2 and later.

The TLB reduces the amount of time that is required to translate a virtual address to a real address. This translation is done by dynamic address translation (DAT) when it must find the correct page for the correct address space.

¹³ In previous IBM Z generations (before z13), these service operations were known as enhanced book availability (EBA) and concurrent book repair (CBR).

Each TLB entry represents one page. As with other buffers or caches, lines are discarded from the TLB on a least recently used (LRU) basis.

The worst-case translation time occurs when a TLB miss occurs and the segment table (which is needed to find the page table) and the page table (which is needed to find the entry for the particular page in question) are not in cache. This case involves two complete real memory access delays plus the address translation delay. The duration of a processor cycle is much shorter than the duration of a memory cycle, so a TLB miss is relatively costly.

It is preferable to have addresses in the TLB. With 4 K pages, holding all of the addresses for 1 MB of storage takes 256 TLB lines. When 1 MB pages are used, it takes only one TLB line. Therefore, large page size users have a much smaller TLB footprint.

Large pages allow the TLB to better represent a large working set and suffer fewer TLB misses by allowing a single TLB entry to cover more address translations.

Users of large pages are better represented in the TLB and are expected to see performance improvements in elapsed time and processor usage. These improvements are because DAT and memory operations are part of processor busy time, even though the processor waits for memory operations to complete without processing anything else in the meantime.

To overcome the processor usage that is associated with creating a 1 MB page, a process must run for some time. It also must maintain frequent memory access to keep the pertinent addresses in the TLB.

Short-running work does not overcome the processor usage. Short processes with small working sets are expected to receive little or no improvement. Long-running work with high memory-access frequency is the best candidate to benefit from large pages.

Long-running work with low memory-access frequency is less likely to maintain its entries in the TLB. However, when it does run, few address translations are required to resolve all of the memory it needs. Therefore, a long-running process can benefit even without frequent memory access.

Weigh the benefits of whether something in this category must use large pages as a result of the system-level costs of tying up real storage. A balance exists between the performance of a process that uses large pages and the performance of the remaining work on the system.

On IBM z16 server, 1 MB large pages become pageable if Virtual Flash Memory¹⁴ is available and enabled. They are available only for 64-bit virtual private storage, such as virtual memory that is above 2 GB.

It is easy to assume that increasing the TLB size is a feasible option to deal with TLB-miss situations. However, this process is not as simple as it seems. As the size of the TLB increases, so does the processor usage that is involved in managing the TLB's contents. Correct sizing of the TLB is subject to complex statistical modeling to find the optimal tradeoff between size and performance.

¹⁴ Virtual Flash Memory replaced IBM zFlash Express. No carry forward of zFlash Express exists.

3.6.2 Main storage

Main storage consists of memory space that is addressable by programs and storage that is not directly addressable by programs. Nonaddressable storage includes the hardware system area (HSA).

Main storage provides the following functions:

- ▶ Data storage and retrieval for PUs and I/O
- ▶ Communication with PUs and I/O
- ▶ Communication with and control of optional expanded storage
- ▶ Error checking and correction

Main storage can be accessed by all processors, but cannot be shared between LPARs. Any system image (LPAR) must include a defined main storage size. This defined main storage is allocated exclusively to the LPAR during partition activation.

3.6.3 Hardware system area

The HSA is a nonaddressable storage area that contains system LIC and configuration-dependent control blocks. On IBM z16 A01 servers, the HSA has a fixed size of 256 GB and is not part of the purchased memory that you order and install.

The fixed size of the HSA eliminates planning for future expansion of the HSA because the hardware configuration definition (HCD)/input/output configuration program (IOCP) always reserves space for the following items:

- ▶ Six channel subsystems (CSSs)
- ▶ A total of 15 LPARs in CSSs 1 through 5, and 10 LPARs for the sixth CSS for a total of 85 LPARs
- ▶ Subchannel set 0 with 63.75-K devices in each CSS
- ▶ Subchannel set 1 with 64-K devices in each CSS
- ▶ Subchannel set 2 with 64-K devices in each CSS
- ▶ Subchannel set 3 with 64-K devices in each CSS

The HSA features sufficient reserved space to allow for dynamic I/O reconfiguration changes to the maximum capability of the processor.

3.6.4 Virtual Flash Memory (FC 0644)

IBM Virtual Flash Memory (VFM, FC 0644) is the replacement for the Flash Express features that were available on the IBM zEC12 and IBM z13. No application changes are required to change from IBM Flash Express to VFM.

For IBM z16 A01, IBM VFM provides up to 6.0 TB of virtual flash memory in 512 GB increments. The minimum is 0, while the maximum is 12 features. The number of VFM features ordered reduces the maximum orderable memory for the IBM z16.

3.7 Logical partitioning

The logical partitioning features are described in this section.

3.7.1 Overview

Logical partitioning is a function that is implemented by the PR/SM on IBM z16. IBM z16 can run in LPAR mode, or in DPM mode. DPM provides a GUI for PR/SM to manage I/O resources dynamically.

PR/SM is aware of the processor drawer structure on IBM z16 servers. However, LPARs do not feature this awareness. LPARs feature resources that are allocated to them from various physical resources. From a systems standpoint, LPARs have no control over these physical resources, but the PR/SM functions do have this control.

PR/SM manages and optimizes allocation and the dispatching of work on the physical topology. Most physical topology that was handled by the operating systems is the responsibility of PR/SM.

As described in 3.5.9, “Processor unit assignment” on page 112, the initial PU assignment is done during POR by using rules to optimize cache usage. This step is the “physical” step, where CPs, zIIPs, IFLs, ICFs, and SAPs are allocated on the processor drawers.

When an LPAR is activated, PR/SM builds logical processors and allocates memory for the LPAR.

PR/SM assigns all logical processors to one CPC drawer that are packed into chips of that drawer and cooperates with operating system use of HiperDispatch.

All processor types of an IBM z16 can be dynamically reassigned, except IFPs.

Memory allocation changed from the previous IBM Z servers. Partition memory is now allocated based on processor drawer affinity. For more information, see “Memory allocation” on page 115.

Logical processors are dispatched by PR/SM on physical processors. The assignment topology that is used by PR/SM to dispatch logical processors on physical PUs is also based on cache usage optimization.

Processor drawers assignment is more important because they optimize virtual L4 cache usage. Therefore, logical processors from a specific LPAR are packed into a processor drawer as much as possible.

PR/SM optimizes chip assignments within the assigned processor drawer (or drawers) to maximize virtual L3 cache efficiency. Logical processors from an LPAR are dispatched on physical processors on the same PU chip as much as possible.

PR/SM also tries to redispach a logical processor on the same physical processor to optimize private cache (L1 and L2) usage.

HiperDispatch

PR/SM and z/OS work in tandem to use processor resources more efficiently. HiperDispatch is a function that combines the dispatcher actions and the knowledge that PR/SM has about the topology of the system.

Performance can be optimized by redispaching units of work to the same processor group, which keeps processes running near their cached instructions and data, and minimizes transfers of data ownership among processors and processor drawers.

The nested topology is returned to z/OS by the Store System Information (STSI) instruction. HiperDispatch uses the information to concentrate logical processors around shared caches (virtual L3 and virtual L4 caches at drawer level), and dynamically optimizes the assignment of logical processors and units of work.

z/OS dispatcher manages multiple queues, called *affinity queues*, with a target number of eight processors per queue, which fits well onto a single PU chip. These queues are used to assign work to as few logical processors as are needed for an LPAR workload. Therefore, even if the LPAR is defined with many logical processors, HiperDispatch optimizes this number of processors to be near the required capacity. The optimal number of processors to be used is kept within a processor drawer boundary, when possible.

Tip: z/VM V7R1 and later also support HiperDispatch.

Logical partitions

PR/SM enables IBM z16 A01 systems to be initialized for a logically partitioned operation, supporting up to 85 LPARs. Each LPAR can run its own operating system image in any image mode, independently from the other LPARs.

An LPAR can be added, removed, activated, or deactivated at any time. Changing the number of LPARs is not disruptive and does not require a POR. Certain facilities might not be available to all operating systems because the facilities might have software corequisites.

Each LPAR has the following resources that are the same as a real CPC:

- ▶ Processors

Called *logical processors*, they can be defined as CPs, IFLs, ICFs, or zIIPs. They can be dedicated to an LPAR or shared among LPARs. When shared, a processor weight can be defined to provide the required level of processor resources to an LPAR. Also, the capping option can be turned on, which prevents an LPAR from acquiring more than its defined weight and limits its processor consumption.

LPARs for z/OS can have CP and zIIP logical processors. The logical processor types can be defined as all dedicated or all shared. The zIIP support is available in z/OS.

The weight and number of online logical processors of an LPAR can be dynamically managed by the LPAR CPU Management function of the Intelligent Resource Director (IRD). These functions can be used to achieve the defined goals of this specific partition and of the overall system. The provisioning architecture of IBM z16 systems adds a dimension to the dynamic management of LPARs, as described in Chapter 8, “System upgrades” on page 331.

PR/SM supports an option to limit the amount of physical processor capacity that is used by an individual LPAR when a PU is defined as a general-purpose processor (CP) or an IFL that is shared across a set of LPARs.

This capability is designed to provide a physical capacity limit that is enforced as an absolute (versus relative) limit. It is not affected by changes to the logical or physical configuration of the system. This physical capacity limit can be specified in units of CPs or IFLs. The Change LPAR Controls and Customize Activation Profiles tasks on the HMC were enhanced to support this new function.

For the z/OS Workload License Charges (WLC) pricing metric and metrics that are based on it, such as Advanced Workload License Charges (AWLC), an LPAR *defined capacity* can be set. This defined capacity enables the soft capping function. Workload charging introduces the capability to pay software license fees that are based on the processor utilization of the LPAR on which the product is running, rather than on the total capacity of the system.

Consider the following points:

- In support of WLC, the user can specify a defined capacity in millions of service units (MSUs) per hour. The defined capacity sets the capacity of an individual LPAR when soft capping is selected.

The defined capacity value is specified on the Options tab in the Customize Image Profiles window.

- WLM keeps a four-hour rolling average of the processor usage of the LPAR. When the four-hour average processor consumption exceeds the defined capacity limit, WLM dynamically activates LPAR capping (soft capping). When the rolling four-hour average returns below the defined capacity, the soft cap is removed.

For more information about WLM, see *System Programmer's Guide to: Workload Manager*, [SG24-6472](#).

For more information about software licensing, see 7.8, “Software licensing” on page 327.

Weight settings: When defined capacity is used to define an uncapped LPAR's capacity, carefully consider the weight settings of that LPAR. If the weight is much smaller than the defined capacity, PR/SM uses a discontinuous cap pattern to achieve the defined capacity setting. This configuration means PR/SM alternates between capping the LPAR at the MSU value that corresponds to the relative weight settings, and no capping at all. It is best to avoid this scenario and instead attempt to establish a defined capacity that is equal or close to the relative weight.

► Memory

Memory (main storage) must be dedicated to an LPAR. The defined storage must be available during the LPAR activation; otherwise, the LPAR activation fails.

Reserved storage can be defined to an LPAR, which enables nondisruptive memory addition to and removal from an LPAR by using the LPAR dynamic storage reconfiguration (z/OS and z/VM). For more information, see 3.7.5, “LPAR dynamic storage reconfiguration” on page 129.

► Channels

Channels can be shared between LPARs by including the partition name in the partition list of a channel-path identifier (CHPID). I/O configurations are defined by the IOCP or the HCD with the CHPID mapping tool (CMT). The CHPID Mapping Tool (CMT) is an optional tool that is used to map CHPIDs onto physical channel IDs (PCHIDs). PCHIDs represent the physical location of a port on a card in a PCIe I/O drawer.

IOCP is available on the z/OS, z/VM, and z/VSE operating systems, and as a stand-alone program on the hardware console. For more information, see *Input/Output Configuration Program User's Guide for ICP IOCP*, SB10-7177. HCD is available on the z/OS and z/VM operating systems. Review the suitable 3931DEVICE Preventive Service Planning (PSP) buckets before implementation.

Fibre Channel connection (FICON) channels can be managed by the Dynamic CHPID Management (DCM) function of the Intelligent Resource Director. DCM enables the system to respond to ever-changing channel requirements by moving channels from lesser-used control units to more heavily used control units, as needed.

Modes of operation

The modes of operation are listed in Table 3-6. All available mode combinations, including their operating modes and processor types, operating systems, and addressing modes, also are listed. Only the currently supported versions of operating systems are considered.

Table 3-6 IBM z16 modes of operation

Image mode	PU type	Operating system	Addressing mode
General ^a	CP and zIIP	<ul style="list-style-type: none"> ▶ z/OS ▶ z/VM 	64-bit
	CP	<ul style="list-style-type: none"> ▶ z/VSE ▶ Linux on IBM Z ▶ z/TPF 	64-bit
Coupling facility	ICF or CP	CFCC	64-bit
Linux only	IFL or CP	<ul style="list-style-type: none"> ▶ Linux on IBM Z (64-bit) ▶ z/VM 	64-bit
		Linux on IBM Z (31-bit)	31-bit
z/VM	CP, IFL, zIIP, or ICF	z/VM	64-bit
SSC ^b	IFL or CP	Linux-based appliance ^c	64 bit

a. General mode uses 64-bit z/Architecture

b. IBM Secure Service Container

c. IBM Db2 Analytics Accelerator (IDAA), Hyper Protect Virtual Servers (HPVS), and others

The 64-bit z/Architecture mode has no special operating mode because the architecture mode is not an attribute of the definable images operating mode. The 64-bit operating systems are in 31-bit mode at IPL and change to 64-bit mode during their initialization. The operating system is responsible for taking advantage of the addressing capabilities that are provided by the architectural mode.

For information about operating system support, see Chapter 7, “Operating system support” on page 251.

Logically partitioned mode

If the IBM z16 A01 system runs in LPAR mode, each of the 85 LPARs can be defined to operate in one of the following image modes:

- ▶ General mode to run the following systems:
 - A z/Architecture operating system, on dedicated or shared CPs
 - A Linux on IBM Z operating system, on dedicated or shared CPs
 - z/OS, on any of the following processor units:
 - Dedicated or shared CPs
 - Dedicated CPs *and* dedicated zIIPs
 - Shared CPs *and* shared zIIPs

zIIP usage: zIIPs can be defined to General mode or z/VM mode image, as listed in Table 3-6 on page 122. However, zIIPs are used by z/OS only. Other operating systems cannot use zIIPs, even if they are defined to the LPAR. z/VM V7R1 and later support real and virtual zIIPs to guest z/OS systems.

- ▶ General mode also is used to run the z/TPF operating system on dedicated or shared CPs
- ▶ CF mode, by loading the CFCC code into the LPAR that is defined as one of the following types:
 - Dedicated or shared CPs
 - Dedicated or shared ICFs
- ▶ Linux only mode to run the following systems:
 - A Linux on IBM Z operating system, on either of the following types:
 - Dedicated or shared IFLs
 - Dedicated or shared CPs
 - A z/VM operating system, on either of the following types:
 - Dedicated or shared IFLs
 - Dedicated or shared CPs
- ▶ z/VM mode to run z/VM on dedicated or shared CPs or IFLs, plus zIIPs and ICFs
- ▶ IBM SSC mode LPAR can run on dedicated or shared:
 - CPs
 - IFLs

All LPAR modes, required characterized PUs, operating systems, and the PU characterizations that can be configured to an LPAR image are listed in Table 3-7. The available combinations of dedicated (DED) and shared (SHR) processors are also included. For all combinations, an LPAR also can include reserved processors that are defined, which allows for nondisruptive LPAR upgrades.

Table 3-7 LPAR mode and PU usage

LPAR mode	PU type	Operating systems	PUs usage
General	CPs	<ul style="list-style-type: none"> ▶ z/Architecture operating systems ▶ Linux on IBM Z 	CPs DED or CPs SHR
	CPs and zIIPs	<ul style="list-style-type: none"> ▶ z/OS ▶ z/VM (guest exploitation) 	CPs DED or zIIPs DED or CPs SHR or zIIPs SHR
General	CPs	z/TPF	CPs DED or CPs SHR
Coupling facility	ICFs or CPs	CFCC	ICFs DED or ICFs SHR or CPs DED or CPs SHR
Linux only	IFLs or CPs	<ul style="list-style-type: none"> ▶ Linux on IBM Z ▶ z/VM 	IFLs DED or IFLs SHR or CPs DED or CPs SHR
z/VM	CPs, IFLs, zIIPs, or ICFs	z/VM (V7R1 and later)	All PUs must be SHR or DED

LPAR mode	PU type	Operating systems	PUs usage
SSC ^a	IFLs, <i>or</i> CPs	Linux-based appliance	IFLs DED or IFLs SHR or CPs DED or CPs SHR

a. IBM Secure Service Container

Dynamically adding or deleting a logical partition name

Dynamically adding or deleting an LPAR name is the ability to add or delete LPARs and their associated I/O resources to or from the configuration without a POR.

The extra channel subsystem and multiple image facility (MIF) image ID pairs (CSSID/MIFID) can be later assigned to an LPAR for use (or later removed). This process can be done through dynamic I/O commands by using the HCD. At the same time, required channels must be defined for the new LPAR.

Partition profile: Cryptographic coprocessors are not tied to partition numbers or MIF IDs. They are set up with Adjunct Processor (AP) numbers and domain indexes. These numbers are assigned to a partition profile of a specific name. The client assigns these AP numbers and domains to the partitions and continues to have the responsibility to clear them out when their profiles change.

Adding logical processors to a logical partition

Logical processors can be concurrently added to an LPAR by defining them as reserved in the image profile and later configuring them online to the operating system by using the suitable console commands.

Logical processors also can be concurrently added to a logical partition dynamically by using the Support Element (SE) “Logical Processor Add” function under the CPC Operational Customization task. This SE function allows the initial and reserved processor values to be dynamically changed. The operating system must support the dynamic addition¹⁵ of these resources.

Adding a crypto feature to a logical partition

You can plan the addition of supported Crypto Express features to an LPAR on the crypto page in the image profile by defining the Cryptographic Candidate List, and the Usage and Control Domain indexes, in the partition profile. By using the Change LPAR Cryptographic Controls task, you can add crypto adapters dynamically to an LPAR without an outage of the LPAR. Also, dynamic deletion or moving of these features does not require planning. Support is provided in z/OS, z/VM, z/VSE, IBM SSC (based on appliance requirements), and Linux on IBM Z.

LPAR dynamic PU reassignment

The system configuration is enhanced to optimize the PU-to-CPC drawer assignment of physical processors dynamically. The initial assignment of client-usable physical processors to physical processor drawers can change dynamically to better suit the LPAR configurations that are in use.

For more information, see 3.5.9, “Processor unit assignment” on page 112.

¹⁵ In z/OS, this support is available since Version 1 Release 10 (z/OS V1R10), while z/VM supports this addition since z/VM V5R4, and z/VSE since V4R3. However, IBM z16 supports z/OS V2R2 and later, z/VSE V6R2 and z/VM V7R1 and later.

Swapping of specialty engines and general processors with each other, with spare PUs, or with both, can occur as the system attempts to compact LPAR configurations into physical configurations that span the least number of processor drawers.

LPAR dynamic PU reassignment can swap client processors of different types between processor drawers. For example, reassignment can swap an IFL on processor drawer 1 with a CP on processor drawer 2. Swaps can also occur between PU chips within a processor drawer or a node and can include spare PUs. The goals are to pack the LPAR on fewer processor drawers and also on fewer PU chips, based on the IBM z16 processor drawers' topology. The effect of this process is evident in dedicated and shared LPARs that use HiperDispatch.

LPAR dynamic PU reassignment is transparent to operating systems.

LPAR group capacity limit (LPAR group absolute capping)

The group capacity limit feature allows the definition of a group of LPARs on an IBM z16 system, and limits the combined capacity usage by those LPARs. This process allows the system to manage the group so that the group capacity limits in MSUs per hour are not exceeded. To take advantage of this feature, you must be running z/OS V2R2 or later in all LPARs in the group.

PR/SM and WLM work together to enforce the capacity that is defined for the group and the capacity that is optionally defined for each individual LPAR.

LPAR absolute capping

Absolute capping is a logical partition control that was made available with zEC12 and is supported on IBM z16 systems. With this support, PR/SM and the HMC are enhanced to support a new option to limit the amount of physical processor capacity that is used by an individual LPAR when a PU is defined as a general-purpose processor (CP), zIIP, or an IFL processor that is shared across a set of LPARs.

Unlike traditional LPAR capping, absolute capping is designed to provide a physical capacity limit that is enforced as an absolute (versus relative) value that is not affected by changes to the virtual or physical configuration of the system.

Absolute capping provides an optional maximum capacity setting for logical partitions that is specified in the absolute processors capacity (for example, 5.00 CPs or 2.75 IFLs). This setting is specified independently by processor type (namely CPs, zIIPs, and IFLs) and provides an enforceable upper limit on the amount of the specified processor type that can be used in a partition.

Absolute capping is ideal for processor types and operating systems that the z/OS WLM cannot control. Absolute capping is not intended as a replacement for defined capacity or group capacity for z/OS, which are managed by WLM.

Absolute capping can be used with any z/OS, z/VM, or Linux on IBM Z LPAR (that is running on an IBM Z server). If specified for a z/OS LPAR, absolute capping can be used concurrently with defined capacity or group capacity management for z/OS. When used concurrently, the absolute capacity limit becomes effective before other capping controls.

Dynamic Partition Manager mode

DPM is an IBM Z server operation mode that provides a simplified approach to create and manage virtualized environments, which reduces the barriers of its adoption for new and existing customers.

The implementation provides built-in integrated capabilities that allow advanced virtualization management on IBM Z servers. With DPM, you can use your Linux and virtualization skills while taking advantage of the full value of IBM Z hardware, robustness, and security in a workload optimized environment.

DPM provides facilities to define and run virtualized computing systems by using a firmware-managed environment that coordinate the physical system resources that are shared by the partitions. The partitions' resources include processors, memory, network, storage, crypto, and accelerators.

DPM provides a new mode of operation for IBM Z servers that provide the following services:

- ▶ Facilitates defining, configuring, and operating PR/SM LPARs in a similar way to how these tasks are performed on another platform.
- ▶ Lays the foundation for a general IBM Z new user experience.

DPM is not another hypervisor for IBM Z servers. DPM uses the PR/SM hypervisor infrastructure and provides an intelligent interface on top of it that allows customers to define, use, and operate the platform virtualization without IBM Z experience or skills.

3.7.2 Storage operations

In IBM z16 A01 systems, memory can be assigned as main storage, supporting up to 85 LPARs. Before you activate an LPAR, main storage must be defined to the LPAR. All installed storage can be configured as main storage.

For more information about operating system main storage support, see the *PR/SM Planning Guide*, SB10-7178.

Memory *cannot* be shared between system images (LPARs). It is possible to dynamically reallocate storage resources for z/Architecture LPARs that run operating systems that support dynamic storage reconfiguration (DSR). This process is supported by z/OS, and z/VM. z/VM, in turn, virtualizes this support to its guests.

For more information, see 3.7.5, “LPAR dynamic storage reconfiguration” on page 129.

Operating systems that run as guests of z/VM can use the z/VM capability of implementing virtual memory to guest virtual machines. The z/VM dedicated real storage can be shared between guest operating systems.

LPAR main storage allocation and usage

The IBM z16 storage allocation and usage possibilities depend on the image mode and the operating system that is deployed in the LPAR.

Important: The memory allocation and usage depends on the operating system architecture and tested (documented for each operating system) limits.

While the maximum supported memory per LPAR for IBM z16 is 32 TB, each operating system has its own support specifications.

For more information about general guidelines, see the *PR/SM Planning Guide*, SB10-7178, which is available at the [IBM Resource Link website](#) (log in required).

The following modes are provided:

► z/Architecture

In z/Architecture (General) mode, storage addressing is 64-bit, which allows for virtual addresses up to 16 exabytes (16 EB). However, the current main storage limit for LPARs on an IBM z16 A01 is 32 TB of main storage.

The operating system that runs in z/Architecture mode must support the real storage. z/OS V2R4 and below support up to 4 TB of real storage, while z/OS V2R5 supports up to 16 TB.

► CF

In CF mode, storage addressing is 64-bit for a CF image that runs at CFCC. This configuration allows for an addressing range up to 16 EB. However, the current IBM z16 A01 definition limit for CF LPARs is 32 TB of storage.

The following CFCC levels are supported in a Sysplex with IBM z16:

- CFCC Level 25, available on IBM z16 (Driver level 51)
- CFCC Level 24, available on IBM z15 (Driver level 41)
- CFCC Level 23, available on IBM z14 (Driver level 36)
- CFCC Level 22, available on IBM z14 (Driver level 32)

For more information, see 3.9.1, “CF Control Code” on page 133.

Only IBM CFCC can run in CF mode.

► Linux only

In Linux only mode, storage addressing can be 31-bit or 64-bit, depending on the operating system architecture and the operating system configuration.

Only Linux and z/VM operating systems can run in Linux only mode. Linux on IBM Z 64-bit distributions (SUSE Linux Enterprise Server 12 SP5, SLES 15 SP3, Red Hat RHEL 7.9, RHEL 8.4, and Ubuntu 20.04.1 LTS and later) use 64-bit addressing and operate in z/Architecture mode. z/VM also uses 64-bit addressing and operates in z/Architecture mode.

Note: For information about the (kernel) supported amount of memory, check the Linux Distribution specific documentation.

► z/VM

In z/VM mode, specific types of processor units can be defined within one LPAR. This feature increases flexibility and simplifies systems management by allowing z/VM to run the following tasks in the same z/VM LPAR:

- Manage guests to operate Linux on IBM Z on IFLs
- Operate z/VSE and z/OS on CPs
- Offload z/OS system software processor usage, such as Db2 workloads on zIIPs
- Provide an economical Java execution environment under z/OS on zIIPs

► IBM SSC

In IBM SSC mode, storage addressing is 64-bit for an embedded product. The amount of usable main storage by the appliance code that is deployed in the SSC LPAR is documented by the appliance code supplier.

3.7.3 Reserved storage

Reserved storage can be optionally defined to an LPAR, which allows a nondisruptive image memory upgrade for this partition. Reserved storage can be defined to central and expanded storage, and to any image mode except CF mode.

An LPAR must define an amount of main storage:

- ▶ The *initial value* is the storage size that is allocated to the partition when it is activated.
- ▶ The *reserved value* is another storage capacity that is beyond its initial storage size that an LPAR can acquire dynamically. The reserved storage sizes that are defined to an LPAR do not have to be available when the partition is activated. Instead, they are predefined storage sizes to allow a storage increase, from an LPAR perspective.

Without the reserved storage definition, an LPAR storage upgrade is a disruptive process that requires the following steps:

1. Partition deactivation.
2. An initial storage size definition change.
3. Partition activation.

The extra storage capacity for an LPAR upgrade can come from the following sources:

- ▶ Any unused available storage
- ▶ Another partition that features released storage
- ▶ A memory upgrade

A concurrent LPAR storage upgrade uses DSR. z/OS uses the reconfigurable storage unit (RSU) definition to add or remove storage units in a nondisruptive way.

z/VM V7R1 and later releases support the dynamic addition of memory to a running LPAR by using reserved storage. It also virtualizes this support to its guests. In z/VM 7.1, removing storage from the z/VM LPAR is disruptive. Removing memory from a z/VM guest is not disruptive to the z/VM LPAR.

z/VM V7R2 and later also support Dynamic Memory Downgrade (DMD), which allows the removal of up to 50% of the real storage from a running z/VM system.

SLES 11 and later supports concurrent add and remove.

3.7.4 Logical partition storage granularity

Granularity of main storage for an LPAR depends on the largest main storage amount that is defined for initial or reserved main storage, as listed in Table 3-8¹⁶.

Table 3-8 Logical partition main storage granularity (IBM z16)

Logical partition: Largest main storage amount	Logical partition: Main storage granularity
Main storage amount <= 512 GB	1 GB
512 GB < main storage amount <= 1 TB	2 GB
1 TB < main storage amount <= 2 TB	4 GB
2 TB < main storage amount <= 4 TB	8 GB
4 TB < main storage amount <= 8 TB	16 GB
8 TB < main storage amount <= 16 TB	32 GB

LPAR storage granularity information is required for LPAR image setup and for z/OS RSU definition. On IBM z16 A01, LPARs are limited to a maximum of 16 TB of main storage. However, the maximum amount of memory that is supported by z/OS V2R2, V2R3, and V2R4 is 4 TB. z/OS V2R5 supports up to 16 TB. For z/VM V7R1 the limit is 2 TB, and z/VM V7R2 increases the limit to 4 TB.

3.7.5 LPAR dynamic storage reconfiguration

Dynamic storage reconfiguration on IBM z16 systems allows an operating system that is running on an LPAR to add (nondisruptively) its reserved storage amount to its configuration. This process can occur only if unused storage exists. This unused storage can be obtained when another LPAR releases storage, or when a concurrent memory upgrade occurs.

With dynamic storage reconfiguration, the unused storage does not have to be continuous.

When an operating system that is running on an LPAR assigns a storage increment to its configuration, PR/SM determines whether any free storage increments are available. PR/SM then dynamically brings the storage online.

PR/SM dynamically takes offline a storage increment and makes it available to other partitions when an operating system running on an LPAR releases a storage increment.

¹⁶ When defining an LPAR on the HMC, the 2 G boundary must be followed in PR/SM.

3.8 Intelligent Resource Director

Intelligent Resource Director (IRD) is an IBM Z capability that is used only by z/OS. IRD is a function that optimizes processor and channel resource utilization across LPARs within a single IBM Z server.

This feature extends the concept of goal-oriented resource management. It does so by grouping system images that are on the same IBM z16 or IBM Z servers that are running in LPAR mode (and in the same Parallel Sysplex) into an *LPAR cluster*. This configuration allows WLM to manage resources (processor and I/O) across the entire cluster of system images and not only in one single image.

An LPAR cluster is shown in Figure 3-21. It contains three z/OS images and one Linux image that is managed by the cluster. Included as part of the entire Parallel Sysplex is another z/OS image and a CF image. In this example, the scope over which IRD has control is the defined LPAR cluster.

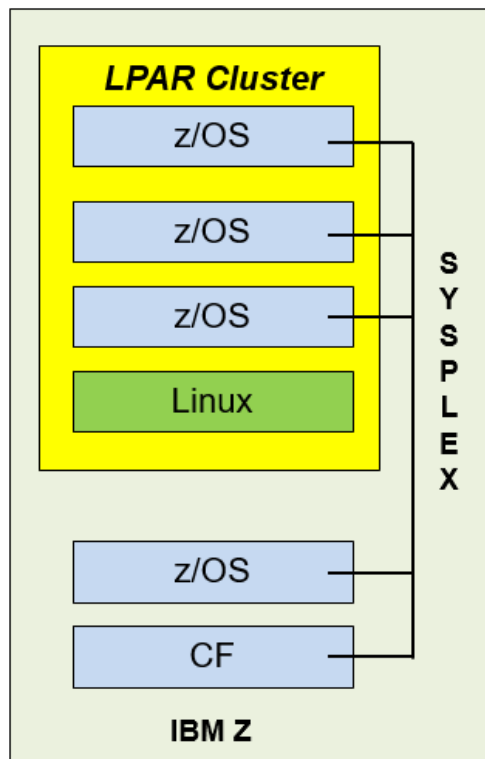


Figure 3-21 IRD LPAR cluster example

IRD features the following characteristics:

- ▶ IRD processor management

WLM dynamically adjusts the number of logical processors within an LPAR and the processor weight based on the WLM policy. The ability to move the processor weights across an LPAR cluster provides processing power where it is most needed, based on WLM goal mode policy.

The processor management function is automatically deactivated when HiperDispatch is active. However, the LPAR weight management function remains active with IRD with HiperDispatch. For more information about HiperDispatch, see 3.7, “Logical partitioning” on page 119.

HiperDispatch manages the number of logical CPs in use. It adjusts the number of logical processors within an LPAR to achieve the optimal balance between CP resources and the requirements of the workload.

HiperDispatch also adjusts the number of logical processors. The goal is to map the logical processor to as few physical processors as possible. This configuration uses the processor resources more efficiently by trying to stay within the local cache structure. Doing so makes efficient use of the advantages of the high-frequency microprocessors, and improves throughput and response times.

- ▶ Dynamic channel path management (DCM)

DCM moves FICON channel bandwidth between disk control units to address current processing needs. IBM z16 systems support DCM within a channel subsystem.

- ▶ Channel subsystem priority queuing

This function on IBM z16 and IBM Z allows the priority queuing of I/O requests in the channel subsystem and the specification of relative priority among LPARs. When running in goal mode, WLM sets the priority for an LPAR and coordinates this activity among clustered LPARs.

For more information about implementing LPAR processor management under IRD, see *z/OS Intelligent Resource Director*, [SG24-5952](#).

3.9 Clustering technology

Parallel Sysplex is the clustering technology that is used with IBM Z servers. The components of a Parallel Sysplex as implemented within the z/Architecture are shown in Figure 3-22. The example in Figure 3-22 shows one of many possible Parallel Sysplex configurations.

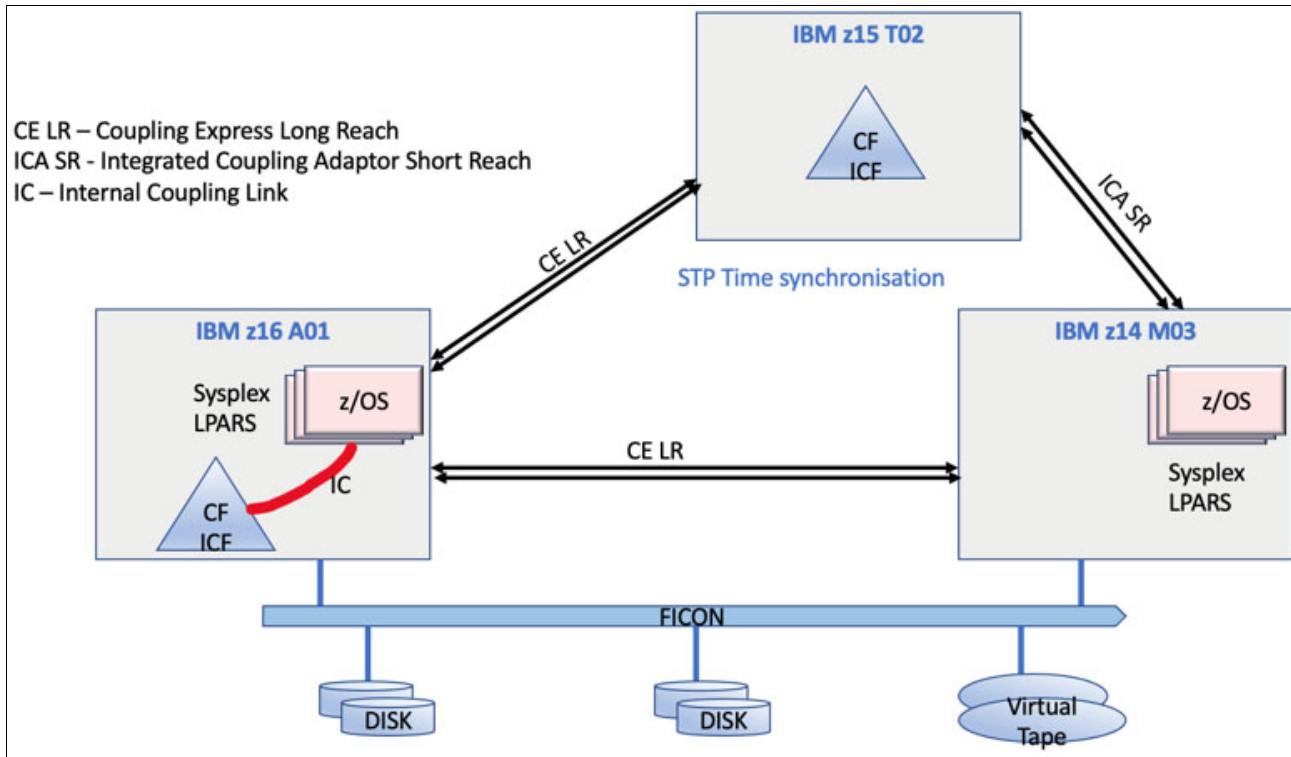


Figure 3-22 Sysplex hardware overview

Figure 3-22 shows an IBM z16 model A01 system that contains multiple z/OS sysplex partitions. It contains an internal CF, an IBM z15 model T02 system that contains a stand-alone CF, and an IBM z14 model M03 that contains multiple z/OS sysplex partitions.

STP over coupling links provides time synchronization to all systems. Selecting the suitable CF link technology Coupling Express2 Long Reach (CE2 LR) or Integrate Coupling Adaptor Short Reach (ICA SR and SR1.1) depends on the system configuration and how distant they are physically.

For more information about link technologies, see “Coupling links” on page 190.

Parallel Sysplex is an enabling technology that allows highly reliable, redundant, and robust IBM Z technology to achieve near-continuous availability. A Parallel Sysplex consists of one or more (z/OS) operating system images that are coupled through one or more Coupling Facility LPARs.

A correctly configured Parallel Sysplex cluster maximizes availability in the following ways:

- ▶ **Continuous availability:** Changes can be introduced, such as software upgrades, one image at a time, while the remaining images continue to process work. For more information, see *Parallel Sysplex Application Considerations*, [SG24-6523](#).
- ▶ **High capacity:** 1 - 32 z/OS images in a Parallel Sysplex that is operating as a single system.
- ▶ **Dynamic workload balancing:** Because it is viewed as a single logical resource, work can be directed to any operating system image in a Parallel Sysplex cluster that has available capacity.
- ▶ **Systems management:** The architecture defines the infrastructure to satisfy client requirements for continuous availability. It also provides techniques for achieving simplified systems management consistent with this requirement.
- ▶ **Resource sharing:** Several base z/OS components use CF shared storage. This configuration enables sharing of physical resources with significant improvements in cost, performance, and simplified systems management.
- ▶ **Single logical system:** The collection of system images in the Parallel Sysplex is displayed as a single entity to the operator, user, and database administrator. A single system view means reduced complexity from operational and definition perspectives.
- ▶ **N-2 support:** Multiple hardware generations (normally three) are supported in the same Parallel Sysplex. This configuration provides for a gradual evolution of the systems in the Parallel Sysplex without changing all of them simultaneously. Software support for multiple releases or versions also is supported.

Note: Parallel sysplex coupling and timing links connectivity for IBM z16 (M/T 3931) is supported to N-2 generation CPCs (IBM z16, IBM z15, and IBM z14).

Through state-of-the-art cluster technology, the power of multiple images can be harnessed to work in concert on common workloads. The IBM Z Parallel Sysplex cluster takes the commercial strengths of the platform to improved levels of system management, competitive price performance, scalable growth, and continuous availability.

3.9.1 CF Control Code

The LPAR that is running the CFCC can be on IBM z16, IBM z15, or IBM z14 systems. For more information about CFCC requirements for supported systems, see “Coupling facility and CFCC considerations” on page 285.

Consideration: IBM z16, IBM z15, and IBM z14 servers cannot coexist in the same sysplex with z13/z13s or earlier generation systems.

CFCC Level 25

CFCC level 25 is delivered on the IBM z16 (M/T 3931) with driver level 51 adds the following features:

- ▶ New cache residency time metrics for directory/data entries are available.

These new metrics allow exploiters (such as Db2) to provide direct, useful feedback on the CF cache structure “cache effectiveness”. They also provide improved recommendations for making structure sizing changes or retargeting work from specific table spaces or data sets to other cache structures.

Consider the following points:

- The metrics show how long data entries or directory entries remain resident in the cache structure from the time they are created until the time they are eventually “reclaimed” out of existence.
- They provide moving weighted average directory entry and data area residency times, in microseconds.
- They allow monitoring of effects of cache-unfriendly batch processes, such as image copy, reorganization, and update-intensive workloads.
- Reclaims from all causes are included in the creation of directory entries or data areas, “structure alter” contractions or reapportionments, incidental reclaims of data areas that are caused by reclaim of a directory entry, and so on.
- Residency times are accounted for only at the time of reclaim (not while the cache objects are still in use).
- Specific deletions of these objects do not factor into the residency time metrics.
- These metrics were implemented as new fields within the CF Storage Class controls:
They are retrieved by using the **IXLCACHE READ_STGSTATS** command or IXLGM/IXLYAMDA services that are requesting CF Storage Class controls.
They are also available in CF structure memory dumps that capture CF Storage Class controls.
- The metrics are included in Db2 Performance Manager statistics and used for improved cache structure management (cache sizing, castout processing, reclaim management, and so on). The inclusion of these metrics in sysplex SMF/RMF data is not planned, but can be added later. APAR OA60650 is required on z/OS V2R3, V2R4, and V2R5 to support the new metrics.

- ▶ New cache retry buffer support was added for IFCC retry idempotency:

Initially, the CF cache structure architecture was defined to be idempotent (commands can be tried again after link glitches, such as IFCCs); therefore, no specific accommodations were available for retrying, such as retry buffer support.

However, the list structure architecture was always recognized as nonidempotent, and a rather sophisticated retry buffer mechanism was incorporated to allow z/OS to retrieve the results of commands (even after link glitches occurred) so that such glitches always were well recovered.

Over time, constructs were added to the cache and lock structure architecture that made them become not perfectly retrievable (nonidempotent), but retry buffers were not added to the architecture to mitigate the lack of retrievability:

- Cache structure serialization objects, such as castout locks and cache entry version numbers
- Performance-optimized lock structure commands with no retry buffer support

z/OS software provided simple retry logic to provide IFCC recovery for these nonidempotent commands, but inevitably cases existed in which z/OS cannot provide unambiguous command results to callers. Users might not handle this ambiguity well.

CF cache users who use of these nonidempotent constructs experienced occasional customer problems based on it. The only approach that cleanly and completely addresses the issue is to provide retry buffers for the small subset of cache and lock commands that manipulate objects in a nonidempotent way, along with the accompanying transparent z/OS retry buffer use. z/OS transparently provides all the required recovery support and no user participation is needed.

Down-level systems can continue to use the “old” software retry support until they are upgraded, while up-level systems that use the same CF structure can take full advantage of the new retry buffers for improved IFCC recovery. APAR OA60275 is required on z/OS V2R2, V2R3, V2R4, and V2R5.

- ▶ New lock record data reserved entries for structure full recovery.

Some lock structure users use “special” lock structure locks to serialize their own processing, such as management of open data sets and table space interest across the sysplex. Not all locks have anything to do with serialization of database updates or user database data or transactions.

When lock structures use up all of the modify lock “record data entries” that track held locks, users might need to perform special back-out or recovery processing to recover from this structure full condition. At times, that processing requires them to obtain more “special” lock structure locks, which are needed to perform the recovery that can lead to a paradoxical situation: They must use more “record data entries” to recover from being out of record data entries.

CFCC level 25 on IBM z16 is providing improved use support for handling of lock structure “record data full” conditions by:

- Thresholding record data structure full conditions to occur when less than 100% full, reserving a special “for emergency use only” pool of record data entries for critical recovery purposes (user-specified threshold)
- Providing new APIs that allow exploiters to make use of this new reserved pool only when needed for recovery actions, but not for normal database locking purposes

z/OS APAR OA60650 and VSAM RLS APAR OA62059 are required in z/OS V2R3, V2R4, and V2R5.

- ▶ DYNDISP=ONIOFF is deprecated on IBM z16, keeping only THIN option for shared-engine CF images.

Coupling Facility images can run with shared or dedicated processors. Dedicated processors are recommended for best performance and production use (continuous polling model). Shared processors are recommended for test and development use in which a CF image requires significantly less than one processor’s worth of capacity, which encourages sharing CF processors across multiple CF images, or for less-performance critical production usage.

In shared-processor mode, the CF can currently use several different Dynamic Dispatching (DYNDISP) models:

- DYNDISP=OFF

LPAR time-slicing completely controls the CF processor; the processor polls the entire time that it is dispatched to a CF image by LPAR. The CF image never voluntarily gives up control of the shared processor. This option provides the least efficient sharing, and worst shared-engine CF performance.

– DYNDISP=ON

An optimization over pure LPAR time-slicing; the CF image sets timer interrupts to give the LPAR the initiative to redispach it, and the CF image voluntarily gives up control of the shared processor. This option provides the most efficient sharing, and better shared-engine CF performance.

– DYNDISP=THIN

An interrupt-driven model in which the CF processor is dispatched in response to a set of events that generate Thin Interrupts, runs until it runs out of work and then, gives up control voluntarily. This option provides the most efficient sharing, and best overall shared-engine CF performance.

DYNDISP=THIN support to use Thin Interrupts was available since zEC12/zBC12, and proved to be efficient and well-performing in several shared-engine coupling facility configurations. IBM z15 made DYNDISP=THIN the default mode of operation for shared-engine coupling facility images, but supported the other options OFF and ON for continued “legacy” use.

Note: In IBM z16, DYNDISP=THIN option is the only available behavior for shared-engine CF dispatching.

Specifying OFF or ON in CF commands and the CF configuration file are preserved for compatibility; however, a warning message is issued to indicate that these options are no longer supported and that DYNDISP=THIN behavior is to be used.

CFCC Level 24

CFCC level 24 is delivered on the IBM z15 (M/T 8561 and 8562) with driver level 41. CFCC level 24 adds the following features:

► CFCC Fair Latch Manager

This feature is an enhancement to the internals of the Coupling Facility (CFCC) dispatcher to provide CF work management efficiency and processor scalability improvements, and improve the “fairness” of arbitration for internal CF resource latches across tasks.

The tasks that are waiting for CF latches are not placed on the global suspend queue at all; instead, they are placed on latch-specific waiter queues for the exact instance of the latch they are requesting, and in the exact order in which they requested the latch. As a result, the global suspend queue is much less heavily used, and thus is much less a source of global contention or cache misses in the CF.

Also, when a latch is released, the specific latch’s latch waiter queue is used to transfer ownership of the latch directly to the next request in line (or multiple requests, in the case of a shared latch), and make that task (or tasks) ready to run, with the transferred latch already held. No possibility exists of any unfairness or “cutters” in line between the time that the latch is released versus when is obtained again.

For managing latches correctly for structures that are System-Managed (SM) synchronous duplexing, it is now important for the CF to understand which of the duplexed pair of requests operates as the “master” versus “slave” from a latching perspective, which requires more SM duplexing setup information from z/OS.

z/OS XCF/XES toleration APAR support is required to provide this enhancement.

► Message Path SYID Resiliency Enhancement

When a z/OS system IPLs, message paths are supposed to be deactivated by using system reset, and their SYIDs are supposed to be cleared in the process. During the IPL, z/OS then reactivates the message paths with a new SYID that represents the new instance of z/OS that uses the paths.

On rare occasions, a message path might not be deactivated during system reset or IPL processing, which leaves the message path active with the z/OS image's OLD, now-obsolete SYID. Because the path erroneously remained active, z/OS does not see any need to reactivate it with a new, correct SYID.

From the perspective of the CF, the incorrect SYID persists and prevents delivery of signals to the z/OS image that uses that message path.

With IBM z15, CFCC provides a new resiliency mechanism that transparently recovers for this "missing" message path deactivate (if and when that situation ever occurs).

The CF provides more information to z/OS about every message path that appears active; namely, the current SYID with which the message path is registered in the CF. Whenever z/OS interrogates the state of the message paths to the CF, z/OS checks this SYID information for currency and correctness. If an obsolete or incorrect SYID exists in the message path for any reason, z/OS performs the following steps:

- i. Requests nondisruptive gathering of diagnostic information for the affected message paths and CF image.
- ii. Reactivates the message path with the correct SYID for the current z/OS image to seamlessly correct the problem.

This enhancement requires z/OS XCF/XES use APAR support for IBM z15.

► Shared-Engine CF Default is changed to "DYNDISP=THIN"

The CF operates with the following Dynamic Dispatching (DYNDISP) models:

- DYNDISP=OFF: LPAR time-slicing completely controls the CF processor. The processor polls the entire time that it is dispatched by LPAR, and it is idle (not dispatched) when undispached by LPAR. The result is least efficient sharing, worst shared-engine performance.
- DYNDISP=ON: An optimization over pure LPAR time slicing, in which the CFCC code judiciously sets timer interrupts to give LPAR the initiative to redispach it, and the CF sometimes voluntarily gives up control of the shared processor when it runs out of work to do. The result is more efficient sharing and better shared-engine performance. This setting is the default setting for CF LPAR running on IBM z15.
- DYNDISP=THIN: An interrupt-driven model in which the CF processor is dispatched in response to a set of events that generate Thin Interrupts and runs until it runs out of things to do and then, gives up control voluntarily (until the next interrupt causes it to get dispatched again). This model is the most efficient sharing, best shared-engine performance.

Thin Interrupt support is available since zEC12/zBC12, and proved to be efficient and performant in numerous different test and customer shared-engine coupling facility configurations.

For CFCC running on IBM z15, DYNDISP=THIN is now the default mode of operation for coupling facility images that use shared processors.

► CF monopolization avoidance

With IBM z15 T01/T02, the CF dispatcher monitors in real-time the number of CF tasks that have a command assigned to them for a specific structure on a structure by structure basis.

When the number of CF tasks that are used by any structure exceeds a model-dependent CF threshold, and a global threshold on the number of active tasks is also exceeded, the structure is considered to be “monopolizing” the CF, and z/OS is informed of this monopolization.

New support in z/OS observes the monopolization state for a structure, and starts to selectively queue and throttle incoming requests to the CF, on a structure-specific basis while other requests for other “nonmonopolizing” structures and workloads are unaffected.

z/OS dynamically manages the queue of requests for the “monopolizing” structures to limit the number of active CF requests (parallelism) to them. It monitors the monopolization state information of the CF to observe the structure becoming “nonmonopolized” again so that request processing can eventually revert to a nonthrottled mode of operation.

The overall goal of z/OS anti-monopolization support is to protect the ability of ALL well-behaved structures and workloads to access the CF, and get their requests processed in the CF in a timely fashion while implementing queuing and throttling mechanisms in z/OS to hold back the specific abusive workloads that are causing problems for other workloads.

z/OS XCF/XES use APAR support is required to provide this function.

CFCC Level 23

CFCC level 23 is delivered on the z14 (M/T 3906 and 3907) with driver level 36. CFCC Level 23 introduces the following enhancements:

- ▶ Asynchronous cross-invalidate (XI) of CF cache structures. Requires PTF support for z/OS and explicit data manager support (Db2 V12 with PTFs). Consider the following points:
 - Instead of performing XI signals synchronously on every cache update request that causes them, data managers can “opt in” for the CF to perform these XIs asynchronously (and then sync them up with the CF at or before transaction completion). Data integrity is maintained if all XI signals complete by the time transaction locks are released.
 - Results in faster completion of cache update CF requests, especially with cross-site distance involved.
 - Provides improved cache structure service times and coupling efficiency.
- ▶ Coupling Facility hang detect enhancements provide a significant reduction in failure scope and client disruption (CF-level to structure-level), with no loss of FFDC collection capability:
 - When a hang is detected, in most cases the CF confines the scope of the failure to “structure damage” for the single CF structure the hung command was processing against, capture diagnostics with a nondisruptive CF memory dump, and continue operating without ending or restarting the CF image.
 - Provides a significant reduction in failure scope and client disruption (CF-level to structure-level), with no loss of FFDC collection capability.
- ▶ Coupling Facility ECR granular latching:
 - With this support, most CF list and lock structure ECR processing no longer use structure-wide latching. It serializes its execution by using the normal structure object latches that all mainline commands use.
 - Eliminates the performance degradation that is caused by structure-wide latching.
 - A few “edge conditions” in ECR processing still require structure-wide latching to be used to serialize them.

- Cache structure ECR processing continues to require and use structure-wide latches for its serialization.

z14 servers with CFCC Level 23 require z/OS V1R13 or later, and z/VM V6R4 or later for virtual guest coupling.

CFCC Level 22

CFCC level 22 is delivered on the IBM z14 (M/T 3906) with driver level D32. CFCC Level 22 introduces the following enhancements:

► CF Enhancements:

- CF structure encryption

CF Structure encryption is transparent to middleware and applications that use CFs, while CF users are unaware of and not involved in the encryption. All data and adjunct data that flows between z/OS and the CF is encrypted. The intent is to encrypt all data that might be sensitive.

Internal control information and related request metadata is not encrypted, including locks and lock structures.

z/OS generates the required structure-related encryption keys and does much of the key management automatically by using CFRM that uses secure, protected keys (never clear keys). Secure keys maintained in CFRM couple data set.

► CF Asynchronous Duplexing for Lock Structures:

- New asynchronous duplexing protocol for lock structures:

- z/OS sends command to primary CF only
- Primary CF processes command and returns result
- Primary CF forwards description of required updates to secondary CF
- Secondary CF updates secondary structure instance asynchronously

- Provided for lock structures only:

- z/OS V2R2 SPE with PTFs for APAR OA47796
- Db2 V12 with PTFs
- Most performance-sensitive structures for duplexing

- Benefit and value:

- Db2 locking receives performance similar to simplex operations
- Reduces CPU and CF link overhead
- Avoids the overhead of synchronous protocol handshakes on every update
- Duplexing failover much faster than log-based recovery

- Targeted at multi-site clients who run split workloads at distance to make duplexing lock structures at distance practical.

► CF Processor Scalability:

- CF work management and dispatcher changes to allow improved efficiency as processors are added to scale up the capacity of a CF image.
- Functionally specialized ICF processors that operate for CF images having more than a threshold number of dedicated processors defined for them:
 - One functionally specialized processor for inspecting suspended commands.
 - One functionally specialized processor for pulling in new commands.
 - The remaining processors are nonspecialized for general CF request processing.
- Avoids many inter-processor contentions that were associated with CF dispatching

- ▶ Enable systems management applications to collect valid CF LPAR information through z/OS BCPII:
 - System Type (CFCC)
 - System Level (CFCC LEVEL)
 - Dynamic Dispatch settings to indicate CF state (dedicated, shared, and Thin Interrupt), which are useful when investigating functional performance problems

To support an upgrade from one CFCC level to the next, different levels of CFCC can be run concurrently while the CF LPARs are running on different servers. CF LPARs that run on the same server share the CFCC level.

IBM z16 servers (CFCC level 25) can coexist in a sysplex with CFCC levels 24, 23, and 22; nevertheless, the latest Coupling Facility Control Code and MCLs levels are always recommended for best performance and availability:

- ▶ On IBM z15 (M/T 8561 and 8562): CFCC 24 - Service level 00.22, Bundle S48 released in August 2021.
- ▶ On IBM z14 (M/T 3906): CFCC 23 - Service Level 00.20, Bundle S64 released in August 2021.

For a CF LPAR with dedicated processors, the CFCC is implemented by using the active wait technique. This technique means that the CFCC is always running (processing or searching for service) and never enters a wait state. Therefore, the CF Control Code uses all the processor capacity that is available for the CF LPAR.

If the LPAR that is running the CFCC includes only dedicated processors (CPs or ICFs), the use of all processor capacity (cycles) is not an issue. However, this configuration can be an issue if the LPAR that is running the CFCC includes shared processors. On IBM z16, Thin Interrupts is the only valid option for shared engines in a CF LPAR (Thin Interrupts is the default option on IBM z15).

Performance consideration: Dedicated processor CF still provides the best CF image performance for production environments.

CF structure sizing changes are expected when moving to CFCC Level 25. Always review the CF structure size by using the CFSizer tool when changing CFCC levels.

For more information about the recommended CFCC levels, see the current exception letter that is published on [IBM Resource Link®](#).

3.9.2 Coupling Thin Interrupts

CFCC Level 19 introduced Coupling Thin Interrupts to improve performance in environments that share CF engines. Although dedicated engines are preferable to obtain the best CF performance, Coupling Thin Interrupts helps facilitate the use of a shared pool of engines, which helps to lower hardware acquisition costs.

The interrupt causes a shared logical processor CF partition to be dispatched by PR/SM (if it is not already dispatched), which allows the request or signal to be processed in a more timely manner. The CF relinquishes control when work is exhausted or when PR/SM takes the physical processor away from the logical processor.

On IBM z16, the use of Coupling Thin Interrupts (DYNDISP=THIN) is now the only option that is available for shared engines in a CF LPAR. Specification of OFF or ON in CF commands and the CF configuration file will be preserved, for compatibility, but a warning message will be issued to indicate that these options are no longer supported, and that DYNDISP=THIN behavior will be used.

3.9.3 Dynamic CF dispatching

With the introduction of the Coupling Thin Interrupt support (only available option on IBM z16), which is used only when the CF partition uses shared engines, the CFCC code is changed to handle these interrupts correctly. CFCC was also changed to relinquish voluntarily control of the processor whenever it runs out of work to do. It relies on Coupling Thin Interrupts to dispatch the image again in a timely fashion when new work (or new signals) arrives at the CF to be processed.

With IBM z16, **DYNDISP=THIN** is the only mode of operation for CF images that use shared processors.

This capability allows ICF engines to be shared by several CF images. In this environment, it provides faster and far more consistent CF service times. It can also provide performance that is reasonably close to dedicated-engine CF performance.

The use of Thin Interrupts allows a CF to run by using a shared processor while maintaining good performance. The shared engine is allowed to be undispached when no more work exists, as in the past. The Thin Interrupt gets the shared processor that is dispatched when a command or duplexing signal is presented to the shared engine.

This function saves processor cycles and is an excellent option to be used by a production backup CF or a testing environment CF. This function is activated by default when a CF processor is shared.

The CPs can run z/OS operating system images and CF images. For software charging reasons, generally use only ICF processors to run CF images.

For more information about CF configurations, see the following resources:

- ▶ *Coupling Facility Configuration Options*, GF22-5042
- ▶ This [IBM Support web page](#)

3.10 Virtual Flash Memory

Flash Express is not supported on IBM z16. This feature was replaced by IBM Z Virtual Flash Memory (VFM), from IBM z14. The Virtual Flash Memory feature code is 0644 on IBM z16 A01.

3.10.1 IBM Z Virtual Flash Memory overview

VFM replaced the PCIe Flash Express feature with support that is based on main memory.

The “storage class memory” that is provided by Flash Express adapters is replaced with memory that is allocated from main memory (VFM).

VFM helps improve availability and handling of paging workload spikes when running z/OS. With this support, z/OS is designed to help improve system availability and responsiveness by using VFM across transitional workload events, such as market openings and diagnostic data collection.

z/OS also helps improve processor performance by supporting middleware use of pageable large (1 MB) pages, and eliminates delays that can occur when collecting diagnostic data during failures.

VFM also can be used in CF images to provide extended capacity and availability for workloads that use IBM WebSphere MQ Shared Queues structures.

3.10.2 VFM feature

A VFM feature (FC 0644) is 512 GB of memory on IBM z16 A01. The maximum number of VFM features is 12 per IBM z16 A01 system.

Ordered VFM memory reduces the maximum orderable memory for the model.

Simplification in its management is of great value because no hardware adapter is needed to manage. It also has no hardware repair and verify. It has a better performance because no I/O to attached adapter occurs. Finally, because this feature is part of memory, it is protected by RAIM and ECC.

VFM provides physical memory DIMMs that are needed to support activation of all customer purchased memory and HSA on a multiple drawer IBM z16 A01 with one drawer that is done for the following features:

- ▶ Scheduled concurrent drawer upgrade, such as memory adds
- ▶ Scheduled concurrent drawer maintenance, such N+1 repair
- ▶ Concurrent repair of an out-of-service CPC drawer “fenced” during Activation (POR)

Note: All of these features can be done without VFM. However, all customer-purchased memory is not available for use in most cases. Some work might need to be shut down or not restarted.

3.10.3 VFM administration

The allocation and definition information of VFM for all partitions is viewed through the Storage Information panel that is under the Operational Customization panel.

The information is relocated during CDR in a manner that is identical to the process that was used for expanded storage. VFM is much simpler to manage (HMC task) and no hardware repair and verify (no cables and no adapters) are needed. Also, because this feature is part of internal memory, VFM is protected by RAIM and ECC and can provide better performance because no I/O to an attached adapter occurs.

Note: Use cases for Flash did not change (for example, z/OS paging and CF shared queue overflow). Instead, they transparently benefit from the changes in the hardware implementation.

No option is available for VFM plan ahead. The only option is to always include VFM plan ahead when Flexible Memory option is selected.

3.11 IBM Secure Service Container

Client applications are subject to several security risks in a production environment. These risks might include external risks (cyber hacker attacks) or internal risks (malicious software, system administrators that use their privileged rights for unauthorized access and many others).

The IBM Secure Service Container (SSC) is a container technology through which you can more quickly and securely deploy software appliances on IBM z16.

An IBM SSC partition is a specialized container for installing and running specific appliances. An *appliance* is an integration of operating system, middleware, and software components that work autonomously and provide core services and infrastructures that focus on usability and security.

IBM SSC hosts most sensitive client workloads and applications. It acts as a highly protected and secured digital vault, enforcing security by encrypting the entire stack: memory, network, and data (both in-flight and at-rest). Applications that are running inside IBM SSC are isolated and protected from outsider and insider threats.

IBM SSC combines hardware, software, and middleware and is unique to IBM Z platform. Though it is called a container, it should not be confused with purely software open source containers (such as Kubernetes or Docker).

IBM SSC is a part of the Pervasive Encryption concept that was introduced with IBM z14, which is aimed at delivering best IBM Security hardware and software enhancements, services, and practices for 360-degree infrastructure protection.

LPAR is defined as IBM SSC by using the HMC.

The IBM SSC solution includes the following key advantages:

- ▶ Applications require zero changes to use IBM SSC; software developers do not need to write any IBM SSC-specific programming code.
- ▶ End-to-end encryption (in-flight and at-rest data):
 - Automatic Network Encryption (TLS, IPsec): Data-in-flight.

- Automatic File System Encryption (LUKS): Data-at-rest.
- Linux Unified Key Setup (LUKS) is the standard way in Linux to provide disk encryption. SSC encrypts all data with a key that is stored within the appliance.
- Protected memory: Up to 16 TB can be defined per IBM SSC LPAR.
- ▶ Encrypted Diagnostic Data

All diagnostic information (debug memory dump data, logs, and so on) are encrypted and do not contain any user or application data.
- ▶ No operating system access

After the IBM SSC appliance is built, Secure Shell (SSH) and the command line-interface (CLI) are disabled, which ensures that even system administrators cannot access the contents of the IBM SSC and do not know which application is running there.
- ▶ Applications that run inside IBM SSC are being accessed externally by REST APIs only, in a transparent way to user.
- ▶ Tamper-proof SSC Secure Boot:
 - IBM SSC-eligible applications are booted into IBM SSC by using verified booting sequence, where only trusted and digitally signed and verified by IBM software code is uploaded into the IBM SSC.
 - Vertical workload isolation, certified by EAL5+ Common Criteria Standard, which is the highest level that ensures workload separation and isolation.
 - Horizontal workload isolation: Separation from the rest of the host environment.

IBM z16 technology provides built-in data encryption with excellent vertical scalability and performance that protects against data breach threats and data manipulation by privileged users. IBM SSC is a powerful IBM technology for providing the extra protection of the most sensitive workloads.

The following IBM solutions and offerings, and more to come, can be deployed in an IBM SSC environment:

- ▶ IBM Hyper Protect Virtual Servers (HPVS) solution is available for running Linux-based virtual servers with sensitive data and applications delivering a confidential computing environment to address your top security concerns.

For more information, see this IBM Cloud® [web page](#).
- ▶ IBM Db2 Analytics Accelerator (IDAA) is a high-performance component that is tightly integrated with Db2 for z/OS. It delivers high-speed processing for complex Db2 queries to support business-critical reporting and analytic workloads. The accelerator transforms the mainframe into a hybrid transaction and analytic processing (HTAP) environment.

For more information, see this IBM [web page](#).
- ▶ IBM Cloud Hyper Protect Data Base as a Service (DBaaS) for PostgreSQL or MongoDB offers enterprise cloud database environments with high availability for sensitive data workloads.

For more information, see this IBM Cloud [web page](#).
- ▶ IBM Cloud Hyper Protect Crypto Services is a key management service and cloud hardware security module (HSM) that supports industry standards such as PKCS #11.

For more information, see this IBM Cloud [web page](#).

- ▶ IBM Security® Guardium® Data Encryption (GDE) consists of a unified suite of products that are built on a common infrastructure. These highly scalable solutions provide data encryption, tokenization, data masking, and key management capabilities to help protect and control access to data across the hybrid multicloud environment.

For more information, see this [web page](#).

- ▶ IBM Blockchain™ platform can be deployed on an IBM z16 by using IBM SSC to host the IBM Blockchain network.

For more information, see this [web page](#).

- ▶ IBM Hyper Protect Data Controller (formerly IBM Data Privacy Passports) provides end-to-end, data-centric encryption and privacy to keep your data protected no matter where it travels in your enterprise. It maintains the suitable use of data, revokes future access at any time, and keeps an audit trail, which permits only authorized users to extract value from your data.

For more information, see this [web page](#).



Central processor complex I/O structure

This chapter describes the I/O system structure and connectivity options that are available on the IBM z16.

This chapter includes the following topics:

- ▶ 4.1, “Introduction to I/O infrastructure” on page 148
- ▶ 4.2, “I/O system overview” on page 150
- ▶ 4.3, “PCIe+ I/O drawer” on page 153
- ▶ 4.4, “CPC drawer fan-outs” on page 156
- ▶ 4.5, “I/O features” on page 160
- ▶ 4.6, “Connectivity” on page 163
- ▶ 4.7, “Cryptographic functions” on page 195
- ▶ 4.8, “Integrated Firmware Processor” on page 198

4.1 Introduction to I/O infrastructure

This section describes the I/O features that are available on the IBM z16. IBM z16 systems support PCIe+ I/O drawers only.

I/O cage, I/O drawer, and PCIe I/O drawer are not supported.

Note: Throughout this chapter, the terms *adapter* and *card* refer to a PCIe I/O feature that is installed in a PCIe+ I/O drawer.

4.1.1 IBM z16 I/O infrastructure at a glance

IBM Z I/O is based on industry-standard Peripheral Component Interconnect Express Generation 3 (PCIe Gen3) I/O infrastructure. The PCIe I/O infrastructure that is provided by the central processor complex (CPC) enhances I/O capability and flexibility, while allowing for the future integration of PCIe adapters and features.

The PCIe I/O infrastructure in IBM z16 A01 consists of the following components:

- ▶ PCIe+ Gen3 dual port fan-outs that support 16 GBps I/O bus for CPC drawer connectivity to the PCIe+ I/O drawers. It connects to the PCIe Interconnect Gen3 in the PCIe+ I/O drawers.
- ▶ Integrated Coupling Adapter Short Reach (ICA SR and ICA SR1.1), which are PCIe Gen3 features that support short distance coupling links. The ICA SR and ICA SR1.1 features have two ports, each port supporting 8 GBps.
- ▶ The 8U, 16-slot, and 2-domain PCIe+ I/O drawer for PCIe I/O features.

Installed features in the PCIe+ I/O drawer

The I/O infrastructure of IBM z16 A01 provides the following benefits:

- ▶ The bus connecting the CPC drawer to the I/O domain in the PCIe+ I/O drawer bandwidth is 16 GBps.
- ▶ Up to 32 channels (16 PCIe I/O cards) are supported in the PCIe+ I/O drawer.
- ▶ Storage connectivity:
 - Storage Area Network (SAN) connectivity:
 - The FICON Express32S
 - FICON Express16SA (carry forward)
 - FICON Express16S+ (carry forward)

These cards provide two channels per feature for Fibre Channel connection (FICON), High-Performance FICON on Z (zHPF), and Fibre Channel Protocol (FCP) storage area networks.
 - IBM zHyperLink Express 1.1: Two ports per feature (new build and carry forward) with ultra high-speed, direct connection to Select DS8000; works in tandem with FICON Express channels
 - IBM zHyperLink Express - two ports per feature (carry forward)
- ▶ Local area network (LAN) connectivity:
 - The following features include two ports each:
 - Open Systems Adapter (OSA)-Express7S 1.2 GbE

- OSA-Express7S 1.2 1000BASE-T
- OSA-Express7S GbE
- OSA-Express7S 1000BASE-T
- OSA-Express6S GbE
- OSA-Express6S 1000BASE-T
- The following features have one port each:
 - OSA-Express7S 1.2 25 GbE
 - OSA-Express7S 1.2 10 GbE
 - OSA-Express7S 25 GbE SR1.1
 - OSA-Express7S 25 GbE
 - OSA-Express7S 10 GbE
 - OSA-Express6S 10 GbE
- ▶ Native PCIe features (plugged into the PCIe+ I/O drawer):
 - 25 GbE and 10 GbE Remote Direct Memory Access (RDMA) over Converged Ethernet (RoCE) Express3 (two ports per feature)
 - 25 GbE and 10 GbE Remote Direct Memory Access (RDMA) over Converged Ethernet (RoCE) Express2.1 (two ports per feature, carry forward)
 - 2 5-GbE and 10-GbE RoCE Express2 (two ports per feature, carry forward)
 - Coupling Express2 Long Reach (CE2 LR): Two ports per feature
 - Crypto Express8S (single/dual HSM)
 - Crypto Express7S (single/dual ports/HSM, carry forward)
 - Crypto Express6s (single HSM, carry forward)

4.1.2 PCIe Generation 3

The PCIe Generation 3 uses 128b/130b encoding for data transmission. This configuration reduces the encoding overhead to approximately 1.54% versus the PCIe Generation 2 overhead of 20% that uses 8b/10b encoding.

The PCIe standard uses a low-voltage differential serial bus. Two wires are used for signal transmission, and a total of four wires (two for transmit and two for receive) form a lane of a PCIe link, which is full-duplex. Multiple lanes can be aggregated into a larger link width. PCIe supports link widths of 1, 2, 4, 8, 12, 16, and 32 lanes (x1, x2, x4, x8, x12, x16, and x32).

The data transmission rate of a PCIe link is determined by the link width (numbers of lanes), the signaling rate of each lane, and the signal encoding rule. The signaling rate of one PCIe Generation 3 lane is eight gigatransfers per second (GTps), which means that nearly 8 gigabits are transmitted per second (Gbps).

Note: I/O infrastructure for IBM z16, as for IBM z15, is implemented as PCIe Generation 3. The PU chip PCIe interface is PCIe Generation 4 (x16 @32 GBps), but the CPC I/O fan-out infrastructure provides external connectivity as PCIe Generation 3 @16GBps

A PCIe Gen3 x16 link features the following data transmission rates:

- ▶ The maximum theoretical data transmission rate per lane:

$$8 \text{ Gbps} * 128/130 \text{ bit (encoding)} = 7.87 \text{ Gbps} = 984.6 \text{ MBps}$$
- ▶ The maximum theoretical data transmission rate per link:

$$984.6 \text{ MBps} * 16 \text{ (lanes)} = 15.75 \text{ GBps}$$

Considering that the PCIe link is full-duplex mode, the data throughput rate of a PCIe Gen3 x16 link is 31.5 GBps (15.75 GBps in both directions).

Link performance: The link speeds do not represent the performance of the link. The performance depends on many factors, including latency through the adapters, cable lengths, and the type of workload.

PCIe Gen3 x16 links are used in IBM z16 servers for driving the PCIe+ I/O drawers, and for coupling links for CPC to CPC communications.

Note: Unless specified otherwise, *PCIe* refers to PCIe Generation 3 in remaining sections of this chapter.

4.2 I/O system overview

The IBM z16 I/O characteristics and supported features are described in this section.

4.2.1 Characteristics

The IBM z16 A01 I/O subsystem provides great flexibility, high availability, and the following excellent performance characteristics:

► High bandwidth

IBM z16 servers use PCIe Gen3 protocol to drive PCIe+ I/O drawers and CPC to CPC (coupling) connections. The I/O bus infrastructure data rate of up to 128 GBps¹ per system (12 PCIe+ Gen3 fan-out slots).

For more information about coupling link connectivity, see 4.6.4, “Parallel Sysplex connectivity” on page 190.

► Connectivity options:

- IBM z16 servers can be connected to an extensive range of interfaces, such as FICON/FCP for SAN connectivity, OSA features for LAN connectivity, and zHyperLink Express for storage connectivity (low latency compared to FICON).
- For CPC to CPC connections, IBM z16 servers use Integrated Coupling Adapter (ICA SR and ICA SR 1.1) and the Coupling Express2 Long Reach (CE2 LR).

The Parallel Sysplex InfiniBand is *not* supported.

- The 25 GbE and 10 GbE RoCE Express3, 25 GbE and 10 GbE RoCE Express2.1, and 25 GbE and 10 GbE RoCE Express2 provide high-speed memory-to-memory data exchange to a remote CPC by using the Shared Memory Communications over RDMA (SMC-R) protocol for TCP (socket-based) communications.

The RoCE Express3 features also can provide local area network (LAN) connectivity for Linux on IBM Z, and comply with IEEE standards. In addition, RoCE Express features assume several functions of the TCP/IP stack that normally are performed by the PU, which allows significant performance benefits by offloading processing from the operating system.

¹ The link speeds do not represent the performance of the link. The performance depends on many factors, including latency through the adapters, cable lengths, and the type of workload.

- ▶ Concurrent I/O upgrade

You can concurrently add I/O features to IBM z16 servers if unused I/O slot positions are available.
- ▶ Concurrent PCIe+ I/O drawer upgrade

More PCIe+ I/O drawers can be installed concurrently if free frame slots for the PCIe+ I/O drawers and PCIe fan-outs in the CPC drawer are available.
- ▶ Dynamic I/O configuration

Dynamic I/O configuration supports the dynamic addition, removal, or modification of the channel path, control units, and I/O devices without a planned outage.
- ▶ Remote Dynamic I/O Activation

Remote dynamic I/O activation is supported for CPCs running Stand-alone CFs, Linux on Z and z/TPF. IBM z14 GA2 provided a remote Dynamic I/O capability for driving hardware-only I/O configuration changes from a “driving” instance of z/OS Hardware Configuration Definition (HCD) on one CPC to a remote “target” standalone Coupling Facility CPC.

IBM z16 provides a supported capability to drive these same kinds of hardware-only changes from a driving z/OS HCD instance to a remote CPC which is not a standalone Coupling facility, but rather a CPC which hosts Linux on Z and /or z/TPF images.

This new support is applicable only when both, the driving CPC and the target CPC are z16 with the required firmware support (Bundle S24 or higher) and the driving systems z/OS is at level 2.3 or higher with APAR OA65559.
- ▶ Pluggable optics:
 - The following features include Small Form-Factor Pluggable (SFP) optics²:
 - FICON Express32S
 - FICON Express16SA
 - FICON Express16S+
 - OSA Express7S 1.2
 - OSA Express7S (including OSA-Express7S 25 GbE SR 1.1)
 - OSA Express6S, RoCE Express3
 - RoCE Express2.1
 - RoCE Express2
 - RoCE Express

These optics allow each channel to be individually serviced in a fiber optic module failure. The traffic on the other channels on the same feature can continue to flow if a channel requires servicing.
 - The zHyperLink Express feature uses fiber optics cable with MTP³ connector and the cable uses a CXP connection to the adapter. The CXP⁴ optics are provided with the adapter.
- ▶ Concurrent I/O card maintenance

Every I/O card that is plugged in a PCIe+ I/O drawer supports concurrent card replacement during a repair action.

² OSA-Express 1000BASE-T features do not have optics (copper only, RJ45 connectors).

³ Multifiber Termination Push-On.

⁴ For more information, see <https://cw.infinibandta.org/document/dl/7157>.

4.2.2 Supported I/O features

The following I/O features are supported on an IBM z16 A01 system (maximum for each individual adapter type):

- ▶ Up to 384 FICON Express32S channels
- ▶ Up to 384 FICON Express16SA channels
- ▶ Up to 320 FICON Express16S+ channels
- ▶ Up to 48 OSA-Express7S 1.2 25 GbE ports
- ▶ Up to 48 OSA-Express7S 1.2 10 GbE ports
- ▶ Up to 96 OSA-Express7S 1.2 GbE ports
- ▶ Up to 96 OSA-Express7S 1.2 1000BASE-T ports
- ▶ Up to 48 OSA-Express7S 25 GbE SR1.1 ports
- ▶ Up to 48 OSA-Express7S 25 GbE SR ports
- ▶ Up to 48 OSA-Express7S 10 GbE ports
- ▶ Up to 96 OSA-Express7S GbE ports
- ▶ Up to 96 OSA-Express7S 1000BASE-T ports
- ▶ Up to 48 OSA-Express6S 10 GbE ports
- ▶ Up to 96 OSA-Express6S GbE ports
- ▶ Up to 96 OSA-Express6S 1000BASE-T ports
- ▶ Up to 16 25 GbE RoCE Express3 features
- ▶ Up to 16 25 GbE RoCE Express2.1 features
- ▶ Up to 16 25 GbE RoCE Express2 features
- ▶ Up to 16 10 GbE RoCE Express3 features
- ▶ Up to 16 10 GbE RoCE Express2.1 features
- ▶ Up to 16 10 GbE RoCE Express2 features
- ▶ Up to 16 zHyperLink Express features
- ▶ Up to 16 zHyperLink Express1.1 features
- ▶ Up to 48 ICA SR1.1 and ICA SR features (combined) with up to 96 ports
- ▶ Up to 32 CE2 LR features with up to 64 ports

Notes: Consider the following points:

- ▶ The number of I/O features that are supported might be affected by the machine power infrastructure (PDU versus BPA). IBM z16 A01 PDU models support a maximum of 12 PCIe+ I/O drawers; BPA models support a maximum of 10 PCIe+ I/O drawers.
- ▶ A maximum of 384 coupling CHPIDs are available for an IBM z16 (as for IBM z15), as a combination of the following examples (not all combinations are possible; subject to I/O configuration options):
 - Up to 96 ICA SR1.1 and ICA SR ports (48 ICA SR features)
 - Up to 64 CE2 LR ports (32 CE2 LR features)
- ▶ zEDC PCIe features are not supported. They were replaced by the IBM Integrated Accelerator for zEDC (on PU chip).
- ▶ The maximum combined number of RoCE features that can be installed is 16; that is, any combination of 25 GbE RoCE Express3, 25 GbE RoCE Express2.1, 25 GbE RoCE Express2, 10 GbE RoCE Express3, 10 GbE RoCE Express2.1, and 10 GbE RoCE Express2 features.
- ▶ The 25 GbE RoCE Express feature should not be configured in the same SMC-R link group with 10 GbE RoCE Express features.

4.3 PCIe+ I/O drawer

The PCIe+ I/O drawers (see Figure 4-1) are attached to the CPC drawer through a PCIe cable and use PCIe Gen3 as the infrastructure bus within the drawer. The PCIe Gen3 I/O bus infrastructure data rate is up to 16 GBps.

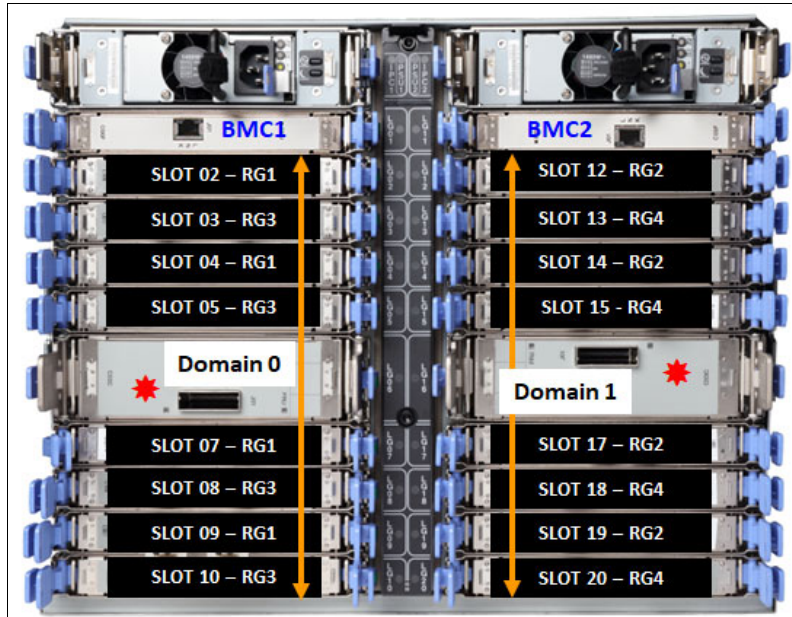


Figure 4-1 Rear view of PCIe+ I/O drawer

PCIe switch application-specific integrated circuits (ASICs) are used to fan out the host bus from the CPC drawer through the PCIe+ I/O drawer to the individual I/O features. Maximum 16 PCIe I/O features (up to 32 channels) per PCIe+ I/O drawer are supported.

The PCIe+ I/O drawer is a one-sided drawer (all I/O cards on one side, in the rear of the drawer) that is 8U high. The PCIe+ I/O drawer contains the 16 I/O slots for PCIe features, two switch cards, and two power supply units (PSUs) to provide redundant power, as shown in Figure 4-1.

The PCIe+ I/O drawer slots numbers are shown in Figure 4-2.

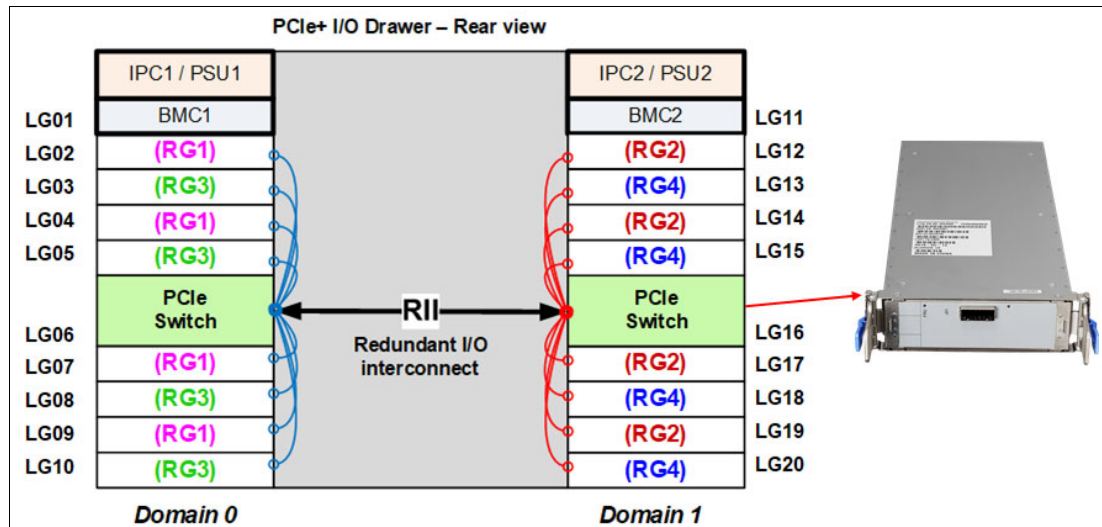


Figure 4-2 PCIe+ I/O drawer slots numbers

The I/O structure in an IBM z16 CPC is shown in Figure 4-3.

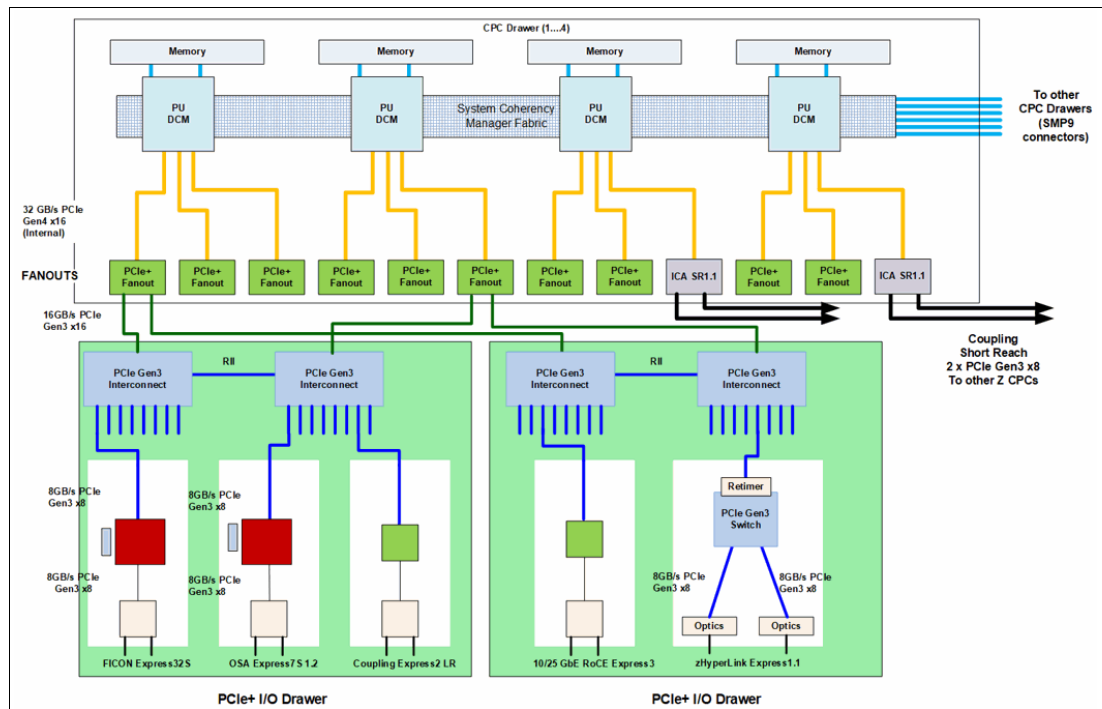


Figure 4-3 IBM z16 I/O connectivity(Max39 feature with two PCIe+ I/O drawers represented)

The PCIe switch card provides the fan-out from the high-speed x16 PCIe host bus to eight individual card slots. The PCIe switch card is connected to the CPC drawer through a single x16 PCIe Gen3 bus from a PCIe fan-out card (PCIe+ fan-out cards on IBM z16 have two PCIe Gen3 x16 ports/busses/links).

In the PCIe+ I/O drawer, the eight I/O feature cards that directly attach to the switch card constitute an I/O domain. The PCIe+ I/O drawer supports concurrent add and replace I/O features with which you can increase I/O capability as needed, depending on the CPC drawer.

The PCIe slots in a PCIe+ I/O drawer are organized into two I/O domains. Each I/O domain supports up to eight features and is driven through a PCIe switch card. Two PCIe switch cards always provide a backup path for each other through the passive connection in the PCIe+ I/O drawer backplane.

During a PCIe fan-out card or cable failure, 16 I/O cards in two domains can be driven through a single PCIe switch card. It is not possible to drive 16 I/O cards after one of the PCIe switch cards is removed.

The two switch cards are interconnected through the PCIe+ I/O drawer board (Redundant I/O Interconnect, or RII). In addition, switch cards in same PCIe+ I/O drawer are connected to PCIe fan-outs across clusters in CPC drawer for higher availability.

The RII design provides a failover capability during a PCIe fan-out card failure. Both domains in one of these PCIe+ I/O drawers are activated with two fan-outs. The Base Management Cards (BMCs) are used for system control.

The domains and their related I/O slots are shown in Figure 4-2 on page 154.

Each I/O domain supports up to eight features (FICON, OSA, Crypto, and so on.) All I/O cards connect to the PCIe switch card through the backplane board. The I/O domains and slots are listed in Table 4-1.

Table 4-1 I/O domains of PCIe+ I/O drawer

Domain	I/O slot in the domain
0	LG02, LG03, LG04, LG05, LG07, LG08, LG09, and LG10
1	LG12, LG13, LG14, LG15, LG17, LG18, LG19, and LG20

4.3.1 PCIe+ I/O drawer offering

Up to 12 (for PDU systems), or up to 10 (for BPA systems PCIe+ I/O drawers can be installed for supporting up to 192 (PDU), or up to 160 (BPA) PCIe I/O features.

Only the following PCIe features can be carried forward for an upgrade to IBM z16 A01 servers:

- ▶ FICON Express16SA
- ▶ FICON Express16S+
- ▶ zHyperLink Express (all features)
- ▶ OSA-Express7S 25 GbE SR1.1
- ▶ OSA-Express7S (all features)
- ▶ OSA-Express6S (all features)
- ▶ 25 GbE RoCE Express2.1
- ▶ 25 GbE RoCE Express2
- ▶ 10 GbE RoCE Express2.1
- ▶ 10 GbE RoCE Express2
- ▶ Crypto Express7S(one or two ports/HSMs)
- ▶ Crypto Express6S

Note: On an IBM z16 system, only PCIe+ I/O drawers are supported. No older generation drawers can be carried forward.

IBM z16 A01 server supports the following PCIe I/O new features that are hosted in the PCIe+ I/O drawers:

- ▶ FICON Express32S
- ▶ OSA-Express7S 1.2 25 GbE
- ▶ OSA-Express7S 1.2 10 GbE
- ▶ OSA-Express7S 1.2 GbE
- ▶ OSA-Express7S 1.2 1000BASE-T
- ▶ 25 GbE RoCE Express3
- ▶ 10 GbE RoCE Express3
- ▶ Crypto Express8S (one or two HSMs)
- ▶ Coupling Express2 Long Reach (CE2 LR)
- ▶ zHyperLink Express1.1

4.4 CPC drawer fan-outs

The IBM z16 server uses PCIe+ Gen3 fan-out cards to connect the I/O subsystem in the CPC drawer to the PCIe+ I/O drawers. The fan-out cards also include the ICA SR (ICA SR and ICA SR1.1) coupling links for Parallel Sysplex. All fan-out cards support concurrent add, remove, and move.

The IBM z16 CPC drawer I/O infrastructure consists of the following features:

- ▶ The PCIe+ Generation 3 fan-out cards: Two ports per card (feature) that connect to PCIe+ I/O drawers.
- ▶ ICA SR (ICA SR and ICA SR1.1) fan-out cards: Two ports per card (feature) that connect to other (external) CPCs.

Note: IBM z16 does *not* support Parallel Sysplex InfiniBand (PSIFB) links.

Also, if and IBM z16 is part of a Parallel Sysplex or Coordinated Timing Network, InfiniBand links cannot be used on older servers, even if installed.

Unless otherwise noted, *ICA SR* is used for ICA SR and ICA SR1.1 for the rest of the chapter.

The PCIe fan-outs cards are installed in the rear of the CPC drawers. Each CPC drawer features 12 PCIe+ Gen3 fan-out slots.

The PCIe fan-outs and ICA SR fan-outs are installed in locations LG01 - LG12 at the rear in the CPC drawers (see Figure 2-8 on page 25).

On the CPC drawer, two BMC/OSC cards are available, each being a combination of a Base Management (BMC) card and an Oscillator Card (OSC) card. Each BMC/OSC card features one PPS port and one ETS port (RJ45 Ethernet) for both PTP and NTP.

An I/O connection diagram is shown in Figure 4-3 on page 154.

4.4.1 PCIe+ Generation 3 fan-out (FC 0175)

The PCIe+ Gen3 fan-out card provides connectivity to a PCIe+ I/O drawer by using a copper cable. This PCIe fan-out card supports a link rate of 16 GBps (with two links per card).

A 16x PCIe copper cable of 1.5 meters (4.92 feet) - 4.0 meters (13.1 feet) is used for connection to the PCIe switch card in the PCIe+ I/O drawer. PCIe fan-out cards are always plugged in pairs and provide redundancy for I/O domains within the PCIe+ I/O drawer.

Note: The PCIe fan-out is used exclusively for I/O and cannot be shared for any other purpose.

4.4.2 Integrated Coupling Adapter (FC 0172 and FC 0176)

The IBM ICA SR (FC 0172) is a two-port fan-out feature that is used for short distance coupling connectivity and uses channel type CS5. For IBM z16, the new build feature is ICA SR1.1 (FC 0176).

The ICA SR (FC 0172) and ICA SR1.1 (FC 0176) use PCIe Gen3 technology, with x16 lanes that are bifurcated into x8 lanes for coupling.

Both cards are designed to drive distances up to 150 meters (492 feet) with a link data rate of 8 GBps. ICA SR supports up to four channel-path identifiers (CHPIDs) per port and eight subchannels (devices) per CHPID.

The coupling links can be defined as shared between images (z/OS) within a CSS. They also can be spanned across multiple CSSs in a CPC. For ICA SR features, a maximum four CHPIDs per port can be defined.

When STP⁵ (FC 1021) is available, ICA SR coupling links can be defined as timing-only links to other IBM z16, IBM z15, IBM z14 ZR1, or IBM z14 M0x systems. The ICA SR cannot be connected to InfiniBand coupling fan-outs.

These two fan-out features are housed in the PCIe+ Gen3 I/O fan-out slot on the IBM z16 CPC drawers. Up to 48 ICA SR and ICA SR1.1 features (up to 96 ports) are supported on an IBM z16 A01 system.

OM3 fiber optic can be used for distances up to 100 meters (328 feet). OM4 fiber optic cables can be used for distances up to 150 meters (492 feet). For more information, see the following publications:

- ▶ *Planning for Fiber Optic Links*, GA23-1409
- ▶ *3931 Installation Manual for Physical Planning*, GC28-7015

⁵ Server Time Protocol

4.4.3 Fan-out considerations

Fan-out slots in the CPC drawer can be used to plug different fan-outs. On IBM z16 A01, the CPC drawers can hold up to 48 PCIe fan-out cards (four-CPC drawers configuration).

Adapter ID number assignment

PCIe fan-outs and ports are identified by an Adapter ID (AID) that is initially dependent on their physical locations, which is unlike channels that are installed in a PCIe+ I/O drawer. Those channels are identified by a physical channel ID (PCHID) number that is related to their physical location. This AID must be used to assign a CHPID to the fan-out in the IOCDs definition. The CHPID assignment is done by associating the CHPID to an AID port (see Table 4-2).

Table 4-2 Fan-out locations and their AIDs for the CPC drawer (IBM z16 A01)

Fan-out locations	CPC0 Location A10 AID (Hex)	CPC1 Location A15 AID (Hex)	CPC2 Location A20 AID (Hex)	CPC3 Location B10 AID (Hex)
LG01	00	0C	18	24
LG02	01	0D	19	25
LG03	02	0E	1A	26
LG04	03	0F	1B	27
LG05	04	10	1C	28
LG06	05	11	1D	29
LG07	06	12	1E	2A
LG08	07	13	1F	2B
LG09	08	14	20	2C
LG10	09	15	21	2D
LG11	0A	16	22	2E
LG12	0B	17	23	2F

Fan-out slots

The fan-out slots are numbered LG01 - LG12 (from left to right), as listed in Table 4-2. All fan-out locations and their AIDs for the CPC drawer are shown for reference only.

Important: The AID numbers that are listed in Table 4-2 are valid for a new build system only. If a fan-out is moved, the AID follows the fan-out to its new physical location.

The AID assignment is listed in the PCHID REPORT that is provided for each new server or for an MES upgrade on servers. Part of a PCHID REPORT for an IBM z16 is shown in Example 4-1 on page 159. In this example, four fan-out cards are installed at locations A10/LG06, A15/LG06, A15/LG12, and A15/LG12 with AIDs 05, 11, and PCHIDs 100, 101, and 10C, respectively.

Example 4-1 AID assignments PCHID REPORT sample

```

CHPIDSTART
31463036                PCHID REPORT                Nov 10,2021
Machine: 3931-A01  SN1
-----
Source      Drwr  Slot  F/C   PCHID/Ports or AID      Comment
A10/LG06    A10B  LG06  0176  AID=05
A15/LG06    A15B  LG06  0176  AID=11
A15/LG12/J02 Z01B  02    0461  100/D1 101/D2
A15/LG12/J02 Z01B  05    0457  10C/D1

```

Fan-out features that are supported by the IBM z16 are listed in Table 4-3, which includes the feature type, feature code, and information about the link that is supported by the fan-out feature.

Table 4-3 Fan-out summary

Fan-out feature	Feature Code	Use	Cable type	Connector type	Maximum distance	Link data rate^a
PCIe+ Gen3 fan-out	0175	PCIe I/O drawer conn.	Copper	N/A	4 m (13.1 ft.)	16 Gbps
ICA SR	0172	Coupling link	OM4	MTP	150 m (492 ft.)	8 Gbps
			OM3	MTP	100 m (328 ft.)	8 Gbps
ICA SR1.1	0176	Coupling link	OM4	MTP	150 m (492 ft.)	8 Gbps
			OM3	MTP	100 m (328 ft.)	8 Gbps

a. The link data rates do not represent the performance of the link. The performance depends on many factors, including latency through the adapters, cable lengths, and the type of workload.

4.5 I/O features

I/O features (adapters) include ports⁶ to connect the IBM z16 to external devices, networks, or other servers. I/O features are plugged into the PCIe+ I/O drawer, based on the configuration rules for the server. Different types of I/O cards are available: one for each channel or link type. I/O cards can be installed or replaced concurrently.

4.5.1 I/O feature card ordering information

The I/O features that are supported by IBM z16 servers and the ordering information for them are listed in Table 4-4.

Table 4-4 I/O features and ordering information

Channel feature	Feature code	New build	Carry-forward
FICON Express32S LX	0461	Y	N/A
FICON Express32S SX	0462	Y	N/A
FICON Express16SA LX	0436	N	Y
FICON Express16SA SX	0437	N	Y
FICON Express16S+ LX	0427	N	Y
FICON Express16S+ SX	0428	N	Y
OSA-Express7S 1.2 25 GbE LR	0460	Y	N/A
OSA-Express7S 1.2 25 GbE SR	0459	Y	N/A
OSA-Express7S 1.2 10 GbE LR	0456	Y	N/A
OSA-Express7S 1.2 10 GbE SR	0457	Y	N/A
OSA-Express7S 1.2 GbE LX	0454	Y	N/A
OSA-Express7S 1.2 GbE SX	0455	Y	N/A
OSA-Express7S 1.2 1000BASE-T	0458	Y	N/A
OSA-Express7S 25 GbE SR1.1	0449	N	Y
OSA-Express7S 25 GbE SR	0429	N	Y
OSA-Express7S 10 GbE LR	0444	N	Y
OSA-Express7S 10 GbE SR	0445	N	Y
OSA-Express7S GbE LX	0442	N	Y
OSA-Express7S GbE SX	0443	N	Y
OSA-Express7S 1000BASE-T Ethernet	0446	N	Y
OSA-Express6S 10 GbE LR	0424	N	Y
OSA-Express6S 10 GbE SR	0425	N	Y
OSA-Express6S GbE LX	0422	N	Y
OSA-Express6S GbE SX	0423	N	Y

⁶ Certain I/O features do not have external ports, such as Crypto Express.

Channel feature	Feature code	New build	Carry-forward
OSA-Express6S 1000BASE-T Ethernet	0426	N	Y
PCIe+ Gen3 fan-out ^a	0175	Y	Y
Integrated Coupling Adapter (ICA SR1.1) ^b	0176	Y	Y
Integrated Coupling Adapter (ICA SR) ^b	0172	N	Y
Coupling Express2 LR	0434	Y	N/A
Crypto Express8S (dual HSM)	0908	Y	N/A
Crypto Express8S (single HSM)	0909	Y	N/A
Crypto Express7S (2 ports)	0898	N	Y
Crypto Express7S (1 port)	0899	N	Y
Crypto Express6S	0893	N	Y
25 GbE RoCE Express3 SR	0452	Y	N/A
25 GbE RoCE Express3 LR	0453	Y	N/A
10 GbE RoCE Express3 SR	0440	Y	N/A
10 GbE RoCE Express3 LR	0441	Y	N/A
25 GbE RoCE Express2.1	0450	N	Y
25 GbE RoCE Express2	0430	N	Y
10 GbE RoCE Express2.1	0432	N	Y
10 GbE RoCE Express2	0412	N	Y
zHyperLink Express1.1	0451	Y	Y
zHyperLink Express	0431	N	Y

a. Installed in the CPC Drawer; provides connectivity for the PCIe+ I/O Drawer.

b. Installed in the CPC Drawer; provides coupling connectivity (short distance: up to 150m).

Coupling links connectivity support: Consider the following points:

- ▶ z13 and z13s and older systems are not supported in same Parallel Sysplex or STP CTN with IBM z16.
- ▶ InfiniBand coupling links (if available on IBM z14 M0x) are *not* supported in a Parallel Sysplex or CTN with an IBM z16 member.

4.5.2 Physical channel ID report

A physical channel ID (PCHID) reflects the physical location of a channel-type interface. A PCHID number is based on the following factors:

- ▶ PCIe+ I/O drawer location
- ▶ Channel feature slot number
- ▶ Port number of the channel feature

A CHPID does not directly correspond to a hardware channel port. Instead, it is assigned to a PCHID in the hardware configuration definition (HCD) or IOCP.

A PCHID REPORT is created for each new build server and for upgrades on servers. The report lists all I/O features that are installed, the physical slot location, and the assigned PCHID. A portion of a sample PCHID REPORT is shown in Example 4-2.

Example 4-2 PCHID REPORT

```

CHPIDSTART
31463036                PCHID REPORT                Nov 10,2021
Machine: 3931-A01  SN1
-----
Source          Drwr  Slot  F/C   PCHID/Ports or AID          Comment
A10/LG06        A10B  LG06  0176  AID=05
A15/LG06        A15B  LG06  0176  AID=11
A15/LG12/J02    Z01B  02    0461  100/D1 101/D2
A15/LG12/J02    Z01B  05    0457  10C/D1
A15/LG12/J02    Z01B  07    0457  110/D1
A15/LG12/J02    Z01B  08    0459  114/D1
A15/LG12/J02    Z01B  09    0908  118/P00 119/P01
A15/LG12/J02    Z01B  10    0440  11C/D1D2          RG3
A20/LG12/J02    Z01B  12    0461  120/D1 121/D2
A20/LG12/J02    Z01B  13    0462  124/D1 125/D2
A20/LG12/J02    Z01B  17    0458  130/D1D2
A20/LG12/J02    Z01B  18    0457  134/D1
A20/LG12/J02    Z01B  19    0457  138/D1
.....<< snippet >>.....

```

The PCHID REPORT that is shown in Example 4-2 includes the following components:

- ▶ Feature Code 0176 (Integrated Coupling Adapters (ICA SR1.1) is installed in the CPC drawer (location A10, slot LG06, and A15 LG06), and has AIDs 05 and 11 assigned.
- ▶ Feature 0461 (FICON Express32SA LX) is installed in PCIe+ I/O drawer 1: Location Z01B, slot 02 with PCHIDs 100/D1 and 101/D2 assigned.
- ▶ Two feature codes 0457 (OSA-Express7S 1.2 10 GbE SR) installed in PCIe+ I/O drawer 1 in slots 05 and 07, with PCHIDs 10C/D1 and 110/D1, respectively.

A resource group (RG) parameter also is shown in the PCHID REPORT for native PCIe features. A balanced plugging of native PCIe features exists between four resource groups (RG1, RG2, RG3, and RG4).

The preassigned PCHID number of each I/O port relates directly to its physical location (jack location in a specific slot).

4.6 Connectivity

I/O channels are part of the CSS. They provide connectivity for data exchange between servers, between servers and external control units (CUs) and devices, or between networks.

For more information about connectivity to external I/O subsystems (for example, disks), see 4.6.2, “Storage connectivity” on page 167.

For more information about communication to LANs, see 4.6.3, “Network connectivity” on page 175.

Communication between servers is implemented by using CE LR, ICA SR, or channel-to-channel (FICON CTC) connections. For more information, see 4.6.4, “Parallel Sysplex connectivity” on page 190.

4.6.1 I/O feature support and configuration rules

The supported I/O features are listed in Table 4-5. Also listed in Table 4-5 are the number of ports per card, port increments, the maximum number of feature cards, and the maximum number of channels for each feature type. The CHPID definitions that are used in the IOCDs also are listed

Table 4-5 IBM z16 A01 supported I/O features

I/O feature	Ports per card	Port increments	Maximum ports ^a	Maximum I/O slots ^a	PCHID	CHPID definition
Storage access						
FICON Express32S LX/SX	2	2	384	192	Yes	FC, FCP ^b
FICON Express16S+ LX/SX	2	2	384	192	Yes	FC, FCP ^b
FICON Express16SA LX/SX	2	2	384	192	Yes	FC, FCP ^b
zHyperLink Express 1.1	2	2	32	16	Yes	N/A ^c
zHyperLink Express	2	2	32	16	Yes	N/A ^c
OSA-Express features^d						
OSA-Express7S 1.2 25 GbE LR/SR	1	1	48	48	Yes	OSD
OSA-Express7S 1.2 10 GbE LR/SR	1	1	48	48	Yes	OSD
OSA-Express7S 1.2 GbE LR/SR	2	2	96	48	Yes	OSC, OSD
OSA-Express7S 1.2 ^e 1000BASE-T	2	2	96	48	Yes	OSC, OSD, OSE
OSA-Express7S 25 GbE SR1.1	1	1	48	48	Yes	OSD
OSA-Express7S 25 GbE SR	1	1	48	48	Yes	OSD
OSA-Express7S 10 GbE LR/SR	1	1	48	48	Yes	OSD

I/O feature	Ports per card	Port increments	Maximum ports ^a	Maximum I/O slots ^a	PCHID	CHPID definition
OSA-Express7S GbE LR/SR	1	1	48	48	Yes	OSC, OSD
OSA-Express7S 1000BASE-T	2	2	96	48	Yes	OSC, OSD, OSE
OSA-Express6S 10 GbE LR/SR	1	1	48	48	Yes	OSD
OSA-Express6S GbE LX/SX	2	2	96	48	Yes	OSD
OSA-Express6S 1000BASE-T	2	2	96	48	Yes	OSC, OSD, OSE
RoCE Express features						
25 GbE RoCE Express3	2	2	32	16	Yes	N/A
10 GbE RoCE Express3	2	2	32	16	Yes	N/A
25 GbE RoCE Express2.1	2	2	32	16	Yes	N/A
10 GbE RoCE Express2.1	2	2	32	16	Yes	N/A
25 GbE RoCE Express2	2	2	8	4	Yes	N/A ^c
10 GbE RoCE Express2	2	2	8	4	Yes	N/A ^c
Coupling features						
Coupling Express2 LR	2	2	64	32	Yes	CL5
Integrated Coupling Adapter (ICA SR1.1) ^f	2	2	96	48	N/A ^g	CS5
Integrated Coupling Adapter (ICA SR) ^f	2	2	96	48	N/A ^g	CS5

a. Maximum number depends on system power option (PDU or BPA).

b. Both ports must be defined with the same CHPID type.

c. These features are defined by using Virtual Functions IDs (FIDs).

d. On IBM z16, the OSX and OSM type CHPIDs cannot be defined. IBM z16 cannot be part of an ensemble that is managed by zManager.

e. IBM z16 is planned to be the last IBM Z server generation to support OSA-Express 1000BASE-T adapters.

f. Installed in the CPC drawer.

g. ICA SR 1.1 and ICA SR features are characterized by Adapter ID (AID).

At least one I/O feature (FICON) or one coupling link feature (ICA SR or CE LR) must be present in the minimum configuration.

The following features can be shared and spanned:

- ▶ FICON channels that are defined as FC or FCP
- ▶ OSA-Express features that are defined as OSC, OSD, or OSE
- ▶ Coupling links that are defined as CS5 or CL5
- ▶ HiperSockets that are defined as IQD

The following features are plugged into a PCIe+ I/O drawer and do not require the definition of a CHPID and CHPID type:

- ▶ Each Crypto Express (8S/7S/6S) feature occupies one I/O slot, but does not include a PCHID type. However, LPARs in all CSSs can access the features. Each Crypto Express adapter can support up to 85 domains.
- ▶ Each 25 GbE RoCE Express(3/2.1/2) feature occupies one I/O slot, but does not include a CHPID type. However, LPARs in all CSSs can access the feature. The 25 GbE RoCE Express3 can be defined to up to 126 virtual functions (VFs) per feature (port is defined in z/OS Communications Server). The 25 GbE RoCE Express3 feature support up to 63 VFs per port (up to 126 VFs per feature).
- ▶ Each 10 GbE RoCE Express(3/2.1/2) feature occupies one I/O slot, but does not include a CHPID type. However, LPARs in all CSSs can access the feature. The 10 GbE RoCE Express3 can be defined to up to 126 virtual functions (VFs) per feature (port is defined in z/OS Communications Server). The 10 GbE RoCE Express3 feature support up to 63 VFs per port (up to 126 VFs per feature).
- ▶ Each zHyperLink Express/zHyperlink Express1.1 feature occupies one I/O slot but does not include a CHPID type. However, LPARs in all CSSs can access the feature. The zHyperLink Express adapter works as native PCIe adapter and can be shared by multiple LPARs. Each port supports up to 127 Virtual Functions (VFs), with one or more VFs/PFIDs being assigned to each LPAR. This support gives a maximum of 254 VFs per adapter.

I/O feature cables and connectors

The IBM Facilities Cabling Services fiber transport system offers a total cable solution service to help with cable ordering requirements. These services can include the requirements for all of the protocols and media types that are supported (for example, FICON, Coupling Links, and OSA). The services can help whether the focus is the data center, SAN, LAN, or the end-to-end enterprise.

Cables: All fiber optic cables, cable planning, labeling, and installation are client responsibilities for new IBM z16 installations and upgrades. Fiber optic conversion kits and mode conditioning patch cables are not orderable as features on IBM z16 servers. All other cables must be sourced separately.

The required connector and cable type for each I/O feature on IBM z16 servers are listed in Table 4-6.

Table 4-6 Feature connector and cable types

Feature Code	Feature name	Connector type	Cable type
0461	FICON Express32S LX	LC Duplex	9 μm SM
0462	FICON Express32S SX	LC Duplex	50 μm MM ^a
0436	FICON Express16SA LX	LC Duplex	9 μm SM
0437	FICON Express16SA SX	LC Duplex	50, 62.5 μm MM
0427	FICON Express16S+ LX 10 km	LC Duplex	9 μm SM
0428	FICON Express16S+ SX	LC Duplex	50 ^a , 62.5 μm MM
0459	OSA-Express7S 1.2 25 GbE SR	LC Duplex	50 μm MM
0460	OSA-Express7S 1.2 25 GbE LR	LC Duplex	9 μm SM

Feature Code	Feature name	Connector type	Cable type
0456	OSA-Express7S1.2 10 GbE LR	LC Duplex	9 µm SM
0457	OSA-Express7S 1.2 10 GbE SR	LC Duplex	50 µm MM ^a
0454	OSA-Express7S 1.2 GbE LX	LC Duplex	9 µm SM
0455	OSA-Express7S 1.2 GbE SX	LC Duplex	50, 62.5 µm MM
0458	OSA-Express7S 1.2 1000BASE-T	RJ-45	Category 5 UTP ^b
0449	OSA-Express7S 25 GbE SR1.1	LC Duplex	50 µm MM ^a
0429	OSA-Express7S 25 GbE SR	LC Duplex	50 µm MM ^a
0444	OSA-Express7S 10 GbE LR	LC Duplex	9 µm SM
0445	OSA-Express7S 10 GbE SR	LC Duplex	50, 62.5 µm MM
0442	OSA-Express7S GbE LX	LC Duplex	9 µm SM
0443	OSA-Express7S GbE SX	LC Duplex	50, 62.5 µm MM
0446	OSA-Express7S 1000BASE-T	RJ-45	Category 5 UTP ^b
0424	OSA-Express6S 10 GbE LR	LC Duplex	9 µm SM
0425	OSA-Express6S 10 GbE SR	LC Duplex	50, 62.5 µm MM
0422	OSA-Express6S GbE LX	LC Duplex	9 µm SM
0423	OSA-Express6S GbE SX	LC Duplex	50, 62.5 µm MM
0426	OSA-Express6S 1000BASE-T	RJ-45	Category 5 UTP ^b
0452	25 GbE RoCE Express3 SR	LC Duplex	50, 62.5 µm MM
0453	25 GbE RoCE Express3 LR	LC Duplex	9 µm SM
0440	10 GbE RoCE Express3 SR	LC Duplex	50, 62.5 µm MM
0441	10 GbE RoCE Express3 LR	LC Duplex	9 µm SM
0450	25 GbE RoCE Express 2.1	LC Duplex	50 µm MM ^a
0405	10 GbE RoCE Express2.1	LC Duplex	50, 62.5 µm MM
0430	25 GbE RoCE Express2	LC Duplex	50 µm MM ^a
0412	10 GbE RoCE Express2	LC Duplex	50, 62.5 µm MM
0411	10 GbE RoCE Express	LC Duplex	50, 62.5 µm MM
0434	CE2 LR	LC Duplex	9 µm SM
0176	Integrated Coupling Adapter SR1.1 (ICA SR1.1)	MTP	50 µm MM OM3/OM4
0172	Integrated Coupling Adapter (ICA SR)	MTP	50 µm MM OM3/OM4
0451	zHyperLink Express1.1	MPO	50 µm MM OM3/OM4
0431	zHyperLink Express	MPO	50 µm MM OM3/OM4

a. 50 µm core Multi Mode (MM) fiber: OM2, OM3, or OM4 (OM4 is highly recommended).

b. UTP is unshielded twisted pair. Consider the use of category 6 UTP for 1000 Mbps connections.

4.6.2 Storage connectivity

Connectivity to external I/O subsystems (for example, disks) is provided by FICON channels and zHyperLink⁷.

FICON channels

IBM z16 supports the following FICON features:

- ▶ FICON Express32S LX and SX (FC 0461/0462)
- ▶ FICON Express16SA LX and SX (FC 0436/0437)
- ▶ FICON Express16S+ LX and SX (FC 0427/0428)

The FICON Express32S, FICON Express16SA, and FICON Express16S+ features conform to the following architectures:

- ▶ Fibre Connection (FICON)
- ▶ High Performance FICON on Z (zHPF)
- ▶ Fibre Channel Protocol (FCP)

The FICON features provide connectivity between any combination of servers, directors, switches, and devices (control units, disks, tapes, and printers) in a SAN.

Each FICON Express feature occupies one I/O slot in the PCIe+ I/O drawer. Each feature includes two ports, each supporting an LC Duplex connector, with one PCHID and one CHPID that is associated with each port.

Each FICON Express feature uses SFP (SFP+ for FICON Express16SA and FICON Express32S) optics that allow for concurrent repairing or replacement for each SFP. The data flow on the unaffected channels on the same feature can continue. A problem with one FICON Express port does not require replacement of a complete feature.

Each FICON Express feature also supports cascading, which is the connection of two FICON Directors in succession. This configuration minimizes the number of cross-site connections and helps reduce implementation costs for disaster recovery applications, IBM Geographically Dispersed Parallel Sysplex (GDPS), and remote copy.

IBM z16 servers support 32 K devices per FICON channel for all FICON features.

Each FICON Express channel can be defined independently for connectivity to servers, switches, directors, disks, tapes, and printers, by using the following CHPID types:

- ▶ CHPID type FC: The FICON, zHPF, and FCTC protocols are supported simultaneously.
- ▶ CHPID type FCP: Fibre Channel Protocol that supports attachment to SCSI devices directly or through Fibre Channel switches or directors.

FICON channels (CHPID type FC or FCP) can be shared among LPARs and defined as spanned. All ports on a FICON feature must be of the same type (LX or SX). The features are connected to a FICON capable control unit (point-to-point or switched point-to-point) through a Fibre Channel switch.

⁷ zHyperLink feature operates with a FICON channel.

FICON Express32S

The FICON Express32S feature is installed in the PCIe+ I/O drawer. Each of the two independent ports is capable of 8 Gbps, 16 Gbps, or 32 Gbps. The link speed depends on the capability of the attached switch or device. The link speed is auto-negotiated, point-to-point, and is transparent to users and applications.

The following types of FICON Express32S optical transceivers are supported (no mix on same card):

- ▶ FICON Express32S LX feature, FC 0461, with two ports per feature, LC Duplex connectors
- ▶ FICON Express32S SX feature, FC 0462, with two ports per feature, LC Duplex connectors

For more information about supported distances, see Table 4-6 on page 165.

Consideration: FICON Express32S features do not support auto-negotiation to a data link rate of 2 or 4 Gbps (only 8, 16, or 32 Gbps) for point-to-point connections. A compatible switch must be used to connect to lower speed devices.

FICON Express16SA

The FICON Express16SA feature is installed in the PCIe+ I/O drawer. Each of the two independent ports is capable of 8 or 16 Gbps. The link speed depends on the capability of the attached switch or device. The link speed is auto-negotiated, point-to-point, and is transparent to users and applications.

The following types of FICON Express16SA optical transceivers are supported (no mix on same card):

- ▶ FICON Express16SA LX feature, FC 0436, with two ports per feature, LC Duplex connectors
- ▶ FICON Express16SA SX feature, FC 0437, with two ports per feature, LC Duplex connectors

For more information about supported distances, see Table 4-6 on page 165.

Consideration: FICON Express16SA features do not support auto-negotiation to a data link rate of 2 or 4 Gbps (only 8 or 16 Gbps) for point-to-point connections. A compatible switch must be used to connect to lower speed devices.

FICON Express16S+

The FICON Express16S+ feature is installed in the PCIe+ I/O drawer. Each of the two independent ports is capable of 4, 8, or 16 Gbps. The link speed depends on the capability of the attached switch or device. The link speed is auto-negotiated, point-to-point, and is transparent to users and applications.

The following types of FICON Express16S+ optical transceivers are supported (no mix on same card):

- ▶ FICON Express16S+ LX feature, FC 0427, with two ports per feature, supporting LC Duplex connectors
- ▶ FICON Express16S+ SX feature, FC 0428, with two ports per feature, supporting LC Duplex connectors

For more information, see the FICON Express chapter *IBM Z Connectivity Handbook*, [SG24-5444](#).

Consideration: FICON Express16S+ features do not support auto-negotiation to a data link rate of 2 Gbps (only 4, 8, or 16 Gbps). A compatible switch must be used to connect to lower speed devices.

FICON features and built-in functions

Together with the FICON Express32S, FICON Express16SA, and FICON Express16S+, IBM z16 servers provide enhancements for FICON in functional and performance aspects with IBM Endpoint Security solution.

IBM Fibre Channel Endpoint Security

IBM z16 Model A01 supports IBM Fibre Channel Endpoint Security feature (FC 1146). FC 1146 provides FC/FCP link encryption and endpoint authentication. It is an end-to-end solution that helps ensure all data flowing on the Fibre Channel links within and across data centers flows between trusted entities.

The following prerequisites must be met for this optionally priced feature:

- ▶ FICON Express32S and FICON Express16SA for both link encryption and endpoint authentication

Note: FICON Express16S+ supports endpoint authentication only (no data-in-flight encryption).

- ▶ Select DS8000 storage
- ▶ Supporting infrastructure: IBM Security Guardium Key Lifecycle Manager
- ▶ CPACF enablement (FC 3863)

Forward Error Correction

Forward Error Correction (FEC) is a technique that is used for reducing data errors when transmitting over unreliable or noisy communication channels (improving signal to noise ratio). By adding redundancy error-correction code (ECC) to the transmitted information, the receiver can detect and correct several errors without requiring retransmission. This process features improve signal reliability and bandwidth use by reducing retransmissions because of bit errors, especially for connections across long distance, such as an inter-switch link (ISL) in a GDPS Metro Mirror environment.

The FICON Express32S, FICON Express16SA, and FICON Express16S+ support FEC coding on top of its 64b/66b data encoding for 16 and 32 Gbps connections. This design can correct up to 11 bit errors per 2112 bits transmitted.

Therefore, while connected to devices that support FEC at 16 Gbps connections, the FEC design allows FICON Express16SE, FICON Express16S+, and FICON Express16S channels to operate at higher speeds, over longer distances, with reduced power and higher throughput. At the same time, the same reliability and robustness for which FICON channels are traditionally known are maintained.

With the IBM DS8870 or newer, IBM z16 servers can extend the use of FEC to the fabric N_Ports for a completed end-to-end coverage of 32 Gbps FC links.

FICON dynamic routing

With the IBM z14 and newer servers, FICON channels are no longer restricted to the use of static SAN routing policies for ISLs for cascaded FICON directors. The IBM Z servers now support dynamic routing in the SAN with the FICON Dynamic Routing (FIDR) feature. It is designed to support the dynamic routing policies that are provided by the FICON director manufacturers; for example, Brocade's exchange-based routing (EBR) and Cisco's originator exchange ID (OxID)⁸ routing.

A static SAN routing policy normally assigns the ISL routes according to the incoming port and its destination domain (port-based routing), or the source and destination ports pairing (device-based routing).

The port-based routing (PBR) assigns the ISL routes statically that is based on "first come, first served" when a port starts a fabric login (FLOGI) to a destination domain. The ISL is round-robin that is selected for assignment. Therefore, I/O flow from same incoming port to same destination domain always is assigned the same ISL route, regardless of the destination port of each I/O.

This setup can result in some ISLs becoming overloaded while some are under-used. The ISL routing table is changed whenever IBM Z server undergoes a power-on-reset (POR), so the ISL assignment is unpredictable.

Device-based routing (DBR) assigns the ISL routes statically that is based on a hash of the source and destination port. That I/O flow from same incoming port to same destination is assigned to same ISL route. Compared to PBR, the DBR is more capable of spreading the load across ISLs for I/O flow from the same incoming port to different destination ports within a destination domain.

When a static SAN routing policy is used, the FICON director features limited capability to assign ISL routes that are based on workload. This limitation can result in unbalanced use of ISLs (some might be overloaded, while others are under-used).

The dynamic routing ISL routes are dynamically changed based on the Fibre Channel exchange ID, which is unique for each I/O operation. ISL is assigned at I/O request time; therefore, different I/Os from same incoming port to same destination port are assigned different ISLs.

With FIDR, IBM z16 servers feature the following advantages for performance and management in configurations with ISL and cascaded FICON directors:

- ▶ Support sharing of ISLs between FICON and FCP (PPRC or distributed)
- ▶ I/O traffic is better balanced between all available ISLs
- ▶ Improved use of FICON director and ISL
- ▶ Easier to manage with a predictable and repeatable I/O performance

FICON dynamic routing can be enabled by defining dynamic routing-capable switches and control units in HCD. Also, z/OS implemented a health check function for FICON dynamic routing.

Improved zHPF I/O execution at distance

By introducing the concept of pre-deposit writes, zHPF reduces the number of round trips of standard FCP I/Os to a single round trip. Originally, this benefit is limited to writes that are less than 64 KB.

⁸ Check with the switch provider for their support statement.

zHPF on IBM z14 and newer servers were enhanced to allow all large write operations (> 64 KB) at distances up to 100 kilometers (62 miles) to be run in a single round trip to the control unit. This improvement avoids elongating the I/O service time for these write operations at extended distances.

Read Diagnostic Parameter Extended Link Service support

To improve the accuracy of identifying a failed component without unnecessarily replacing components in a SAN fabric, a new Extended Link Service (ELS) command called Read Diagnostic Parameters (RDP) was added to the Fibre Channel T11 standard. This command allows IBM Z servers to obtain extra diagnostic data from the SFP optics that are throughout the SAN fabric.

IBM z14 and newer servers can read this extra diagnostic data for all the ports that are accessed in the I/O configuration and make the data available to an LPAR. For z/OS LPARs that use FICON channels, z/OS displays the data with a [new message and display](#) command. For Linux on IBM Z, z/VM, and z/VSE, and LPARs that use FCP channels, this diagnostic data is available in a new window in the SAN Explorer tool.

N_Port ID Virtualization

N_Port ID Virtualization (NPIV) allows multiple system images (in LPARs or z/VM guests) to use a single FCP channel as though each were the sole user of the channel. First introduced with IBM z9® EC, this feature can be used with earlier FICON features that were carried forward from earlier servers.

By using the FICON Express16S (or newer) as an FCP channel with NPIV enabled, the maximum numbers of the following aspects for one FCP physical channel are doubled:

- ▶ Maximum number of NPIV hosts defined: Increased from 32 to 64
- ▶ Maximum number of remote N_Ports communicated: Increased from 512 to 1024
- ▶ Maximum number of addressable LUNs: Increased from 4096 to 8192
- ▶ Concurrent I/O operations: Increased from 764 to 1528

For more information about operating systems that support NPIV, see [“N_Port ID Virtualization” on page 300](#).

Export and import physical port WWPNs for FCP Channels

IBM Z automatically assign worldwide port names (WWPNs) to the physical ports of an FCP channel that is based on the PCHID. This WWPN assignment changes when an FCP channel is moved to a different physical slot position.

IBM z14 and newer servers allow for the modification of these default assignments, which also allows FCP channels to keep previously assigned WWPNs, even after being moved to a different slot position. This capability can eliminate the need for reconfiguration of the SAN in many situations, and is especially helpful during a system upgrade (FC 0099 - WWPN Persistence).

FICON support for multiple-hop cascaded SAN configurations

Before the introduction of z13 and z13s servers, IBM Z FICON SAN configurations supported a single ISL (a single hop) in a cascaded FICON SAN environment only.

IBM z14 and newer servers support up to three hops in a cascaded FICON SAN environment. This support allows clients to more easily configure a three- or four-site disaster recovery solution.

For more information about the FICON multi-hop, see the [FICON Multihop: Requirements and Configurations white paper](#) at the IBM Techdocs Library website.

FICON feature summary

The FICON feature codes, cable type, maximum unrepeated distance, and the link data rate on an IBM z16 A01 server are listed in Table 4-7. All FICON features use LC Duplex connectors.

Table 4-7 FICON features

Channel feature	Feature Codes	Bit rate	Cable type	Maximum unrepeated distance ^a (MHz -km)
FICON Express32S 10KM LX	0461	8, 16 or 32 Gbps ^c	SM 9 μm	10 km ^b
FICON Express32S SX ^d	0462	32 Gbps	MM 50 μm	<ul style="list-style-type: none"> ▶ 20 m (500) ▶ 70 m (2000) ▶ 100 m (4700)
		16 Gbps	<ul style="list-style-type: none"> ▶ MM 62.5 μm ▶ MM 50 μm 	<ul style="list-style-type: none"> ▶ 15 m (200) ▶ 35 m (500) ▶ 100 m (2000) ▶ 125 m (4700)
		8 Gbps	<ul style="list-style-type: none"> ▶ MM 62.5 μm ▶ MM 50 μm 	<ul style="list-style-type: none"> ▶ 21 m (200) ▶ 50 m (500) ▶ 150 m (2000) ▶ 190 m (4700)
FICON Express16SA 10KM LX	0436	8, or 16 Gbps ^c	SM 9 μm	10 km
FICON Express16SA SX ^d	0437	16 Gbps	<ul style="list-style-type: none"> ▶ MM 62.5 μm ▶ MM 50 μm 	<ul style="list-style-type: none"> ▶ 15 m (200) ▶ 35 m (500) ▶ 100 m (2000) ▶ 125 m (4700)
		8 Gbps	<ul style="list-style-type: none"> ▶ MM 62.5 μm ▶ MM 50 μm 	<ul style="list-style-type: none"> ▶ 21 m (200) ▶ 50 m (500) ▶ 150 m (2000) ▶ 190 m (4700)
FICON Express16S+ 10KM LX	0427	4, 8, or 16 Gbps	SM 9 μm	10 km
FICON Express16S+ SX	0428	16 Gbps	MM 50 μm	<ul style="list-style-type: none"> ▶ 35 m (500) ▶ 100 m (2000) ▶ 125 m (4700)
		8 Gbps	<ul style="list-style-type: none"> ▶ MM 62.5 μm ▶ MM 50 μm 	<ul style="list-style-type: none"> ▶ 21 m (200) ▶ 50 m (500) ▶ 150 m (2000) ▶ 190 m (4700)
		4 Gbps	<ul style="list-style-type: none"> ▶ MM 62.5 μm ▶ MM 50 μm 	<ul style="list-style-type: none"> ▶ 70 m (200) ▶ 150 m (500) ▶ 380 m (2000) ▶ 400 m (4700)

a. Minimum fiber bandwidths in MHz/km for multimode fiber optic links are included in parentheses, where applicable.

b. For Single Mode fiber, at 1310 nm, link running at 32 Gbps are limited for point-to-point connectivity to 5 km.

c. 2 and 4 Gbps connectivity is not supported for point-to-point connections

d. 2 and 4 Gbps connectivity is supported through a SAN switch.

zHyperLink Express1.1 (FC 0451)

zHyperLink is a new technology that provides up to 5x reduction in I/O latency times for Db2 read requests with the qualities of service IBM Z clients expect from I/O infrastructure for Db2 v11 plus fixes (for read support) and v12 plus fixes (for write support) with z/OS.

The following z/OS versions are supported for zHyperLink:

- ▶ z/OS V2.5
- ▶ z/OS V2.4 with PTFs
- ▶ z/OS V2.3 with PTFs
- ▶ z/OS V2.2 with PTFs

The zHyperLink Express1.1 feature (FC 0451) provides a low latency direct connection between IBM z16 and DS8000 storage system.

The zHyperLink Express1.1 is the result of new business requirements that demand fast and consistent application response times. It dramatically reduces latency by interconnecting the IBM z16 directly to I/O Bay of the DS8k by using PCIe Gen3 x 8 physical link (up to 150 meters [492 feet]). A new transport protocol is defined for reading and writing IBM CKD data records⁹, as documented in the zHyperLink interface specification.

On IBM z16, zHyperLink Express1.1 card is a PCIe Gen3 adapter, which installed in the PCIe+ I/O drawer. HCD definition support was added for new PCIe function type with PORT attributes.

Requirements of zHyperLink Express1.1

The zHyperLink Express1.1 feature is available on IBM z16 servers, and includes the following requirements:

- ▶ z/OS 2.2 or later
- ▶ 150 m (492 feet) maximum distance in a point-to-point configuration
- ▶ Supported DS8000 (see *Getting Started with IBM zHyperLink for z/OS*, [REDP-5493](#))
- ▶ zHyperLink Express1.1 adapter (FC 0451) installed
- ▶ FICON channel as a driver
- ▶ Only ECKD supported
- ▶ z/VM is not supported

Up to 16 zHyperLink Express1.1 adapters can be installed in an IBM z16 (up to 32 links).

The zHyperLink Express1.1 is virtualized as a native PCIe adapter and can be shared by multiple LPARs. Each port can support up to 127 Virtual Functions (VFs), with one or more VFs/PFIDs being assigned to each LPAR. This configuration gives a maximum of 254 VFs per adapter.

The zHyperLink Express requires the following components:

- ▶ zHyperLink connector on DS8k I/O Bay
 - For DS8880 firmware R8.3 or newer, the I/O Bay planar is updated to support the zHyperLink interface. This update includes the update of the PEX 8732 switch to PEX8733 that includes a DMA engine for the zHyperLink transfers, and the upgrade from a copper to optical interface by a CXP connector (provided).
- ▶ Cable
 - The zHyperLink Express1.1 uses optical cable with MTP connector. Maximum supported cable length is 150 meters (492 feet).

⁹ CKD data records are handled by using IBM Enhanced Count Key Data (ECKD) command set.

zHyperLink Express (FC 0431)

zHyperLink is a new technology that provides up to 5x reduction in I/O latency times for Db2 read requests with the qualities of service IBM Z clients expect from I/O infrastructure for Db2 v12 with z/OS. The z/OS supported versions are the same as for zHyperLink Express 1.1.

The zHyperLink Express feature (FC 0431) provides a low latency direct connection between IBM z16 and DS8000 I/O Port.

The zHyperLink Express is the result of new business requirements that demand fast and consistent application response times. It dramatically reduces latency by interconnecting the IBM z16 directly to I/O Bay of the DS8880 by using PCIe Gen3 x 8 physical link (up to 150 meters [492 feet]). A new transport protocol is defined for reading and writing IBM CKD data records¹⁰, as documented in the zHyperLink interface specification.

On IBM z16, the zHyperLink Express card is a carry forward PCIe adapter that installed in the PCIe+ I/O drawer. HCD definition support was added for new PCIe function type with PORT attributes.

Requirements of zHyperLink

The zHyperLink Express feature is available on IBM z16 servers, and includes the following requirements:

- ▶ z/OS 2.2 or later
- ▶ Supported DS8000 (see *Getting Started with IBM zHyperLink for z/OS*, [REDP-5493](#))
- ▶ zHyperLink Express adapter (FC 0431) installed
- ▶ FICON channel as a driver
- ▶ Only ECKD supported
- ▶ z/VM is not supported

Up to 16 zHyperLink Express adapters can be installed in an IBM z16 (up to 32 links).

The zHyperLink Express is virtualized as a native PCIe adapter and can be shared by multiple LPARs. Each port can support up to 127 Virtual Functions (VFs), with one or more VFs/PFIDs being assigned to each LPAR. This configuration gives a maximum of 254 VFs per adapter.

The zHyperLink Express requires the following components:

- ▶ zHyperLink connector on supported DS8000 I/O Bay.
- ▶ Optic Fiber Cable

The zHyperLink Express uses optical cable with MTP connector. Maximum supported cable length is 150 meters (492 feet).

¹⁰ CKD data records are handled by using IBM Enhanced Count Key Data (ECKD) command set.

4.6.3 Network connectivity

Communication for LANs is provided by the OSA-Express7S 1.2, OSA-Express7S, OSA-Express6S, 25 GbE and 10 GbE RoCE Express3, 25 GbE and 10 GbE RoCE Express2.1, and 25 GbE and 10 GbE RoCE Express2 features.

OSA-Express7S 1.2 25 GbE SR (FC 0459)

OSA-Express7S 1.2 25 Gigabit Ethernet SR (FC 0459) is installed in the PCIe+ I/O Drawer.

OSA-Express7S 1.2 25 Gigabit Ethernet Short Reach (SR) feature includes one PCIe Gen3 adapter and one port per feature. The port supports CHPID types OSD.

The OSA-Express7S 1.2 25 GbE SR feature supports attachment to a multimode fiber 25 Gbps Ethernet LAN or Ethernet switch that is capable of 25 Gbps. The port can be defined as a spanned channel and shared among LPARs within and across logical channel subsystems.

The OSA-Express7S 1.2 25 GbE SR feature supports the use of an industry standard small form factor (SFP+) LC Duplex connector. Ensure that the attaching or downstream device includes an SR transceiver. The sending and receiving transceivers must be the same (SR to SR).

The OSA-Express7S 1.2 25 GbE SR feature does *not* support auto-negotiation to any other speed and runs in full duplex mode only.

A 50 μ m multimode fiber optic cable that ends with an LC Duplex connector is required for connecting each port on this feature to the selected device.

OSA-Express7S 1.2 25 GbE LR (FC 0460)

The OSA-Express7S 1.2 25 Gigabit Ethernet (GbE) Long Reach (LR) feature includes one PCIe Gen3 adapter and one port per feature. The port supports CHPID types OSD. The 25 GbE feature is designed to support attachment to a single-mode fiber 25 Gbps Ethernet LAN or Ethernet switch that is capable of 25 Gbps. The port can be defined as a spanned channel and can be shared among LPARs within and across logical channel subsystems.

The OSA-Express7S 1.2 25 GbE LR feature supports the use of an industry standard small form factor (SFP+) LC Duplex connector. Ensure that the attaching or downstream device includes an LR transceiver. The transceivers at both ends must be the same (LR to LR).

The OSA-Express7S 1.2 25 GbE LR feature does not support auto-negotiation to any other speed and runs in full duplex mode only.

A 9 μ m single-mode fiber optic cable that ends with an LC Duplex connector is required for connecting this feature to the selected device.

OSA-Express7S 1.2 10 GbE LR (FC 0456)

The OSA-Express7S 1.2 10 Gigabit Ethernet (GbE) Long Reach (LR) feature includes one PCIe Gen3 adapter and one port per feature. The port supports CHPID types OSD. The 10 GbE feature is designed to support attachment to a single-mode fiber 10 Gbps Ethernet LAN or Ethernet switch that is capable of 10 Gbps. The port can be defined as a spanned channel and can be shared among LPARs within and across logical channel subsystems.

The OSA-Express7S 1.2 10 GbE LR feature supports the use of an industry standard small form factor (SFP+) LC Duplex connector. Ensure that the attaching or downstream device includes an LR transceiver. The transceivers at both ends must be the same (LR to LR).

The OSA-Express7S 1.2 10 GbE LR feature does *not* support auto-negotiation to any other speed and runs in full duplex mode only.

A 9 µm single-mode fiber optic cable that ends with an LC Duplex connector is required for connecting this feature to the selected device.

OSA-Express7S 1.2 10 GbE SR (FC 0457)

The OSA-Express7S 1.2 10 GbE Short Reach (SR) feature includes one PCIe Gen3 adapter and one port per feature. The port supports CHPID types OSD. The 10 GbE feature is designed to support attachment to a multimode fiber 10 Gbps Ethernet LAN or Ethernet switch that is capable of 10 Gbps. The port can be defined as a spanned channel and shared among LPARs within and across logical channel subsystems.

The OSA-Express7S 1.2 10 GbE SR feature supports the use of an industry standard small form factor (SFP+) LC Duplex connector. Ensure that the attaching or downstream device includes an SR transceiver. The sending and receiving transceivers must be the same (SR to SR).

The OSA-Express7S 1.2 10 GbE SR feature does *not* support auto-negotiation to any other speed and runs in full duplex mode only.

A 50 or a 62.5 µm multimode fiber optic cable that ends with an LC Duplex connector is required for connecting each port on this feature to the selected device.

OSA-Express7S 1.2 GbE LX (FC 0454)

The OSA-Express7S 1.2 GbE LX feature includes one PCIe adapter and two ports. The two ports share a channel path identifier (CHPID type OSD). The ports support attachment to a 1 Gbps Ethernet LAN. Each port can be defined as a spanned channel and can be shared among LPARs and across logical channel subsystems.

The OSA-Express7S 1.2 GbE LX feature supports the use of an LC Duplex connector. Ensure that the attaching or downstream device has an LX transceiver. The sending and receiving transceivers must be the same (LX to LX).

A 9 µm single-mode fiber optic cable that ends with an LC Duplex connector is required for connecting each port on this feature to the selected device. If multimode fiber optic cables are being reused, a pair of Mode Conditioning Patch cables is required, with one cable for each end of the link.

OSA-Express7S 1.2 GbE SX (FC 0455)

The OSA-Express7S 1.2 GbE SX feature includes one PCIe adapter and two ports. The two ports share a channel path identifier (CHPID type OSD). The ports support attachment to a 1 Gbps Ethernet LAN. Each port can be defined as a spanned channel and shared among LPARs and across logical channel subsystems.

The OSA-Express7S 1.2 GbE SX feature supports the use of an LC Duplex connector. Ensure that the attaching or downstream device has an SX transceiver. The sending and receiving transceivers must be the same (SX to SX).

A multi-mode fiber optic cable that ends with an LC Duplex connector is required for connecting each port on this feature to the selected device.

OSA-Express7S 1.2 1000BASE-T (FC 0458)

Feature code 0458 occupies one slot in the PCIe+ I/O drawer. It features two ports that connect to a 1000 Mbps (1 Gbps) Ethernet LAN. Each port has an SFP+ with an RJ-45 receptacle for cabling to an Ethernet switch. The RJ-45 receptacle is required to be attached by using an EIA/TIA Category 5 or Category 6 UTP cable with a maximum length of 100 meters (328 feet). The SFP allows a concurrent repair or replace action.

The OSA-Express7S 1.2 1000BASE-T Ethernet feature does not support auto-negotiation. It supports links at 1000 Mbps in full duplex mode only.

The OSA-Express7S 1.2 1000BASE-T Ethernet feature can be configured as CHPID type OSC, OSD, OSE. Non-QDIO operation mode requires CHPID type OSE.

Note: CHPID types OSM, OSN, and OSX are not supported on IBM z16.

OSA-Express7S 25 GbE SR1.1 (FC 0449)

OSA-Express7S 25 Gigabit Ethernet SR1.1 (FC 0449) is installed in the PCIe+ I/O Drawer when carried forward to an IBM z16.

OSA-Express7S 25 Gigabit Ethernet Short Reach1.1 (SR1.1) feature includes one PCIe Gen3 adapter and one port per feature. The port supports CHPID types OSD.

The OSA-Express7S 25 GbE SR1.1 feature is designed to support attachment to a multimode fiber 25 Gbps Ethernet LAN or Ethernet switch that is capable of 25 Gbps. The port can be defined as a spanned channel and shared among LPARs within and across logical channel subsystems.

The OSA-Express7S 25 GbE SR1.1 feature supports the use of an industry standard small form factor (SFP+) LC Duplex connector. Ensure that the attaching or downstream device includes an SR transceiver. The sending and receiving transceivers must be the same (SR to SR).

The OSA-Express7S 25 GbE SR1.1 feature does not support auto-negotiation to any other speed and runs in full duplex mode only.

A 50 μ m multimode fiber optic cable that ends with an LC Duplex connector is required for connecting each port on this feature to the selected device.

OSA-Express7S 25 GbE SR (FC 0429)

OSA-Express7S 25 Gigabit Ethernet SR (FC 0429) is installed in the PCIe+ I/O Drawer when carried forward to an IBM z16.

The OSA-Express7S 25 GbE Short Reach (SR) feature includes one PCIe adapter and one port per feature. The port supports CHPID types OSD. The OSA-Express7S 25 GbE feature is designed to support attachment to a multimode fiber 25 Gbps Ethernet LAN or Ethernet switch that is capable of 25 Gbps. The port can be defined as a spanned channel and shared among LPARs within and across logical channel subsystems.

The OSA-Express7S 25 GbE SR feature supports the use of an industry standard small form factor (SFP+) LC Duplex connector. Ensure that the attaching or downstream device has an SR transceiver. The sending and receiving transceivers must be the same (SR to SR).

The OSA-Express7S 25 GbE SR feature does not support auto-negotiation to any other speed and runs in full duplex mode only.

A 50 µm multimode fiber optic cable that ends with an LC Duplex connector is required for connecting each port on this feature to the selected device.

The following other OSA-Express7S features can be installed on IBM z16 servers (when carried forward):

- ▶ OSA-Express7S 10 Gigabit Ethernet LR, FC 0444
- ▶ OSA-Express7S 10 Gigabit Ethernet SR, FC 0445
- ▶ OSA-Express7S Gigabit Ethernet LX, FC 0442
- ▶ OSA-Express7S Gigabit Ethernet SX, FC 0443
- ▶ OSA-Express7S 1000BASE-T Ethernet, FC 0446

The supported OSA-Express7S features are listed in Table 4-5 on page 163.

OSA-Express7S 10 Gigabit Ethernet LR (FC 0444)

The OSA-Express7S 10 Gigabit Ethernet (GbE) Long Reach (LR) feature includes one PCIe Gen3 adapter and one port per feature. The port supports CHPID types OSD. The 10 GbE feature is designed to support attachment to a single-mode fiber 10 Gbps Ethernet LAN or Ethernet switch that is capable of 10 Gbps. The port can be defined as a spanned channel and can be shared among LPARs within and across logical channel subsystems.

The OSA-Express7S 10 GbE LR feature supports the use of an industry standard small form factor (SFP+) LC Duplex connector. Ensure that the attaching or downstream device includes an LR transceiver. The transceivers at both ends must be the same (LR to LR).

The OSA-Express7S 10 GbE LR feature does not support auto-negotiation to any other speed and runs in full duplex mode only.

A 9 µm single-mode fiber optic cable that ends with an LC Duplex connector is required for connecting this feature to the selected device.

OSA-Express7S 10 Gigabit Ethernet SR (FC 0445)

The OSA-Express7S 10 GbE Short Reach (SR) feature includes one PCIe Gen3 adapter and one port per feature. The port supports CHPID types OSD. The 10 GbE feature is designed to support attachment to a multimode fiber 10 Gbps Ethernet LAN or Ethernet switch that is capable of 10 Gbps. The port can be defined as a spanned channel and shared among LPARs within and across logical channel subsystems.

The OSA-Express7S 10 GbE SR feature supports the use of an industry standard small form factor (SFP+) LC Duplex connector. Ensure that the attaching or downstream device has an SR transceiver. The sending and receiving transceivers must be the same (SR to SR).

The OSA-Express7S 10 GbE SR feature does not support auto-negotiation to any other speed and runs in full duplex mode only.

A 50 or a 62.5 µm multimode fiber optic cable that ends with an LC Duplex connector is required for connecting each port on this feature to the selected device.

OSA-Express7S Gigabit Ethernet LX (FC 0442)

The OSA-Express7S GbE LX feature includes one PCIe adapter and two ports. The two ports share a channel path identifier (CHPID type OSD). The ports support attachment to a 1 Gbps Ethernet LAN. Each port can be defined as a spanned channel and can be shared among LPARs and across logical channel subsystems.

The OSA-Express7S GbE LX feature supports the use of an LC Duplex connector. Ensure that the attaching or downstream device includes an LX transceiver. The sending and receiving transceivers must be the same (LX to LX).

A 9 µm single-mode fiber optic cable that ends with an LC Duplex connector is required for connecting each port on this feature to the selected device. If multimode fiber optic cables are being reused, a pair of Mode Conditioning Patch cables is required, with one cable for each end of the link.

OSA-Express7S Gigabit Ethernet SX (FC 0443)

The OSA-Express7S GbE SX feature includes one PCIe adapter and two ports. The two ports share a channel path identifier (CHPID type OSD). The ports support attachment to a 1 Gbps Ethernet LAN. Each port can be defined as a spanned channel and shared among LPARs and across logical channel subsystems.

The OSA-Express7S GbE SX feature supports the use of an LC Duplex connector. Ensure that the attaching or downstream device has an SX transceiver. The sending and receiving transceivers must be the same (SX to SX).

A multi-mode fiber optic cable that ends with an LC Duplex connector is required for connecting each port on this feature to the selected device.

OSA-Express7S 1000BASE-T Ethernet (FC 0446)

Feature code 0446 occupies one slot in the PCIe+ I/O drawer. It features two ports that connect to a 1000 Mbps (1 Gbps) Ethernet LAN. Each port has an SFP+ with an RJ-45 receptacle for cabling to an Ethernet switch. The RJ-45 receptacle is required to be attached by using an EIA/TIA Category 5 or Category 6 UTP cable with a maximum length of 100 meters (328 feet). The SFP allows a concurrent repair or replace action.

The OSA-Express7S 1000BASE-T Ethernet feature does not support auto-negotiation. It supports links at 1000 Mbps in full duplex mode only.

The OSA-Express7S 1000BASE-T Ethernet feature can be configured as CHPID type OSC, OSD, OSE, or OSM. Non-QDIO operation mode requires CHPID type OSE.

Note: CHPID types OSM, OSN, and OSX are not supported on IBM z16.

OSA-Express6S

The OSA-Express6S feature is installed in the PCIe+ I/O drawer. The following OSA-Express6S features can be installed on IBM z16 servers (when carried forward):

- ▶ OSA-Express6S 10 Gigabit Ethernet LR, FC 0424
- ▶ OSA-Express6S 10 Gigabit Ethernet SR, FC 0425
- ▶ OSA-Express6S Gigabit Ethernet LX, FC 0422
- ▶ OSA-Express6S Gigabit Ethernet SX, FC 0423
- ▶ OSA-Express6S 1000BASE-T Ethernet, FC 0426

The supported OSA-Express6S features are listed in Table 4-8 on page 181.

OSA-Express6S 10 Gigabit Ethernet LR (FC 0424)

The OSA-Express6S 10 Gigabit Ethernet (GbE) Long Reach (LR) feature includes one PCIe adapter and one port per feature. The port supports CHPID types OSD and OSX. The 10 GbE feature is designed to support attachment to a single-mode fiber 10 Gbps Ethernet LAN or Ethernet switch that is capable of 10 Gbps. The port can be defined as a spanned channel and can be shared among LPARs within and across logical channel subsystems.

The OSA-Express6S 10 GbE LR feature supports the use of an industry standard small form factor LC Duplex connector. Ensure that the attaching or downstream device includes an LR transceiver. The transceivers at both ends must be the same (LR to LR).

The OSA-Express6S 10 GbE LR feature does not support auto-negotiation to any other speed and runs in full duplex mode only.

A 9 μ m single-mode fiber optic cable that ends with an LC Duplex connector is required for connecting this feature to the selected device.

For more information about supported distances, see Table 4-8 on page 181.

OSA-Express6S Gigabit Ethernet SX (FC 0423)

The OSA-Express6S GbE SX feature includes one PCIe adapter and two ports. The two ports share a channel path identifier (CHPID type OSD). The ports support attachment to a 1 Gbps Ethernet LAN. Each port can be defined as a spanned channel and shared among LPARs and across logical channel subsystems.

The OSA-Express6S GbE SX feature supports the use of an LC Duplex connector. Ensure that the attaching or downstream device includes an SX transceiver. The sending and receiving transceivers must be the same (SX to SX).

A multi-mode fiber optic cable that ends with an LC Duplex connector is required for connecting each port on this feature to the selected device.

For more information about supported distances, see Table 4-8 on page 181.

OSA-Express6S 1000BASE-T Ethernet feature (FC 0426)

Feature code 0426 occupies one slot in the PCIe+ I/O drawer. It features two ports that connect to a 1000 Mbps (1 Gbps) or 100 Mbps Ethernet LAN. Each port has an SFP with an RJ-45 receptacle for cabling to an Ethernet switch. The RJ-45 receptacle is required to be attached by using an EIA/TIA Category 5 or Category 6 UTP cable with a maximum length of 100 meters (328 feet). The SFP allows a concurrent repair or replace action.

The OSA-Express6S 1000BASE-T Ethernet feature supports auto-negotiation when attached to an Ethernet router or switch. If you allow the LAN speed and duplex mode to default to auto-negotiation, the OSA-Express port and the attached router or switch auto-negotiate the LAN speed and duplex mode settings between them. They then connect at the highest common performance speed and duplex mode of interoperation. If the attached Ethernet router or switch does not support auto-negotiation, the OSA-Express port examines the signal that it is receiving and connects at the speed and duplex mode of the device at the other end of the cable.

The OSA-Express6S 1000BASE-T Ethernet feature can be configured as CHPID type OSC, OSD, OSE, or OSM. Non-QDIO operation mode requires CHPID type OSE.

Note: CHPID types OSM, OSN, and OSX are not supported on IBM z16

The following settings are supported on the OSA-Express6S 1000BASE-T Ethernet feature port:

- ▶ Auto-negotiate
- ▶ 100 Mbps half-duplex or full-duplex
- ▶ 1000 Mbps full-duplex

If auto-negotiate is not used, the OSA-Express port attempts to join the LAN at the specified speed and duplex mode. If this specified speed and duplex mode do not match the speed and duplex mode of the signal on the cable, the OSA-Express port does not connect.

For more information about supported distances, see Table 4-8 on page 181.

OSA-Express features summary

The OSA-Express feature codes, cable type, maximum unrepeated distance, and the link rate on an IBM z16 are listed in Table 4-8.

Table 4-8 OSA features

Channel feature	Feature Code	Bit rate in Gbps	Cable type	Maximum unrepeated distance ^a (MHz - km)
OSA-Express7S 1.2 25 GbE SR	0459	25	MM 50 μm	▶ 70 m (2000) ▶ 100 m (4700)
OSA-Express7S 1.2 25 GbE LR	0460	25	SM 9 μm	10 km (6.8 miles)
OSA-Express7S 1.2 10 GbE LR	0456	10	SM 9 μm	10 km (6.8 miles)
OSA-Express7S 1.2 10 GbE SR	0457	10	MM 62.5 μm MM 50 μm	▶ 33 m (200) ▶ 82 m (500) ▶ 300 m (2000)
OSA-Express7S 1.2 GbE LX	0454	1.25	SM 9 μm	5 km (3.1 miles)
OSA-Express7S 1.2 GbE SX	0455	1.25	MM 62.5 μm MM 50 μm	▶ 275 m (200) ▶ 550 m (500)
OSA-Express7S 1.2 1000BASE-T	0458	1000 Mbps	Cat 5, Cat 6 unshielded twisted pair (UTP)	100 m
OSA-Express7S 25 GbE SR1.1	0449	25	MM 50 μm	▶ 70 m (2000) ▶ 100 m (4700)
OSA-Express7S 25 GbE SR	0429			
OSA-Express7S 10 GbE LR	0444	10	SM 9 μm	10 km (6.8 miles)
OSA-Express7S 10 GbE SR	0445	10	MM 62.5 μm MM 50 μm	▶ 33 m (200) ▶ 82 m (500) ▶ 300 m (2000)
OSA-Express7S GbE LX	0442	1.25	SM 9 μm	5 km (3.1 miles)
OSA-Express7S GbE SX	0443	1.25	MM 62.5 μm MM 50 μm	▶ 275 m (200) ▶ 550 m (500)
OSA-Express7S 1000BASE-T	0446	1000 Mbps	Cat 5, Cat 6 unshielded twisted pair (UTP)	100 m
OSA-Express6S 10 GbE LR	0424	10	SM 9 μm	10 km (6.8 miles)
OSA-Express6S 10 GbE SR	0425	10	MM 62.5 μm MM 50 μm	▶ 33 m (200) ▶ 82 m (500) ▶ 300 m (2000)
OSA-Express6S GbE LX	0422	1.25	SM 9 μm	5 km (3.1 miles)
OSA-Express6S GbE SX	0423	1.25	MM 62.5 μm MM 50 μm	▶ 275 m (200) ▶ 550 m (500)
OSA-Express6S 1000BASE-T	0426	100 or 1000 Mbps	Cat 5, Cat 6 unshielded twisted pair (UTP)	100 m

a. Minimum fiber bandwidths in MHz/km for multimode fiber optic links are included in parentheses, where applicable.

25 GbE RoCE Express3 SR (FC 0452)

25 GbE RoCE Express3 SR (FC 0452) is installed in the PCIe+ I/O drawer and is supported on IBM z16 servers only. The 25 GbE RoCE Express3 SR is a native PCIe feature. It does not use a CHPID. It is defined by using the IOCP **FUNCTION** statement or in the hardware configuration definition (HCD).

The maximum supported unrepeatable distance, point-to-point, is 100 meters (328 feet). A client-supplied cable is required. Two types of cables can be used for connecting the port to the selected 25 GbE switch or to another 25 GbE RoCE Express3 SR feature:

- ▶ OM3 50-micron multimode fiber optic cable that is rated at 2000 MHz-km that ends with an LC Duplex connector, which supports 70 meters (229 feet)
- ▶ OM4 50-micron multimode fiber optic cable that is rated at 4700 MHz-km that ends with an LC Duplex connector, which supports 100 meters (328 feet)

The virtualization capabilities for IBM z16 are 63 Virtual Functions per port (126 VFs per feature/PCHID). One RoCE Express feature can be shared by up to 126 partitions (LPARs) (one adapter is one PCHID). The 25 GbE RoCE Express3 feature uses SR optics and supports the use of a multimode fiber optic cable that ends with an LC Duplex connector.

Note: Consider the following 25 GbE RoCE requirements:

- ▶ The 25 GbE RoCE Express3 SR feature does not support auto-negotiation to any other speed and runs in full duplex mode only.
- ▶ 25 GbE/10 GbE RoCE features should not be mixed in a z/OS SMC-R Link Group.

Point-to-point connections and switched connections with an enterprise-class 25 GbE switch are supported.

25 GbE RoCE Express3 LR (FC 0453)

25 GbE RoCE Express3 LR(FC 0453) is installed in the PCIe+ I/O drawer and is supported on IBM z16 servers only. The 25 GbE RoCE Express3 LR is a native PCIe feature. It does not use a CHPID. It is defined by using the IOCP **FUNCTION** statement or in the hardware configuration definition (HCD).

The maximum supported unrepeatable distance, point-to-point, is 100 meters (328 feet). A client-supplied cable is required. Two types of cables can be used for connecting the port to the selected 25 GbE switch or to another 25 GbE RoCE Express3 LR feature:

- ▶ OM3 50-micron multimode fiber optic cable that is rated at 2000 MHz-km that ends with an LC Duplex connector, which supports 70 meters (229 feet)
- ▶ OM4 50-micron multimode fiber optic cable that is rated at 4700 MHz-km that ends with an LC Duplex connector, which supports 100 meters (328 feet)

The virtualization capabilities for IBM z16 are 63 Virtual Functions per port (126 VFs per feature/PCHID). One RoCE Express feature can be shared by up to 126 partitions (LPARs) (one adapter is one PCHID). The 25 GbE RoCE Express3 feature uses LR optics and supports the use of a single mode fiber optic cable that ends with an LC Duplex connector.

Note: Consider the following 25 GbE RoCE requirements:

- ▶ The 25 GbE RoCE Express3 LR feature does not support auto-negotiation to any other speed and runs in full duplex mode only.
- ▶ 25 GbE/10 GbE RoCE features should not be mixed in a z/OS SMC-R Link Group.

Point-to-point connections and switched connections with an enterprise-class 25 GbE switch are supported.

10 GbE RoCE Express3 SR (FC 0440)

10 GbE RoCE Express3 SR(FC 0440) is installed in the PCIe+ I/O drawer and is supported on IBM z16 servers only. The 10 GbE RoCE Express3 SR is a native PCIe feature. It does not use a CHPID and is defined by using the IOCP **FUNCTION** statement or in the HCD.

The maximum supported unrepeatd distance, point-to-point, is 100 meters (328 feet). A client-supplied cable is required. Two types of cables can be used for connecting the port to the selected 10 GbE switch or to another 10 GbE RoCE Express3 SR feature:

- ▶ OM3 50-micron multimode fiber optic cable that is rated at 2000 MHz-km that ends with an LC Duplex connector, which supports 70 meters (229 feet)
- ▶ OM4 50-micron multimode fiber optic cable that is rated at 4700 MHz-km that ends with an LC Duplex connector, which supports 100 meters (328 feet)

The virtualization capabilities for IBM z16 are 63 Virtual Functions per port (126 VFs per feature/PCHID). One RoCE Express feature can be shared by up to 126 partitions (LPARs) (one adapter is one PCHID). The 10 GbE RoCE Express3 feature uses SR optics and supports the use of a multimode fiber optic cable that ends with an LC Duplex connector.

Note: Consider the following 10 GbE RoCE Express3 requirements:

- ▶ The 10 GbE RoCE Express3 SR feature does not support auto-negotiation to any other speed and runs in full duplex mode only.
- ▶ 25 GbE/10 GbE RoCE features should not be mixed in a z/OS SMC-R Link Group.

Point-to-point connections and switched connections with an enterprise-class 10 GbE switch are supported.

10 GbE RoCE Express3 LR (FC 0441)

10 GbE RoCE Express3 LR(FC 0441) is installed in the PCIe+ I/O drawer and is supported on IBM z16 servers only. The 10 GbE RoCE Express3 LR is a native PCIe feature. It does not use a CHPID. It is defined by using the IOCP **FUNCTION** statement or in the HCD.

The maximum supported unrepeatd distance, point-to-point, is 100 meters (328 feet). A client-supplied cable is required. Two types of cables can be used for connecting the port to the selected 10 GbE switch or to another 10 GbE RoCE Express3 LR feature:

- ▶ OM3 50-micron multimode fiber optic cable that is rated at 2000 MHz-km that ends with an LC Duplex connector, which supports 70 meters (229 feet)
- ▶ OM4 50-micron multimode fiber optic cable that is rated at 4700 MHz-km that ends with an LC Duplex connector, which supports 100 meters (328 feet)

The virtualization capabilities for IBM z16 are 63 Virtual Functions per port (126 VFs per feature/PCHID). One RoCE Express feature can be shared by up to 126 partitions (LPARs) (one adapter is one PCHID). The 10 GbE RoCE Express3 feature uses LR optics and supports the use of a single mode fiber optic cable that ends with an LC Duplex connector.

Note: Consider the following 10 GbE RoCE Express3 requirements:

- ▶ The 10 GbE RoCE Express3 LR feature does not support auto-negotiation to any other speed and runs in full duplex mode only.
- ▶ 25 GbE/10 GbE RoCE features should not be mixed in a z/OS SMC-R Link Group.

Point-to-point connections and switched connections with an enterprise-class 10 GbE switch are supported.

25 GbE RoCE Express2.1 (FC 0450)

25 GbE RoCE Express2.1 (FC 0450) is installed in the PCIe+ I/O drawer and is supported on IBM z16 servers when carried forward. The 25 GbE RoCE Express2.1 is a native PCIe feature. It does not use a CHPID and is defined by using the IOCP **FUNCTION** statement or in the HCD.

Switch configuration for 25 GbE RoCE Express2.1: The switches must meet the following requirements:

- ▶ Global Pause function is enabled
- ▶ Priority flow control (PFC) is disabled

The maximum supported unrepeatable distance, point-to-point, is 100 meters (328 feet). A client-supplied cable is required. Two types of cables can be used for connecting the port to the selected 25 GbE switch or to the 25 GbE RoCE Express2.1 feature on the attached server:

- ▶ OM3 50-micron multimode fiber optic cable that is rated at 2000 MHz-km that ends with an LC Duplex connector, which supports 70 meters (229 feet).
- ▶ OM4 50-micron multimode fiber optic cable that is rated at 4700 MHz-km that ends with an LC Duplex connector, which supports 100 meters (328 feet).

The virtualization capabilities for IBM z16 are 63 Virtual Functions per port (126 VFs per feature/PCHID). One RoCE Express feature can be shared by up to 126 partitions (LPARs) (one adapter is one PCHID). The 25 GbE RoCE Express2.1 feature uses SR optics and supports the use of a multimode fiber optic cable that ends with an LC Duplex connector.

Note: Consider the following 25 GbE RoCE Express2.1 requirements:

- ▶ The 25 GbE RoCE Express2.1 feature does not support auto-negotiation to any other speed and runs in full duplex mode only.
- ▶ 25 GbE and 10 GbE RoCE features should not be mixed in a z/OS SMC-R Link Group.

Point-to-point connections and switched connections with an enterprise-class switch are supported (ports running at matching speeds).

10 GbE RoCE Express2.1 (FC 0432)

10 GbE RoCE Express2.1 (FC 0432) is installed in the PCIe+ I/O drawer and is supported on IBM z16 servers (carry forward). The 10 GbE RoCE Express2.1 is a native PCIe feature. It does not use a CHPID. It is defined by using the IOCP **FUNCTION** statement or in the hardware configuration definition (HCD).

Switch configuration for 10 GbE RoCE Express2.1: The 10 GbE switches must meet the following requirements:

- ▶ Global Pause function is enabled
- ▶ Priority flow control (PFC) is disabled

The maximum supported unrepeatable distance, point-to-point, is 100 meters (328 feet). A client-supplied cable is required. Two types of cables can be used for connecting the port to the selected 10 GbE switch or to another 10 GbE RoCE Express2 feature:

- ▶ OM3 50-micron multimode fiber optic cable that is rated at 2000 MHz-km that ends with an LC Duplex connector, which supports 70 meters (229 feet)
- ▶ OM4 50-micron multimode fiber optic cable that is rated at 4700 MHz-km that ends with an LC Duplex connector, which supports 100 meters (328 feet)

The virtualization capabilities for IBM z16 are 63 Virtual Functions per port (126 VFs per feature/PCHID). One RoCE Express feature can be shared by up to 126 partitions (LPARs) (one adapter is one PCHID). The 10 GbE RoCE Express2.1 feature uses SR optics and supports the use of a multimode fiber optic cable that ends with an LC Duplex connector.

Note: Consider the following 10 GbE RoCE Express2.1 requirements:

- ▶ The 10 GbE RoCE Express2.1 feature does not support auto-negotiation to any other speed and runs in full duplex mode only.
- ▶ 25 GbE and 10 GbE RoCE features should not be mixed in a z/OS SMC-R Link Group.

Point-to-point connections and switched connections with an enterprise-class 10 GbE switch are supported.

25 GbE RoCE Express2 (FC 0430)

25 GbE RoCE Express2 (FC 0430) is installed in the PCIe I/O drawer and is supported on IBM z16 servers (carry forward). The 25 GbE RoCE Express2 is a native PCIe feature. It does not use a CHPID. It is defined by using the IOCP FUNCTION statement or in the hardware configuration definition (HCD).

Switch configuration for RoCE Express2: If the IBM 25 GbE RoCE Express2 features are connected to 25 GbE switches, the switches must meet the following requirements:

- ▶ Global Pause function is enabled
- ▶ Priority flow control (PFC) is disabled

The maximum supported unrepeatable distance, point-to-point, is 300 meters (984 feet). A client-supplied cable is required. The following types of cables can be used for connecting the port to the selected 10 GbE switch or to the 10 GbE RoCE Express2 feature on the attached server:

- ▶ OM3 50-micron multimode fiber optic cable that is rated at 2000 MHz-km that ends with an LC Duplex connector; supports 300 meters (984 feet)
- ▶ OM2 50-micron multimode fiber optic cable that is rated at 500 MHz-km that ends with an LC Duplex connector; supports 82 meters (269 feet)
- ▶ OM1 62.5-micron multimode fiber optic cable that is rated at 200 MHz-km that ends with an LC Duplex connector; supports 33 meters (108 feet)

The virtualization capabilities for IBM z16 are 63 Virtual Functions per port (126 VFs per feature/PCHID). One RoCE Express feature can be shared by up to 126 partitions (LPARs) (one adapter is one PCHID). The 25 GbE RoCE Express2.1 feature uses SR optics and supports the use of a multimode fiber optic cable that ends with an LC Duplex connector.

Note: Consider the following 25 GbE RoCE Express2 requirements:

- ▶ The 25 GbE RoCE Express2 feature does not support auto-negotiation to any other speed and runs in full duplex mode only.
- ▶ 25 GbE and 10 GbE RoCE features should not be mixed in a z/OS SMC-R Link Group.

Point-to-point connections and switched connections with an enterprise-class switch are supported (ports running at matching speeds).

10 GbE RoCE Express2 (FC 412)

10 GbE RoCE Express2 (FC 0412) is installed in the PCIe I/O drawer and is supported on IBM z16 servers as carry forward. The 10 GbE RoCE Express2 is a native PCIe feature. It does not use a CHPID. It is defined by using the IOCP FUNCTION statement or in the hardware configuration definition (HCD).

Switch configuration for RoCE Express2: The switches must meet the following requirements:

- ▶ Global Pause function is enabled
- ▶ Priority flow control (PFC) is disabled

The maximum supported unrepeatable distance, point-to-point, is 300 meters (984 feet). A client-supplied cable is required. The following types of cables can be used for connecting the port to the selected 10 GbE switch or to another 10 GbE RoCE Express2 feature:

- ▶ OM3 50-micron multimode fiber optic cable that is rated at 2000 MHz-km that ends with an LC Duplex connector; supports 300 meters (984 feet)
- ▶ OM2 50-micron multimode fiber optic cable that is rated at 500 MHz-km that ends with an LC Duplex connector; supports 82 meters (269 feet)
- ▶ OM1 62.5-micron multimode fiber optic cable that is rated at 200 MHz-km that ends with an LC Duplex connector; supports 33 meters (108 feet)

The virtualization capabilities for IBM z16 are 63 Virtual Functions per port (126 VFs per feature/PCHID). One RoCE Express feature can be shared by up to 126 partitions (LPARs) (one adapter is one PCHID). The 10 GbE RoCE Express2 feature uses SR optics and supports the use of a multimode fiber optic cable that ends with an LC Duplex connector.

Note: Consider the following 10 GbE RoCE Express2 requirements:

- ▶ The 10 GbE RoCE Express2 feature does not support auto-negotiation to any other speed and runs in full duplex mode only.
- ▶ 25 GbE and 10 GbE RoCE features should not be mixed in a z/OS SMC-R Link Group.

Point-to-point connections and switched connections with an enterprise-class switch are supported (ports running at matching speeds).

Shared Memory Communications functions

The Shared Memory Communication (SMC) capabilities of the IBM z16 help optimize the communications between applications for server-to-server (SMC-R) or LPAR-to-LPAR (SMC-D) connectivity.

Shared Memory Communications Version 1

The following versions of SMC are available:

► SMC-R

SMC-R provides application transparent use of the RoCE-Express feature. This feature reduces the network overhead and latency of data transfers, which effectively offers the benefits of optimized network performance across processors.

► SMC-D

SMC-D was used with the introduction of the Internal Shared Memory (ISM) virtual PCI function. ISM is a virtual PCI network adapter that enables direct access to shared virtual memory, which provides a highly optimized network interconnect for IBM Z intra-CPC communications.

SMC-D maintains the socket-API transparency aspect of SMC-R so that applications that use TCP/IP communications can benefit immediately without requiring any application software or IP topology changes. SMC-D completes the overall SMC solution, which provides synergy with SMC-R.

SMC-R and SMC-D use shared memory architectural concepts, which eliminate the TCP/IP processing in the data path, yet preserves TCP/IP Qualities of Service for connection management purposes.

Internal Shared Memory

ISM is a function that is supported by IBM z16, IBM z15, and IBM z14 systems. It provides connectivity by using shared memory access between multiple operating system images within the same CPC. ISM creates virtual adapters with shared memory that is allocated for each operating system image.

ISM is defined by the FUNCTION statement with a virtual CHPID (VCHID) in HCD/IOCDs. Identified by the PNETID parameter, each ISM VCHID defines an isolated, internal virtual network for SMC-D communication, without any hardware component required. Virtual adapters are defined by virtual function (VF) statements. Multiple LPARs can access the same virtual network for SMC-D data exchange by associating their VF with same VCHID.

Applications that use HiperSockets can realize network latency and CPU reduction benefits and performance improvement by using the SMC-D over ISM.

IBM z16 servers support up to 32 ISM VCHIDs per CPC. Each VCHID supports up to 255 VFs, with a total maximum of 8,000 VFs.

Shared Memory Communications Version 2

Shared Memory Communications v2 is available in z/OS V2R4 (with PTFs) and z/OS V2R5.

The initial version of SMC was limited to TCP/IP connections over the same layer 2 network; therefore, it was not routable across multiple IP subnets. The associated TCP/IP connection was limited to hosts within a single IP subnet that requires the hosts to have direct access to the same physical layer 2 network (that is, the same Ethernet LAN over a single VLAN ID). The scope of eligible TCP/IP connections for SMC was limited to and defined by the single IP subnet.

SMC Version 2 (SMCv2) provides support for SMC over multiple IP subnets for SMC-D and SMC-R and is referred to as SMC-Dv2 and SMC-Rv2. SMCv2 requires updates to the underlying network technology. SMC-Dv2 requires ISMv2 and SMC-Rv2 requires RoCEv2.

The SMCv2 protocol is downward compatible, which allows SMCv2 hosts to continue to communicate with SMCv1 down-level hosts.

Although SMCv2 changes the SMC connection protocol enabling multiple IP subnet support, SMCv2 does not change how user TCP socket data is transferred, which preserves the benefits of SMC to TCP workloads.

TCP/IP connections that require IPsec are not eligible for any form of SMC.

HiperSockets

The HiperSockets function of IBM z16 servers provides up to 32 high-speed virtual LAN attachments.

HiperSockets can be customized to accommodate varying traffic sizes. Because HiperSockets does not use an external network, it can free up system and network resources. This advantage can help eliminate attachment costs and improve availability and performance.

HiperSockets eliminates the need to use I/O subsystem operations and traverse an external network connection to communicate between LPARs in the same IBM z16 CPC. HiperSockets offers significant value in server consolidation when connecting many virtual servers. It can be used instead of certain coupling link configurations in a Parallel Sysplex.

HiperSockets internal networks support the following transport modes:

- ▶ Layer 2 (link layer)
- ▶ Layer 3 (network or IP layer)

Traffic can be IPv4 or IPv6, or non-IP, such as AppleTalk, DECnet, IPX, NetBIOS, or SNA.

HiperSockets devices are protocol-independent and Layer 3-independent. Each HiperSockets device (Layer 2 and Layer 3 mode) features its own Media Access Control (MAC) address. This address allows the use of applications that depend on the existence of Layer 2 addresses, such as Dynamic Host Configuration Protocol (DHCP) servers and firewalls.

Layer 2 support helps facilitate server consolidation, and can reduce complexity and simplify network configuration. It also allows LAN administrators to maintain the mainframe network environment similarly to nonmainframe environments.

Packet forwarding decisions are based on Layer 2 information instead of Layer 3. The HiperSockets device can run automatic MAC address generation to create uniqueness within and across LPARs and servers. The use of Group MAC addresses for multicast is supported, and broadcasts to all other Layer 2 devices on the same HiperSockets networks.

Datagrams are delivered only between HiperSockets devices that use the same transport mode. A Layer 2 device cannot communicate directly to a Layer 3 device in another LPAR network. A HiperSockets device can filter inbound datagrams by VLAN identification, the destination MAC address, or both.

Analogous to the Layer 3 functions, HiperSockets Layer 2 devices can be configured as primary or secondary connectors, or multicast routers. This configuration enables the creation of high-performance and high-availability link layer switches between the internal HiperSockets network and an external Ethernet network. It also can be used to connect to the HiperSockets Layer 2 networks of different servers.

HiperSockets Layer 2 is supported by Linux on IBM Z, and by z/VM for Linux guest use.

IBM z16 supports the HiperSockets Completion Queue function that is designed to allow HiperSockets to transfer data synchronously (if possible) and asynchronously, if necessary. This feature combines ultra-low latency with more tolerance for traffic peaks.

With the asynchronous support, data can be temporarily held until the receiver has buffers that are available in its inbound queue during high volume situations. The HiperSockets Completion Queue function requires the following minimum applications¹¹:

- ▶ z/OS V2.2 with PTFs
- ▶ Linux on IBM Z distributions:
 - Red Hat Enterprise Linux (RHEL) 6.2
 - SUSE Linux Enterprise Server (SLES) 11 SP2
 - Ubuntu server 16.04 LTS
- ▶ z/VSE V6.2
- ▶ z/VM V6.4¹² with maintenance

The z/VM virtual switch function transparently bridges a guest virtual machine network connection on a HiperSockets LAN segment. This bridge allows a single HiperSockets guest virtual machine network connection to communicate directly with the following systems:

- ▶ Other guest virtual machines on the virtual switch
- ▶ External network hosts through the virtual switch OSA UPLINK port

¹¹ Minimum OS support for IBM z16 can differ. For more information, see Chapter 7, “Operating system support” on page 251.

¹² z/VM V6 is not supported on IBM z16. z/VM V7.1 or newer is needed.

RoCE Express features summary

The RoCE Express feature codes, cable type, maximum unrepeated distance, and the link rate on an IBM z16 are listed in Table 4-9.

Table 4-9 RoCE Express features summary

Channel feature	Feature code	Bit rate in Gbps	Cable type	Maximum unrepeated distance ^a (MHz - km)
25 GbE RoCE Express3 SR	0452	25	MM 50 μm	▶ 70 m (2000) ▶ 100 m (4700)
25 GbE RoCE Express3 LR	0453	25	SM 9 μm	10 km
10 GbE RoCE Express3 SR	0440	10	MM 50 μm	▶ 70 m (2000) ▶ 100 m (4700)
10 GbE RoCE Express3 LR	0441	10	SM 9 μm	10 km
25 GbE RoCE Express2.1	0450	25	MM 50 μm	▶ 70 m (2000) ▶ 100 m (4700)
10 GbE RoCE Express2.1	0432	10	MM 62.5 μm MM 50 μm	▶ 33 m (200) ▶ 82 m (500) ▶ 300 m (2000)
25 GbE RoCE Express2	0430	25	MM 50 μm	▶ 70 m (2000) ▶ 100 m (4700)
10 GbE RoCE Express2	0412	10	MM 62.5 μm MM 50 μm	▶ 33 m (200) ▶ 82 m (500) ▶ 300 m (2000)

a. Minimum fiber bandwidths in MHz/km for multimode fiber optic links are included in parentheses, where applicable.

4.6.4 Parallel Sysplex connectivity

Coupling links are required in a Parallel Sysplex configuration to provide connectivity from the z/OS images to the coupling facility (CF). A properly configured Parallel Sysplex provides a highly reliable, redundant, and robust IBM Z technology solution to achieve near-continuous availability. A Parallel Sysplex is composed of one or more z/OS operating system images that are coupled through one or more CFs.

This section describes coupling link features supported in a Parallel Sysplex in which an IBM z16 can participate.

Coupling links

The type of coupling link that is used to connect a CF to an operating system LPAR is important. The link performance significantly affects response times and coupling processor usage. For configurations that extend over large distances, the time that is spent on the link can be the largest part of the response time.

IBM z16, IBM z15, and IBM z14¹³ support the following coupling link types:

- ▶ Integrated Coupling Adapter Short Reach (ICA SR1.1 and ICA SR) links connect directly to the CPC drawer and are intended for short distances between CPCs of up to 150 meters (492 feet).
- ▶ Coupling Express2 Long Reach (CE2 LR) adapters for IBM z16 and Coupling Express Long Reach (CE LR) are in the PCIe+ drawer and support unrepeated distances of up to 10 km (6.2 miles) or up to 100 km (62.1 miles) over qualified WDM services.
- ▶ Internal Coupling (IC) links are for internal links within a CPC.

Note: Parallel Sysplex supports connectivity between systems that differ by up to two generations (n-2). For example, an IBM z16 can participate in an IBM Parallel Sysplex cluster with IBM z15, and IBM z14 systems.

Only Integrated Coupling Adapter Short Reach (ICA SR) and Coupling Express2 Long Reach (CE2 LR) features are supported on IBM z16.

Figure 4-4 shows the supported Coupling Link connections for the IBM z16. Only ICA SR and CE LR links are supported on IBM z16, IBM z15, and IBM z14 ZR1 systems.

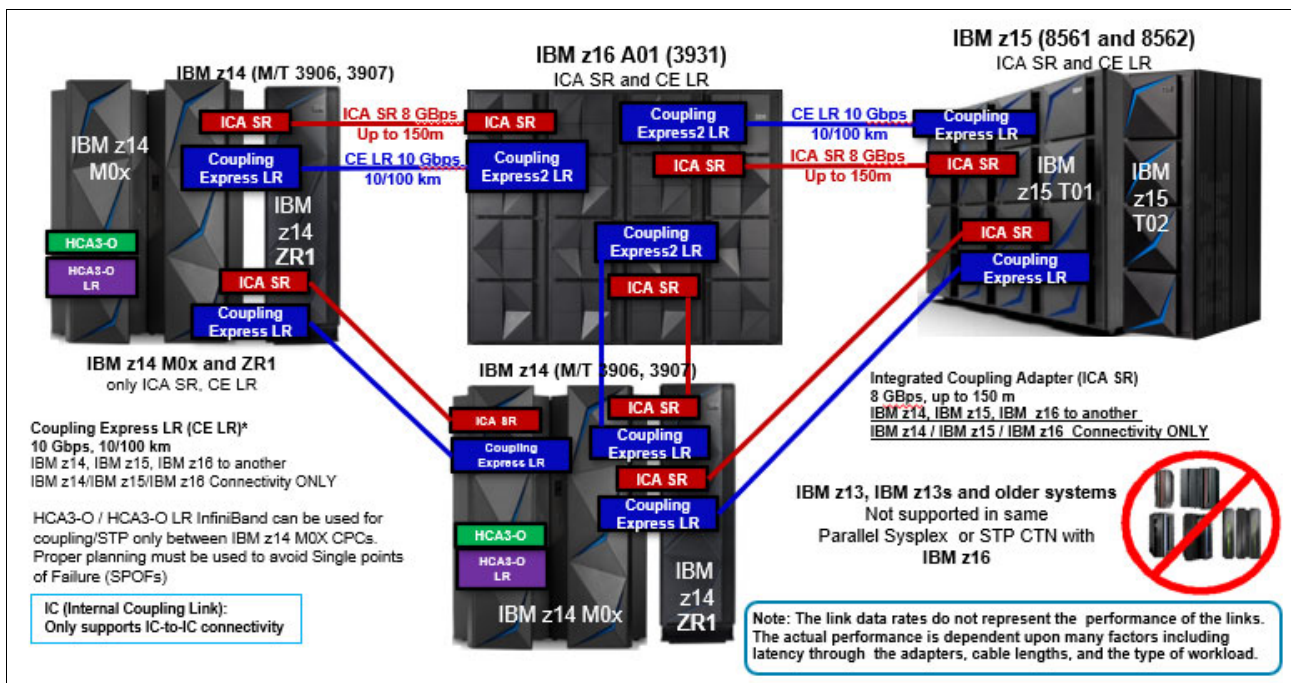


Figure 4-4 Parallel Sysplex connectivity options

¹³ IBM z14 M0x (M/T 3906) also supports InfiniBand coupling links; however, these links are not supported on IBM z16, IBM z15, and IBM z14 ZR1. Careful connectivity planning is needed if InfiniBand links are present in the supported systems.

The coupling link options are listed in Table 4-10. Also listed is the coupling link support for each IBM Z platform. Restrictions on the maximum numbers can apply, depending on the configuration. Always check with your IBM support team for more information.

Table 4-10 Coupling link options that are supported on IBM z16

Type	Description	Feature Code	Link rate	Max unrepeated distance	Maximum number of supported links			
					IBM z16	IBM z15	IBM z14 ZR1	IBM z14 M0x
CE2 LR	Coupling Express2 LR	0434	10 Gbps	10 km (6.2 miles)	64	N/A	N/A	N/A
CE LR	Coupling Express LR	0433	10 Gbps	10 km (6.2 miles)	N/A	64	32	64
ICA SR1.1	Integrated Coupling Adapter	0176	8 GBps	150 meters (492 feet)	96	96	N/A	N/A
ICA SR	Integrated Coupling Adapter	0172	8 GBps	150 meters (492 feet)	96	96	16	80
IC	Internal Coupling	N/A	Internal speeds	N/A	64	64	32	32

The maximum number of combined external coupling links (active CE LR, ICA SR links) is 160 per IBM z16 A01 system. IBM z16 systems support up to 384 coupling CHPIDs per CPC. An IBM z16 coupling link support summary is shown in Table 4-10.

Consider the following points:

- ▶ The maximum supported links depends on the IBM Z model or capacity feature code.
- ▶ IBM z16 ICA SR maximum depends on the number of CPC drawers. A total of 12 PCIe+ fan-outs are used per CPU drawer, which gives a maximum of 24 ICA SR ports. IBM z16 supports up to 96 ICA SR1.1 and ICA SR ports combined.

For more information about distance support for coupling links, see *IBM Z End-to-End Extended Distance Guide*, [SG24-8047](#).

Internal Coupling link

IC links are Licensed Internal Code-defined links that are used to connect a CF to a z/OS logical partition in the same CPC. These links are available on all IBM Z platforms. The IC link is an IBM Z coupling connectivity option that enables high-speed, efficient communication between a CF partition and one or more z/OS logical partitions that are running on the same CPC. The IC is a linkless connection (implemented in LIC) and does not require any hardware or cabling.

An IC link is a fast coupling link that uses memory-to-memory data transfers. IC links do not have PCHID numbers, but do require CHPIDs.

IC links have the following attributes:

- ▶ They provide the fastest connectivity that is significantly faster than external link alternatives.

- ▶ They result in better coupling efficiency than with external links, which effectively reduces the CPU cost that is associated with Parallel Sysplex.
- ▶ They can be used in test or production configurations, reduce the cost of moving into Parallel Sysplex technology, and enhance performance and reliability.
- ▶ They can be defined as spanned channels across multiple channel subsystems.
- ▶ They are available at no extra hardware cost (no feature code). Employing ICFs with IC links results in considerable cost savings when configuring a cluster.

IC links are enabled by defining CHPID type ICP. A maximum of 64 IC links can be defined on an IBM z16.

Integrated Coupling Adapter Short Reach

The ICA SR (FC 0172) was introduced with the IBM z13. ICA SR1.1 (FC 0176) was introduced with IBM z15.

ICA SR and ICA SR1.1 are two-port, short-distance coupling features that allow the supported IBM Z to connect to each other. ICA SR and ICA SR1.1 use coupling channel type: CS5.

The ICA SR uses PCIe Gen3 technology, with x16 lanes that are bifurcated into x8 lanes for coupling. ICA SR1.1 uses PCIe Gen4 technology, with x16 lanes that are bifurcated into x8 lanes for coupling.

The ICA SR and SR1.1 are designed to drive distances up to 150 m (492 feet) and supports a link data rate of 8 GBps. It is designed to support up to four CHPIDs per port and eight subchannels (devices) per CHPID.

For more information, see *IBM Z Planning for Fiber Optic Links (FICON/FCP, Coupling Links, and Open System Adapters)*, GA23-1409. This publication is available in [the Library section of Resource Link](#) (log-in required).

Coupling Express2 Long Reach

The Coupling Express2 LR (FC 0434) occupies one slot in a PCIe I/O drawer or PCIe+ I/O drawer¹⁴. It allows the supported IBM Z to connect to each other over extended distance. The Coupling Express2 LR (FC 0434) is a two-port card that uses coupling channel type CL5.

The Coupling Express2 LR uses 10 GbE RoCE technology and is designed to drive distances up to 10 km (6.21 miles) unrepeated and support a link data rate of 10 Gigabits per second (Gbps). For distance requirements greater than 10 km (6.21 miles), clients must use a Wavelength Division Multiplexer (WDM). The WDM vendor must be qualified by IBM Z.

Coupling Express2 LR is designed to support up to four CHPIDs per port, 32 buffers (that is, 32 subchannels) per CHPID. The Coupling Express2 LR feature is in the PCIe+ I/O drawer on IBM z16.

For more information, see *IBM Z Planning for Fiber Optic Links (FICON/FCP, Coupling Links, Open Systems Adapters, and zHyperLink Express)*, GA23-1409. This publication is available in [the Library section of Resource Link](#) (log-in required).

¹⁴ PCIe+ I/O drawer (FC 4023 on IBM z16, FC 4021 on IBM z15, and FC 4001 on IBM z14 ZR1) is installed in a 19-inch rack. PCIe+ I/O Drawers contains and can host up to 16 PCIe I/O features (adapters). They are not supported on IBM z14 M0x or older servers. Also, the PCIe I/O drawer cannot be carried forward during and MES upgrade to IBM z14 ZR1 or newer. IBM z16, IBM z15, and IBM z14 ZR1 support PCIe+ I/O drawers only.

Extended distance support

For more information about extended distance support, see *System z End-to-End Extended Distance Guide*, [SG24-8047](#).

Migration considerations

Upgrading from previous generations of IBM Z systems in a Parallel Sysplex to IBM z16 servers in that same Parallel Sysplex requires proper planning for coupling connectivity. Planning is important because of the change in the supported type of coupling link adapters and the number of available fan-out slots of the IBM z16 CPC drawers.

The ICA SR fan-out features provide short-distance connectivity to another IBM z16, IBM z15, or IBM z14 server.

The CE LR adapter provides long-distance connectivity to another IBM z16, IBM z15, or IBM z14 server.

The IBM z16 fan-out slots in the CPC drawer provide coupling link connectivity through the ICA SR fan-out cards. In addition to coupling links for Parallel Sysplex, the fan-out cards provide connectivity for the PCIe+ I/O drawer (PCIe+ Gen3 fan-out).

Up to 12 PCIe fan-out cards can be installed in an IBM z16 CPC drawer.

To migrate from an older generation machine to an IBM z16 without disruption in a Parallel Sysplex environment requires that the older machines are no more than n-2 generation (namely, at least IBM z14) and that they carry enough coupling links to connect to the existing systems while also connecting to the new machine. This requirement is necessary to allow individual components (z/OS LPARs and CFs) to be shut down and moved to the target machine and continue to be connected to the remaining systems.

It is beyond the scope of this book to describe all possible migration scenarios. Always consult with subject matter experts to help you to develop your migration strategy.

Coupling links and Server Time Protocol

All external coupling links can be used to pass time synchronization signals by using Server Time Protocol (STP). STP is a message-based protocol in which timing messages are passed over data links between servers. The same coupling links can be used to exchange time and CF messages in a Parallel Sysplex.

The use of the coupling links to exchange STP messages has the following advantages:

- ▶ By using the same links to exchange STP messages and CF messages in a Parallel Sysplex, STP can scale with distance. Servers that are exchanging messages over short distances (ICA SR links), can meet more stringent synchronization requirements than servers that exchange messages over long distance (CE2 LR links), with distances up to 100 kilometers (62 miles)¹⁵. This advantage is an enhancement over the IBM Sysplex Timer implementation, which does not scale with distance.
- ▶ Coupling links provide the connectivity that is necessary in a Parallel Sysplex. Therefore, a potential benefit can be realized of minimizing the number of cross-site links that is required in a multi-site Parallel Sysplex.

¹⁵ 10 km (6.2 miles) without DWDM extenders; 100 km (62 miles) with certified DWDM equipment.

Between any two servers that are intended to exchange STP messages, configure each server so that at least two coupling links exist for communication between the servers. This configuration prevents the loss of one link from causing the loss of STP communication between the servers. If a server does not have a CF LPAR, timing-only links can be used to provide STP connectivity.

IBM z16 Precision Time Protocol support

Precision Time Protocol (PTP) is introduced as an alternative to NTP. Consider the following points:

- ▶ PTP provides more accurate timestamps to connected devices
- ▶ Initially used for Power Distribution Systems, Telecommunications, and Laboratories
- ▶ Requires Customer Network Infrastructure to be PTP capable
- ▶ IBM z16 provides PTP connectivity direct to the CPC

4.7 Cryptographic functions

Cryptographic functions are provided by the CP Assist for Cryptographic Function (CPACF) and the PCI Express cryptographic adapters. IBM z16 servers support the Crypto Express8S, and as carry forward, Crypto Express7S and crypto Express6S features.

4.7.1 CPACF functions (FC 3863)

FC 3863 is required to enable Cryptographic functions (subject to export regulations).

4.7.2 Crypto Express8S feature (FC 0908 and FC 0909)

The Crypto Express8S represents the newest generation of the Peripheral Component Interconnect Express (PCIe) cryptographic coprocessors, which are an optional feature that is available on the IBM z16.

These coprocessors are Hardware Security Modules (HSMs) that provide high-security cryptographic processing as required by banking and other industries. This feature provides a secure programming and hardware environment wherein crypto processes are performed.

Each cryptographic coprocessor includes general-purpose processors, nonvolatile storage, and specialized cryptographic electronics, which are all contained within a tamper-sensing and tamper-responsive enclosure that eliminates all keys and sensitive data on any attempt to tamper with the device. The security features of the HSM are designed to meet the requirements of FIPS 140-2, Level 4, which is the highest-defined security level.

The Crypto Express8S (2 HSM) includes two IBM PCIe Cryptographic Co-processors (PCIeCC); the Crypto Express8S (1 HSM) includes one PCIeCC per feature. For availability reasons, a minimum of two features is required. Up to 30 Crypto Express8S (2 HSM) features are supported. The maximum number of the 1 HSM features is 16. The Crypto Express8S feature occupies one I/O slot in a PCIe+ I/O drawer.

Each adapter can be configured as a Secure IBM CCA coprocessor, a Secure IBM Enterprise PKCS #11 (EP11) coprocessor, or as an accelerator.

Crypto Express8S provides domain support for up to 85 logical partitions.

The accelerator function is designed for maximum-speed Secure Sockets Layer and Transport Layer Security (SSL/TLS) acceleration, rather than for specialized financial applications for secure, long-term storage of keys or secrets. The Crypto Express8S can also be configured as one of the following configurations:

- ▶ The Secure IBM CCA coprocessor includes secure key functions with emphasis on the specialized functions that are required for banking and payment card systems. It is optionally programmable to add custom functions and algorithms by using User Defined Extensions (UDX).

Payment Card Industry (PCI) PIN[®] Transaction Security (PTS) Hardware Security Module (HSM) (PCI-HSM), is available for Crypto Express6S and newer in CCA mode. PCI-HSM mode simplifies compliance with PCI requirements for hardware security modules.

- ▶ The Secure IBM Enterprise PKCS #11 (EP11) coprocessor implements an industry-standardized set of services that adheres to the PKCS #11 specification v2.20 and more recent amendments. It was designed for extended FIPS and Common Criteria evaluations to meet industry requirements

This cryptographic coprocessor mode introduced the PKCS #11 secure key function.

TKE feature: The Trusted Key Entry (TKE) Workstation feature is required for supporting the administration of the Crypto Express6S when configured as an Enterprise PKCS #11 coprocessor or managing the CCA mode PCI-HSM.

When the Crypto Express8S PCI Express adapter is configured as a secure IBM CCA co-processor, it still provides accelerator functions. However, up to 3x better performance for those functions can be achieved if the Crypto Express8S PCI Express adapter is configured as an accelerator.

CCA enhancements include the ability to use triple-length (192-bit) Triple-DES (TDES) keys for operations, such as data encryption, IBM PIN processing, and key wrapping to strengthen security. CCA also extended the support for the cryptographic requirements of the German Banking Industry Committee Deutsche Kreditwirtschaft (DK).

Several features that support the use of the AES algorithm in banking applications also were added to CCA. These features include the addition of AES-related key management features and the AES ISO Format 4 (ISO-4) PIN blocks as defined in the ISO 9564-1 standard. PIN block translation is supported and use of AES PIN blocks in other CCA callable services.

IBM continues to add enhancements as AES finance industry standards are released.

4.7.3 Crypto Express7S feature (FC 0898 and FC 0899) as carry forward only

The Crypto Express7S are supported on IBM z16. These coprocessors are HSMs that provide high-security cryptographic processing as required by banking and other industries. This feature provides a secure programming and hardware environment wherein crypto processes are performed.

Each cryptographic coprocessor includes general-purpose processors, nonvolatile storage, and specialized cryptographic electronics, which are all contained within a tamper-sensing and tamper-responsive enclosure that eliminates all keys and sensitive data on any attempt to tamper with the device. The security features of the HSM are designed to meet the requirements of FIPS 140-2, Level 4, which is the highest security level defined.

The Crypto Express7S (2 port), FC 0898 includes two IBM PCIe Cryptographic Coprocessors (PCIeCC) per feature. The IBM PCIeCC is an HSM.

The Crypto Express7S (1 port), FC 0899 includes one IBM PCIe Cryptographic Coprocessors (PCIeCC) per feature. For availability reasons, a minimum of two features is required for the one port feature.

Up to 30 Crypto Express7S (2 port) features are supported on IBM z15 T01. The maximum number of the one-port features is 16. The total number of HSMs supported on IBM z16 A01 is 60 in a combination of Crypto Express8S (2 HSM), Crypto Express8S (1 HSM), Crypto Express7S (2 port), Crypto Express7S (1 port), or Crypto Express6S.

The Crypto Express7S feature occupies one I/O slot in a PCIe+ I/O drawer.

Each adapter can be configured as a Secure IBM CCA coprocessor, Secure IBM Enterprise PKCS #11 (EP11) coprocessor, or accelerator.

Crypto Express7S provides domain support for up to 85 logical partitions.

The accelerator function is designed for maximum-speed Secure Sockets Layer and Transport Layer Security (SSL/TLS) acceleration, rather than for specialized financial applications for secure, long-term storage of keys or secrets.

The Crypto Express7S can also be configured as one of the following configurations:

- ▶ The Secure IBM CCA coprocessor includes secure key functions with an emphasis on the specialized functions that are required for banking and payment card systems. It is optionally programmable to add custom functions and algorithms by using UDX.

A new mode (called PCI-HSM) is available exclusively for Crypto Express6S in CCA mode. PCI-HSM mode simplifies compliance with PCI requirements for hardware security modules.

- ▶ The Secure IBM Enterprise PKCS #11 (EP11) coprocessor implements an industry-standardized set of services that adheres to the PKCS #11 specification v2.20 and more recent amendments. It was designed for extended FIPS and Common Criteria evaluations to meet industry requirements.

This cryptographic coprocessor mode introduced the PKCS #11 secure key function.

TKE feature: The TKE Workstation feature is required for supporting the administration of the Crypto Express8S when configured as an Enterprise PKCS #11 coprocessor or managing the CCA mode PCI-HSM.

When the Crypto Express7S PCI Express adapter is configured as a secure IBM CCA co-processor, it still provides accelerator functions. However, up to 3x better performance for those functions can be achieved if the Crypto Express7S PCI Express adapter is configured as an accelerator.

CCA enhancements include the ability to use triple-length (192-bit) Triple-DES (TDES) keys for operations, such as data encryption, PIN processing, and key wrapping to strengthen security. CCA also extended the support for the cryptographic requirements of the German Banking Industry Committee Deutsche Kreditwirtschaft (DK).

Several features that support the use of the AES algorithm in banking applications also were added to CCA. These features include AES-related key management features and the AES ISO Format 4 (ISO-4) PIN blocks as defined in the ISO 9564-1 standard. PIN block translation is supported and the use of AES PIN blocks in other CCA callable services.

IBM continues to add enhancements as AES finance industry standards are released.

4.7.4 Crypto Express6S feature (FC 0893) as carry forward only

Crypto Express6S was introduced from IBM z14 servers. On the initial configuration, a minimum of two features are installed (for availability). The number of features then increases one at a time up to a maximum of 16 features.

Each Crypto Express6S feature holds one PCI Express cryptographic adapter. Each adapter can be configured by the installation as a Secure IBM Common Cryptographic Architecture (CCA) coprocessor, as a Secure IBM Enterprise Public Key Cryptography Standards (PKCS) #11 (EP11) coprocessor, or as an accelerator.

The tamper-resistant hardware security module, which is contained on the Crypto Express6S feature, conforms to the Federal Information Processing Standard (FIPS) 140-2 Level 4 Certification. It supports UDX services to implement cryptographic functions and algorithms (when defined as an IBM CCA coprocessor).

The following CCA compliance levels are available:

- ▶ Noncompliant (default)
- ▶ PCI-HSM 2016
- ▶ PCI-HSM 2016 (migration, key tokens while migrating to compliant)

The following EP11 compliance levels are available (Crypto Express6S and Crypto Express5S):

- ▶ FIPS 2009 (default)
- ▶ FIPS 2011
- ▶ BSI 2009
- ▶ BSI 2011

Each Crypto Express6S feature occupies one I/O slot in the PCIe I/O drawer, and features no CHPID assigned. However, it includes one PCHID.

4.8 Integrated Firmware Processor

The Integrated Firmware Processor (IFP) was introduced with the zEC12 and zBC12 servers. The IFP is used for managing PCIe native features. The following features are installed in the PCIe+ I/O drawer:

- ▶ 25 GbE RoCE Express3 SR
- ▶ 25 GbE RoCE Express3 LR
- ▶ 10 GbE RoCE Express3 SR
- ▶ 10 GbE RoCE Express3 LR
- ▶ 25 GbE RoCE Express2.1
- ▶ 10 GbE RoCE Express2.1
- ▶ 25 GbE RoCE Express2

- ▶ 10 GbE RoCE Express2
- ▶ IBM zHyperlink Express1.1
- ▶ IBM zHyperlink Express
- ▶ Coupling Express2 Long Reach (CE LR)

All native PCIe features should be ordered in pairs for redundancy. The features are assigned to one of the four resource groups (RGs) that are running on the IFP according to their physical location in the PCIe+ I/O drawer, which provides management functions and virtualization functions.

If two features of the same type are installed, one always is managed by resource group 1 (RG 1) or resource group 3 (RG3); the other feature is managed by resource group 2 (RG 2) or resource group 4 (RG 4). This configuration provides redundancy if one of the features or resource groups needs maintenance or fails.

The IFP and RGs support the following infrastructure management functions:

- ▶ Firmware update of adapters and resource groups
- ▶ Error recovery and failure data collection
- ▶ Diagnostic and maintenance tasks



Central processor complex channel subsystem

This chapter describes the concepts of the IBM z16 A01 channel subsystem, including multiple channel subsystems and multiple subchannel sets. It also describes the technology, terminology, and implementation aspects of the channel subsystem.

This chapter includes the following topics:

- ▶ 5.1, “Channel subsystem” on page 202
- ▶ 5.2, “I/O configuration management” on page 210
- ▶ 5.3, “Channel subsystem summary” on page 211

5.1 Channel subsystem

Channel subsystem (CSS) is a collective name of facilities that IBM Z servers use to control I/O operations.

The channel subsystem directs the flow of information between I/O devices and main storage. It allows data processing to proceed concurrently with I/O processing, which relieves data processors (central processor (CP) and Integrated Facility for Linux [IFL]) of the task of communicating directly with I/O devices.

The channel subsystem includes subchannels, I/O devices that are attached through control units, and channel paths between the subsystem and control units. For more information about the channel subsystem, see 5.1.1, “Multiple logical channel subsystems”.

The design of IBM Z servers offers considerable processing power, memory size, and I/O connectivity. In support of the larger I/O capability, the CSS structure is scaled up by introducing the multiple logical channel subsystem (LCSS) since IBM z990, and multiple subchannel sets (MSS) since IBM z9.

An overview of the channel subsystem for IBM z16 servers is shown in Figure 5-1. IBM z16 A01 systems are designed to support up to six logical channel subsystems, each with four subchannel sets and up to 256 channels.

IBM z16 Model A01					
HSA = 256 GB					
LCSS 0	LCSS 1	LCSS 2	LCSS 3	LCSS 4	LCSS 5
Up to 15 Logical Partitions	Up to 15 Logical Partitions	Up to 15 Logical Partitions	Up to 15 Logical Partitions	Up to 15 Logical Partitions	Up to 10 Logical Partitions
Subchannel Sets: SS 0 – 63.75 k SS 1 – (64 k -1) SS 2 – (64 k -1) SS 3 – (64 k -1)	Subchannel Sets: SS 0 – 63.75 k SS 1 – (64 k -1) SS 2 – (64 k -1) SS 3 – (64 k -1)	Subchannel Sets: SS 0 – 63.75 k SS 1 – (64 k -1) SS 2 – (64 k -1) SS 3 – (64 k -1)	Subchannel Sets: SS 0 – 63.75 k SS 1 – (64 k -1) SS 2 – (64 k -1) SS 3 – (64 k -1)	Subchannel Sets: SS 0 – 63.75 k SS 1 – (64 k -1) SS 2 – (64 k -1) SS 3 – (64 k -1)	Subchannel Sets: SS 0 – 63.75 k SS 1 – (64 k -1) SS 2 – (64 k -1) SS 3 – (64 k -1)
Up to 256 Channels	Up to 256 Channels	Up to 256 Channels	Up to 256 Channels	Up to 256 Channels	Up to 256 Channels

Figure 5-1 Multiple channel subsystem and multiple subchannel sets

All channel subsystems are defined within a single configuration, which is called *I/O configuration data set* (IOCDS). The IOCDS is loaded into the hardware system area (HSA) during a central processor complex (CPC) power-on reset (POR) to start all of the channel subsystems.

On IBM z16 A01 systems, the HSA is pre-allocated in memory with a fixed size of 256 GB, which is in addition to the customer purchased memory. This fixed size memory for HSA eliminates the requirement for more planning of the initial I/O configuration and planning for future I/O expansions.

CPC drawer repair: The HSA can be moved from one CPC drawer to a different drawer in an enhanced availability configuration as part of a concurrent CPC drawer repair (CDR) action.

The following objects are always reserved in the IBM z16 A01 HSA during POR, whether they are defined in the IOCDS for use:

- ▶ Six CSSs
- ▶ A total of 15 LPARs in each CSS0 to CSS4
- ▶ A total of 10 LPARs in CSS5
- ▶ Subchannel set 0 with 63.75 K devices in each CSS
- ▶ Subchannel set 1 with 64 K minus one device in each CSS
- ▶ Subchannel set 2 with 64 K minus one device in each CSS
- ▶ Subchannel set 3 with 64 K minus one device in each CSS

5.1.1 Multiple logical channel subsystems

In the z/Architecture, a single channel subsystem can have up to 256 channel paths that are defined, which limited the total numbers of I/O connectivity on older IBM Z servers to 256.

The introduction of multiple LCSSs enabled an IBM Z server to have more than one channel subsystems logically, while each logical channel subsystem maintains the same manner of I/O processing. Also, a logical partition (LPAR) is now attached to a specific logical channel subsystem, which makes the extension of multiple logical channel subsystems not apparent to the operating systems and applications. The multiple image facility (MIF) in the structure enables resource sharing across LPARs within a single LCSS or across the LCSSs.

The multiple LCSS structure extended the IBM Z servers' total number of I/O connectivity to support a balanced configuration for the growth of processor and I/O capabilities.

A one-digit number ID starting from 0 (CSSID) is assigned to an LCSS, and a one-digit hexadecimal ID (MIF ID) starting from 0 is assigned to an LPAR within the LCSS.

Note: The phrase *channel subsystem* has same meaning as *logical channel subsystem* in this section, unless otherwise stated.

Subchannels

A *subchannel* provides the logical appearance of a device to the program and contains the information that is required for sustaining a single I/O operation. Each device is accessible by using one subchannel in a channel subsystem to which it is assigned according to the active IOCDs of the IBM Z server.

A *subchannel set* (SS) is a collection of subchannels within a channel subsystem. The maximum number of subchannels of a subchannel set determines how many devices are accessible to a channel subsystem.

In z/Architecture, the first subchannel set of an LCSS can have 63.75 K subchannels (with 0.25 K reserved), with a subchannel set ID (SSID) of 0. By enabling the multiple subchannel sets, extra subchannel sets are available to increase the device addressability of a channel subsystem.

For more information about multiple subchannel sets, see 5.1.2, “Multiple subchannel sets” on page 204.

Channel paths

A *channel path* provides a connection between the channel subsystem and control units that allows the channel subsystem to communicate with I/O devices. Depending on the type of connections, a channel path might be a physical connection to a control unit with I/O devices, such as FICON, or an internal logical control unit, such as HiperSockets.

Each channel path in a channel subsystem features a unique 2-digit hexadecimal identifier that is known as a *channel-path identifier* (CHPID), which ranges 00 - FF. Therefore, a total of 256 CHPIDs are supported by a CSS, and a maximum of 1536 CHPIDs are available on an IBM z16 with six logical channel subsystems.

By assigning a CHPID to a physical port of an I/O feature adapter, such as FICON Express32S, or a fan-out adapter (ICA SR) port, the channel subsystem connects to the I/O devices through these physical ports.

A port on an I/O feature card features a unique physical channel identifier (PCHID) according to the physical location of this I/O feature adapter, and the sequence of this port on the adapter.

In addition, a port on a fan-out adapter has a unique adapter identifier (AID), according to the physical location of this fan-out adapter, and the sequence of this port on the adapter.

A CHPID is assigned to a physical port by defining the corresponding PCHID or AID in the I/O configuration definitions.

Control units

A *control unit* provides the logical capabilities that are necessary to operate and control an I/O device. It adapts the characteristics of each device so that it can respond to the standard form of control that is provided by the CSS.

A control unit can be housed separately or can be physically and logically integrated with the I/O device, channel subsystem, or within the IBM Z server.

I/O devices

An *I/O device* provides external storage, a means of communication between data-processing systems, or a means of communication between a system and its environment. In the simplest case, an I/O device is attached to one control unit and is accessible through one or more channel paths that are connected to the control unit.

5.1.2 Multiple subchannel sets

A *subchannel set* is a collection of subchannels within a channel subsystem. The maximum number of subchannels of a subchannel set determines how many I/O devices that a channel subsystem can access. This number also determines the number of addressable devices to the program (for example, an operating system) that is running in the LPAR.

Each subchannel has a unique four-digit hexadecimal number 0x0000 - 0xFFFF. Therefore, a single subchannel set can address and access up to 64 K I/O devices.

The IBM z16 A01 systems support four subchannel sets for each logical channel subsystem. The IBM z16 A01 system can access a maximum of 255.74 K devices for a logical channel subsystem and a logical partition and the programs that are running on it.

Note: Do not confuse the multiple subchannel sets function with multiple channel subsystems.

Subchannel number

The *subchannel number* is a four-digit hexadecimal number 0x0000 - 0xFFFF, which is assigned to a subchannel within a subchannel set of a channel subsystem. Subchannels in each subchannel set are always assigned subchannel numbers within a single range of contiguous numbers.

The lowest-numbered subchannel is subchannel 0; the highest-numbered subchannel includes a subchannel number equal to one less than the maximum numbers of subchannels that are supported by the subchannel set. Therefore, a subchannel number is always unique within a subchannel set of a channel subsystem and depends on the sequence of assigning.

With the subchannel numbers, a program that is running on an LPAR (for example, an operating system) can specify all I/O functions relative to a specific I/O device by designating a subchannel that is assigned to the I/O devices.

Normally, subchannel numbers are used only in communication between the programs and the channel subsystem.

Subchannel set identifier

While introducing the MSS, the channel subsystem is extended to assign a value 0 - 3 for each subchannel set, which is the SSID. A subchannel can be identified by its SSID and subchannel number.

Device number

A device number is an arbitrary number 0x0000 - 0xFFFF, which is defined by a system programmer in an I/O configuration for naming an I/O device. The device number must be unique within a subchannel set of a channel subsystem. It is assigned to the corresponding subchannel by channel subsystem when an I/O configuration is activated. Therefore, a subchannel in a subchannel set of a channel subsystem includes a device number together with a subchannel number for designating an I/O operation.

The device number provides a means to identify a device that is independent of any limitations that are imposed by the system model, configuration, or channel-path protocols.

A device number also can be used to designate an I/O function to a specific I/O device. Because it is an arbitrary number, it can easily be fit into any configuration management and operating management scenarios. For example, a system administrator can set all of the z/OS systems in an environment to device number 1000 for their system RES volumes.

With multiple subchannel sets, a subchannel is assigned to a specific I/O device by the channel subsystem with an automatically assigned subchannel number and a device number that is defined by user. An I/O device can always be identified by an SSID with a subchannel number or a device number. For example, a device with device number AB00 of subchannel set 1 can be designated as 1AB00.

Normally, the subchannel number is used by the programs to communicate with the channel subsystem and I/O device, whereas the device number is used by a system programmer, operator, and administrator.

Device in subchannel set 0 and extra subchannel sets

An LCSS always includes the first subchannel set (SSID 0), which can have up to 63.75 K subchannels with 256 subchannels that are reserved by the channel subsystem. Users can always define their I/O devices in this subchannel set for general use.

For the extra subchannel sets enabled by the MSS facility, each has 65535 subchannels (64 K minus one) for specific types of devices. These extra subchannel sets are referred as *alternative subchannel sets* in z/OS.

Also, a device that is defined in an alternative subchannel set is considered a special device, which normally features a special device type in the I/O configuration.

Currently, an IBM z16 A01 system that is running z/OS defines the following types of devices in another subchannel set, with proper APAR or PTF installed:

- ▶ Alias devices of the parallel access volumes (PAV).
- ▶ Secondary devices of GDPS Metro Mirror Copy Service (formerly Peer-to-Peer Remote Copy [PPRC]).
- ▶ IBM FlashCopy® SOURCE and TARGET devices with program temporary fix (PTF) OA46900.
- ▶ Db2 data backup volumes with PTF OA24142.

The use of another subchannel set for these special devices helps reduce the number of devices in the subchannel set 0, which increases the growth capability for accessing more devices.

Initial program load from an alternative subchannel set

IBM z16 A01 systems support initial program load (IPL) from alternative subchannel sets in addition to subchannel set 0. Devices that are used early during IPL processing now can be accessed by using subchannel set 1, subchannel set 2, or subchannel set 3 on an IBM z16.

This configuration allows the users of Metro Mirror (formerly PPRC) secondary devices that are defined by using the same device number and a new device type in an alternative subchannel set to be used for IPL, an I/O definition file (IODF), and stand-alone memory dump volumes, when needed.

The display ios,config command

The z/OS `display ios,config(a11)` command that is shown in Figure 5-2 includes information about the MSSs.

```
D IOS,CONFIG(ALL)
IOS506I 11.14.46 I/O CONFIG DATA 606
ACTIVE IODF DATA SET = SYS9.IODF81
CONFIGURATION ID = ITS0          EDT ID = 01
TOKEN:  PROCESSOR DATE      TIME      DESCRIPTION
SOURCE: PAVO      22-03-04 09:12:20 SYS9      IODF81
ACTIVE CSS: 3      SUBCHANNEL SETS CONFIGURED: 0, 1, 2, 3
CHANNEL MEASUREMENT BLOCK FACILITY IS ACTIVE
SUBCHANNEL SET FOR PPRC PRIMARY: INITIAL = 0  ACTIVE = 0
HYPERSWAP FAILOVER HAS OCCURRED: NO
LOCAL SYSTEM NAME (LSYSTEM): PAVO
HARDWARE SYSTEM AREA AVAILABLE FOR CONFIGURATION CHANGES
PHYSICAL CONTROL UNITS          8061
CSS 0 - LOGICAL CONTROL UNITS   4027
  SS 0  SUBCHANNELS             59510
  SS 1  SUBCHANNELS             65535
  SS 2  SUBCHANNELS             65535
  SS 3  SUBCHANNELS             65535
CSS 1 - LOGICAL CONTROL UNITS   4005
  SS 0  SUBCHANNELS             59218
  SS 1  SUBCHANNELS             65535
  SS 2  SUBCHANNELS             65535
  SS 3  SUBCHANNELS             65535
CSS 2 - LOGICAL CONTROL UNITS   4025
  SS 0  SUBCHANNELS             59410
  SS 1  SUBCHANNELS             65535
  SS 2  SUBCHANNELS             65535
  SS 3  SUBCHANNELS             65535
CSS 3 - LOGICAL CONTROL UNITS   4026
  SS 0  SUBCHANNELS             60906
  SS 1  SUBCHANNELS             65535
  SS 2  SUBCHANNELS             65535
  SS 3  SUBCHANNELS             65535
CSS 4 - LOGICAL CONTROL UNITS   4043
  SS 0  SUBCHANNELS             61266
  SS 1  SUBCHANNELS             65535
  SS 2  SUBCHANNELS             65535
  SS 3  SUBCHANNELS             65535
CSS 5 - LOGICAL CONTROL UNITS   4088
  SS 0  SUBCHANNELS             65280
  SS 1  SUBCHANNELS             65535
  SS 2  SUBCHANNELS             65535
  SS 3  SUBCHANNELS             65535
ELIGIBLE DEVICE TABLE LATCH COUNTS
      0 OUTSTANDING BINDS ON PRIMARY EDT
```

Figure 5-2 Output for `display ios,config(all)` command with MSS

5.1.3 Channel path spanning

With the implementation of multiple LCSSs, a channel path can be available to LPARs as dedicated, shared, and spanned.

Although a shared channel path can be shared by LPARs within a same LCSS, a spanned channel path can be shared by LPARs within and across LCSSs.

By assigning the same CHPID from different LCSSs to the same channel path (for example, a PCHID), the channel path can be accessed by any LPARs from these LCSSs at the same time. The CHPID is spanned across those LCSSs. The use of spanned channels paths decreases the number of channels that are needed in an installation of IBM Z servers.

A sample of channel paths that are defined as dedicated, shared, and spanned is shown in Figure 5-3.

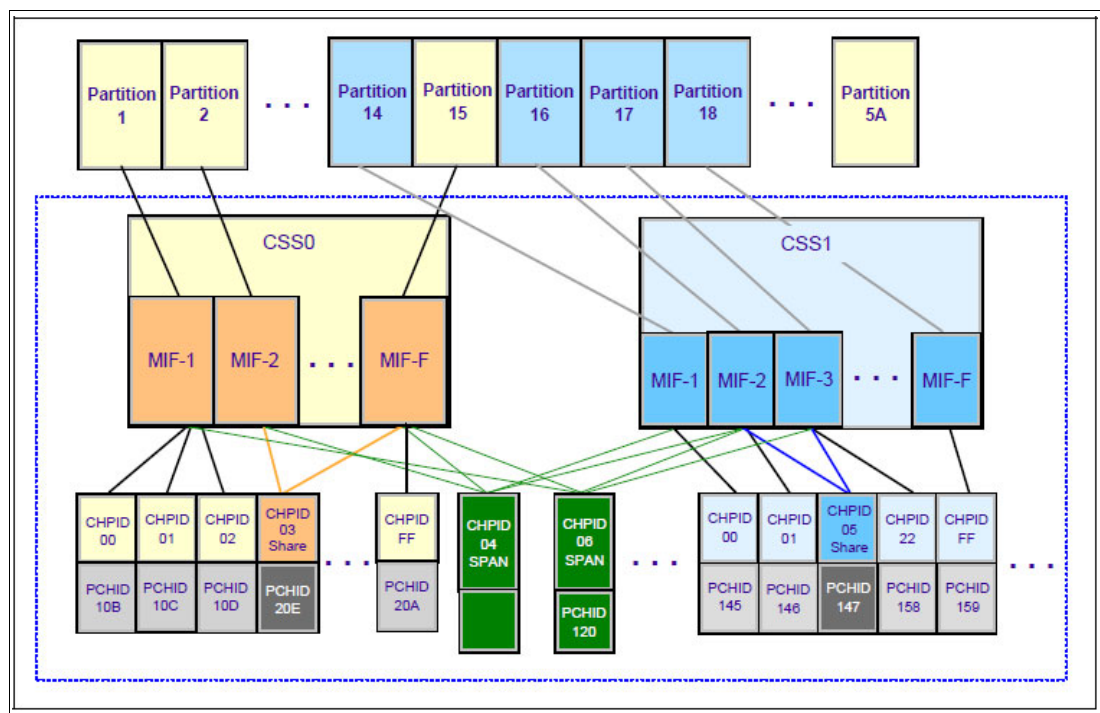


Figure 5-3 IBM Z CSS: Channel subsystems with channel spanning

The following definitions of a channel path are shown in Figure 5-3:

- ▶ CHPID FF, assigned to PCHID 20A, is dedicated access for partition 15 of LCSS0. The same applies to CHPID 00,01,02 of LCSS0, and CHPID 00,01,FF of LCSS1.
- ▶ CHPID 03, assigned to PCHID 20E, is shared access for partition 2, and 15 of LCSS0. The same applies to CHPID 05 of LCSS1.
- ▶ CHPID 06, assigned to PCHID 120 is spanned access for partition 1, 15 of LCSS0, and partition 16, 17 of LCSS1. The same applies to CHPID 04.

Channel spanning is supported for internal links (HiperSockets and IC links) and for specific types of external links. External links that are supported on IBM z16 A01 systems include FICON Express32S, FICON Express16SA, FICON Express16S+, OSA-Express7S 1.2, OSA-Express7S, OSA-Express6S, and Coupling Links.

The definition of LPAR name, MIF image ID, and LPAR ID are used to identify an LPAR by the channel subsystem to identify I/O functions from different LPARs of multiple LCSSs, which support the implementation of these dedicated, shared, and spanned paths.

An example of definition of these LPAR-related identifications is shown in Figure 5-4.

CSS0			CSS1			CSS2		CSS3		CSS4		CSS5		Specified in HCD / IOCP
Logical Partition Name			Logical Partition Name			LPAR Name		LPAR Name		LPAR Name		LPAR Name		Specified in HCD / IOCP
TST1	PROD1	PROD2	TST2	PROD3	PROD4	TST3	TST4	PROD5	PROD6	TST5	PROD7	PROD8	TST6	
Logical Partition ID			Logical Partition ID			LPAR ID		LPAR ID		LPAR ID		LPAR ID		Specified in Image Profile
02	04	0A	14	16	1D	22	26	35	3A	44	47	56	5A	
MIF ID			MIF ID			MIF ID		MIF ID		MIF ID		MIF ID		Specified in HCD / IOCP
2	4	A	4	6	D	2	6	5	A	4	7	6	A	

Figure 5-4 CSS, LPAR, and identifier example

LPAR name

The LPAR name is defined as partition name parameter in the RESOURCE statement of an I/O configuration. The LPAR name must be unique across the server.

MIF image ID

The MIF image ID is defined as a parameter for each LPAR in the RESOURCE statement of an I/O configuration. It ranges 1 - F, and must be unique within an LCSS. However, duplicates are allowed in different LCSSs.

If a MIF image ID is not defined, an arbitrary ID is assigned when the I/O configuration activated. The IBM z16 server supports a maximum of six LCSSs, with a total of 85 LPARs that can be defined.

Each LCSS of an IBM z16 A01 system can support the following numbers of LPARs:

- ▶ LCSS0 to LCSS4 support 15 LPARs each, and the MIF image ID is 1 - F.
- ▶ LCSS5 supports 10 LPARs, and the MIF image IDs are 1 - A.

LPAR ID

The LPAR ID is defined by a user in an image activation profile for each LPAR. It is a 2-digit hexadecimal number 00 - 7F. The LPAR ID must be unique across the server.

Although it is arbitrarily defined by the user, an LPAR ID often is the CSS ID concatenated to its MIF image ID, which makes the value more meaningful for the system administrator. For example, an LPAR with LPAR ID 1A defined in that manner means that the LPAR is defined in LCSS1, with the MIF image ID A.

5.2 I/O configuration management

The following tools are available to help maintain and optimize the I/O configuration:

▶ IBM Configurator for e-business (eConfig)

The eConfig tool is used by your IBM representative. It is used to create configurations or upgrades of a configuration, and maintains tracking to the installed features of those configurations. eConfig produces reports that help you understand the changes that are being made for a new system, or a system upgrade, and what the target configuration looks like.

▶ Hardware configuration definition (HCD)

HCD supplies an interactive dialog to generate the IODF, and later the IOCDs. Generally, use HCD or Hardware Configuration Manager (HCM) to generate the I/O configuration rather than writing I/O configuration program (IOCP) statements. The validation checking that HCD runs against a IODF source file helps minimize the risk of errors before an I/O configuration is activated.

HCD support for multiple channel subsystems is available with z/VM and z/OS. HCD provides the capability to make dynamic hardware and software I/O configuration changes.

Note: Specific functions might require specific levels of an operating system, PTFs, or both.

Consult the suitable fix categories:

- IBM z16 A01:IBM.Device.Server.IBM z16-3931
- IBM z15 T01: IBM.Device.Server.IBM z15-8561
- IBM z15 T02: IBM.Device.Server.IBM z15-8562
- IBM z14 M0x: IBM.Device.Server.IBM z14-3906
- IBM z14 ZR1: IBM.Device.Server.IBM z14ZR1-3907

▶ HCM

HCM is a priced optional feature that supplies a graphical interface of HCD. It is installed on a PC and allows you to manage the physical and logical aspects of a mainframe's hardware configuration.

▶ CHPID Mapping Tool (CMT)

The CMT helps to map CHPIDs onto PCHIDs that are based on an IODF source file and the eConfig configuration file of a mainframe. It provides a CHPID to PCHID mapping with high availability for the targeted I/O configuration. It also features built-in mechanisms to generate a mapping according to customized I/O performance groups. More enhancements are implemented in CMT to support IBM z16 servers.

The CMT is available for download from the [IBM Resource Link](#) (log-in required).

The configuration file for a new machine or upgrade also us available from the [IBM Resource Link](#) (log-in required). Contact your IBM technical sales representative for the name of the file to download.

5.3 Channel subsystem summary

IBM z16 A01 systems support the channel subsystem features of multiple LCSS, MSS, and the channel spanning that is described in this chapter. The channel subsystem capabilities of IBM z16 A01 systems are listed in Table 5-1.

Table 5-1 IBM z16 A01 CSS overview

Maximum number of CSSs	6
Maximum number of LPARs per CSS	CSS0 - CSS4: 15 CSS5: 10
Maximum number of LPARs per system	85
Maximum number of subchannel sets per CSS	4
Maximum number of subchannels per CSS	255.74 K SS0: 65280 SS1 - SS3: 65535
Maximum number of CHPIDs per CSS	256



Cryptographic features

This chapter describes the hardware cryptographic functions that are available on IBM z16. The CP Assist for Cryptographic Function (CPACF), together with the IBM Peripheral Component Interconnect Express (PCIe) cryptographic coprocessors (PCIeCC), offer a balanced use of processing resources and unmatched scalability for fulfilling pervasive encryption demands.

This chapter also introduces the principles of cryptography and describes the implementation of cryptography in the hardware and software architecture of IBM Z. It also describes the features that IBM z16 offers.

Finally, the cryptographic features and required software are summarized.

This chapter includes the following topics:

- ▶ 6.1, “Cryptography enhancements on IBM z16” on page 214
- ▶ 6.2, “Cryptography overview” on page 215
- ▶ 6.3, “Cryptography on IBM z16” on page 219
- ▶ 6.4, “CP Assist for Cryptographic Functions” on page 223
- ▶ 6.5, “Crypto Express8S” on page 228
- ▶ 6.6, “Trusted Key Entry workstation” on page 243
- ▶ 6.7, “Cryptographic functions comparison” on page 246
- ▶ 6.8, “Cryptographic operating system support for IBM z16” on page 248

6.1 Cryptography enhancements on IBM z16

IBM recognizes that with any new technology, new threats exist, and as such, suitable counter measures must be taken. Quantum technology can be used for incredible good, but in the hands of an adversary, it has the potential to weaken or break core cryptographic primitives that were used to secure systems and communications. Quantum-safe cryptography aims to provide protection against attacks that can be started by quantum computers.

The IBM z16 uses quantum-safe technologies to help protect your business-critical infrastructure and data from potential attacks.

The IBM z16 delivers a transparent and consumable approach that enables extensive (pervasive) encryption of data in flight and at rest, with the goal of substantially simplifying data security and reducing the costs that are associated with protecting data while achieving compliance mandates.

Naming: The IBM z16, Machine Type 3931 (M/T 3931), Model A01 is further identified as *IBM z16*, unless otherwise specified.

IBM z16 introduced the new PCI Crypto Express8S feature (that can be managed by a new Trusted Key Entry (TKE) workstation) together with a further improved CPACF Coprocessor. In addition, the IBM Common Cryptographic Architecture (CCA) and the IBM Enterprise PKCS #11 (EP11) Licensed Internal Code (LIC) were enhanced.

The new features support new standards and meet the following compliance requirements:

- ▶ Payment Card Industry (PCI) Hardware Security Module (HSM) certification to strength the cryptographic standards for attack resistance in the payment card systems area.
PCI HSM certification is available for Crypto Express8S, Crypto Express7S, and Crypto Express6S.
- ▶ National Institute of Standards and Technology (NIST) through the Federal Information Processing Standard (FIPS) standard to implement guidance requirements.
- ▶ Common Criteria EP11 EAL4.
- ▶ German Banking Industry Commission (GBIC).
- ▶ Visa Format Preserving Encryption (VFPE) for credit card numbers.
- ▶ Enhanced public key Elliptic Curve Cryptography (ECC) for users such as Chrome, Firefox, and Apple's iMessage.
- ▶ Accredited Standards Committee X9 Inc Technical Report-34 (ASC X9 TR-34)

These enhancements are described in this chapter.

IBM z16 includes standard cryptographic hardware and optional cryptographic features for flexibility and growth capability. IBM has a long history of providing hardware cryptographic solutions. This history stretches from the development of the Data Encryption Standard (DES) in the 1970s to the Crypto Express tamper-sensing and tamper-responding programmable features.

Crypto Express meets the US Government's highest security rating of FIPS 140-3 Level 4 certification¹. It also meets several other security ratings, such as the Common Criteria for Information Technology Security Evaluation, the PCI HSM criteria, and the criteria for German Banking Industry Commission (formerly known as Deutsche Kreditwirtschaft evaluation).

¹ FIPS 140-3 certification - Security Requirements for Cryptographic Modules.

The cryptographic functions include the full range of cryptographic operations that are necessary for local and global business and financial institution applications. User Defined Extensions (UDX) allow you to add custom cryptographic functions to the functions that IBM z16 systems offer.

6.2 Cryptography overview

Throughout history, a need existed for secret communication between people that cannot be understood by outside parties.

Also, it is necessary to ensure that a message cannot be corrupted (message integrity), while ensuring that the sender and the receiver really are the persons who they claim to be. Over time, several methods were used to achieve these objectives, with more or less success. Many procedures and algorithms for encrypting and decrypting data were developed that are increasingly complicated and time-consuming.

6.2.1 Modern cryptography

With the development of computing technology, the encryption and decryption algorithms can be performed by computers, which enables the use of complicated mathematical algorithms. Most of these algorithms are based on the prime factorization of large numbers.

Cryptography is used to meet the following requirements:

- ▶ Data protection

The protection of data usually is the main concept that is associated with cryptography. Only authorized persons should be able to read the message or get information about it. Data is encrypted by using a known algorithm and secret keys, such that the intended party can de-scramble the data, but an interloper cannot. This concept is also referred to as *confidentiality*.

- ▶ Authentication (identity validation)

This process decides whether the communication partners are who they claim to be, which can be done by using certificates and signatures. It must be possible to clearly identify the owner of the data or the sender and the receiver of the message.

- ▶ Message (data) Integrity

The verification of data ensures that what was received is identical to what was sent. It must be proven that the data is complete and was not altered during the moment it was transmitted (by the sender) and the moment it was received (by the receiver).

- ▶ Nonrepudiation

It must be impossible for the owner of the data or the sender of the message to deny authorship. Nonrepudiation ensures that both sides of a communication know that the other side agreed to what was exchanged, and not someone else. This specification implies a legal liability and contractual obligation, which is the same as a signature on a contract.

These goals should all be possible without unacceptable overhead to the communication. The goal is to keep the system secure, manageable, and productive.

The basic data protection method is achieved by encrypting and decrypting the data, while hash algorithms, message authentication codes (MACs), digital signatures, and certificates are used for authentication, data integrity, and nonrepudiation.

When encrypting a message, the sender transforms the clear text into a secret text. Doing so requires the following main elements:

- ▶ The *algorithm* is the mathematical or logical formula that is applied to the key and the clear text to deliver a ciphered result, or to take a ciphered text and deliver the original clear text.
- ▶ The *key* ensures that the result of the encrypting data transformation by the algorithm is only the same when the same key is used. That decryption of a ciphered message results only in the original clear message when the correct key is used. Therefore, the receiver of a ciphered message must know which algorithm and key must be used to decrypt the message.

6.2.2 Kerckhoffs' principle

In modern cryptography, the algorithm is published and known to everyone, whereas the keys are kept secret. This configuration corresponds to Kerckhoffs' principle, which is named after Auguste Kerckhoffs, a Dutch cryptographer, who formulated it in 1883:

“A system should not depend on secrecy, and it should be able to fall into the enemy's hands without disadvantage.”

In other words, the security of a cryptographic system should depend on the security of the key, so the key must be kept secret. Therefore, the secure management of keys is the primal task of modern cryptographic systems.

Adhering to Kerckhoffs' Principle is done for the following reasons:

- ▶ It is much more difficult to keep an algorithm secret than a key.
- ▶ It is harder to exchange a compromised algorithm than to exchange a compromised key.
- ▶ Secret algorithms can be reconstructed by reverse engineering software or hardware implementations.
- ▶ Errors in public algorithms can generally be found more easily, when many experts examine it.
- ▶ In history, most secret encryption methods proved to be weak and inadequate.
- ▶ When a secret encryption method is used, it is possible that a back door was built in.
- ▶ If an algorithm is public, many experts can form an opinion about it. Also, the method can be more thoroughly investigated for potential weaknesses and vulnerabilities.

6.2.3 Keys

The keys that are used for the cryptographic algorithms often are sequences of numbers and characters, but can also be any other sequence of bits. The length of a key influences the security (strength) of the cryptographic method. The longer the used key, the more difficult it is to compromise a cryptographic algorithm.

For example, the DES (symmetric key) algorithm uses keys with a length of 56 bits, Triple-DES (TDES) uses keys with a length of 112 bits, and Advanced Encryption Standard (AES) uses keys of 128, 192, or 256 bits. The asymmetric key RSA algorithm (named after its inventors Rivest, Shamir, and Adleman) uses keys with a length of 1024, 2048, or 4096 bits.

In modern cryptography, keys must be kept secret. Depending on the effort that is made to protect the key, keys are classified into the following levels:

- ▶ A *clear key* is a key that is transferred from the application in clear text to the cryptographic function. The key value is stored in the clear (at least briefly) somewhere in unprotected memory areas. Therefore, the key can be made available to someone under specific circumstances who is accessing this memory area.

This risk must be considered when clear keys are used. However, many applications exist where this risk can be accepted. For example, the transaction security for the (widely used) encryption methods Secure Sockets Layer (SSL) and Transport Layer Security (TLS) is based on clear keys.

- ▶ The value of a *protected key* is stored only in clear in memory areas that cannot be read by applications or users. The key value does not exist outside of the physical hardware, although the hardware might not be tamper-resistant. The principle of protected keys is unique to IBM Z. For more information, see 6.4.2, “CPACF protected key” on page 226.
- ▶ For a *secure key*, the key value does not exist in clear format outside of a special hardware device (HSM), which must be secured and tamper-resistant. A secure key is protected from disclosure and misuse, and can be used for the trusted execution of cryptographic algorithms on highly sensitive data. If used and stored outside of the HSM, a secure key must be encrypted with a *master key*, which is created within the HSM and never leaves the HSM.

Because a secure key must be handled in a special hardware device, the use of secure keys usually is far slower than the use of clear keys, as shown in Figure 6-1.

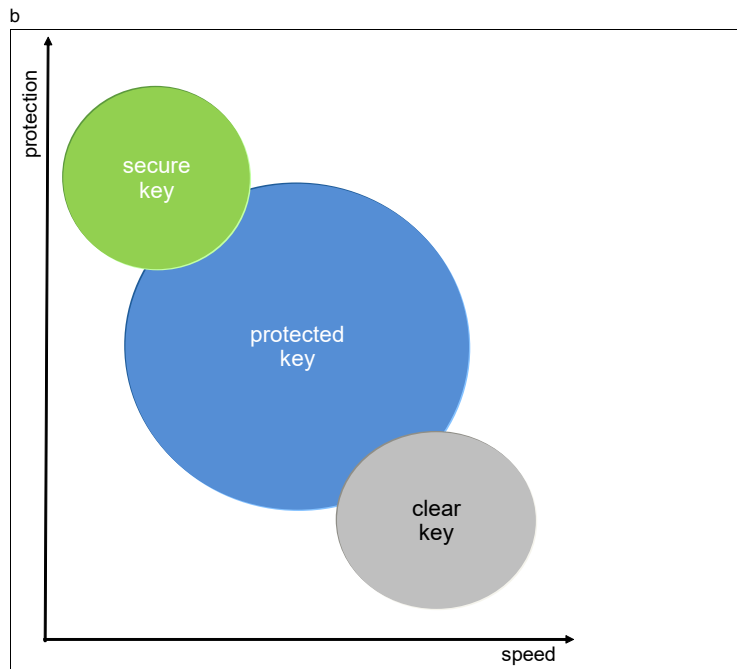


Figure 6-1 Three levels of protection with three levels of speed

6.2.4 Algorithms

The following algorithms of modern cryptography are differentiated based on whether they use the same key for the encryption of the message as for the decryption:

- ▶ *Symmetric algorithms* use the same key to encrypt and decrypt data. The function that is used to decrypt the data is the opposite of the function that is used to encrypt the data. Because the same key is used on both sides of an operation, it must be negotiated between both parties and kept secret. Therefore, symmetric algorithms are also known as *secret key algorithms*.

The main advantage of symmetric algorithms is that they are fast and therefore can be used for large amounts of data, even if they are not run on specialized hardware. The disadvantage is that the key must be known by both sender and receiver of the messages, which implies that the key must be exchanged between them. This key exchange is a weak point that can be attacked.

Prominent examples for symmetric algorithms are DES, TDES, and AES.

- ▶ *Asymmetric algorithms* use two distinct but related keys: the *public key* and the *private key*. As the names imply, the private key must be kept secret, whereas the public key is shown to everyone. However, with asymmetric cryptography, it is not important who sees or knows the public key. Whatever is done with one key can be undone by the other key only.

For example, data that is encrypted by the public key can be decrypted by the associated private key only, and vice versa. Unlike symmetric algorithms, which use distinct functions for encryption and decryption, only one function is used in asymmetric algorithms.

Depending on the values that are passed to this function, it encrypts or decrypts the data. Asymmetric algorithms are also known as *public key algorithms*.

Asymmetric algorithms use complex calculations and are relatively slow (about 100 - 1000 times slower than symmetric algorithms). Therefore, such algorithms are not used for the encryption of bulk data.

Because the private key is never exchanged between the parties in communication, they are less vulnerable than symmetric algorithms. Asymmetric algorithms mainly are used for authentication, digital signatures, and for the encryption and exchange of secret keys, which in turn are used to encrypt bulk data with a symmetric algorithm.

Examples for asymmetric algorithms are RSA and the elliptic curve algorithms.

- ▶ *One-way algorithms* are not cryptographic functions. They do not use keys, and they can scramble data only, not de-scramble it. These algorithms are used extensively within cryptographic procedures for digital signing and tend to be developed and governed by using the same principles as cryptographic algorithms. One-way algorithms are also known as *hash algorithms*.

The most prominent one-way algorithms are the Secure Hash Algorithms (SHA).

6.3 Cryptography on IBM z16

In principle, cryptographic algorithms can run on processor hardware. However, these workloads are compute-intensive, and the handling of secure keys also requires special hardware protection. Therefore, IBM Z offer several cryptographic hardware features, which are specialized to meet the requirements for cryptographic workload.

The cryptographic hardware that is supported on IBM z16 is shown in Figure 6-2. These features are described in this chapter.

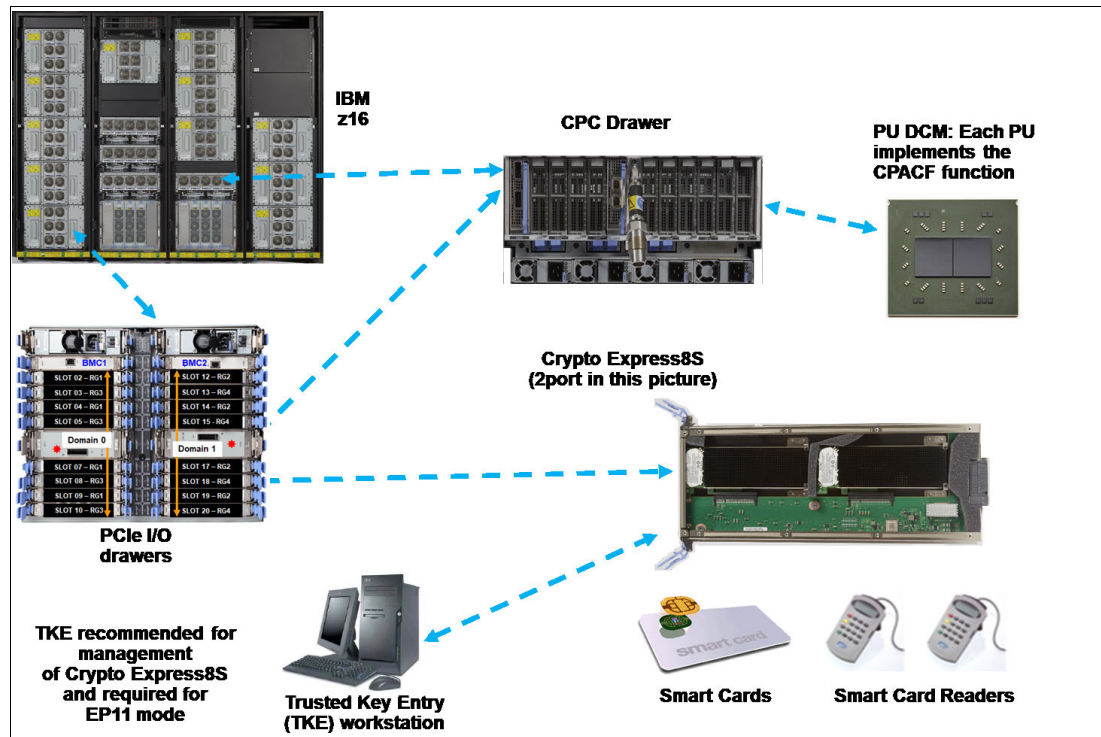


Figure 6-2 Cryptographic hardware that is supported in IBM z16

Implemented in every processor unit (PU) or core in a central processor complex (CPC) is a cryptographic coprocessor that can be used² for cryptographic algorithms that uses clear keys or protected keys. For more information, see 6.4, “CP Assist for Cryptographic Functions” on page 223.

The Crypto Express8S adapter is an HSM that is placed in the PCIe+ I/O drawer of IBM z16. It also supports cryptographic algorithms by using secret keys. For more information, see 6.5, “Crypto Express8S” on page 228.

Finally, a TKE workstation is required for entering keys in a secure way into the Crypto Express8S HSM, which often also is equipped with smart card readers. For more information, see 6.6, “Trusted Key Entry workstation” on page 243.

² CPACF enablement feature must be ordered (FC 3863).

The feature codes and purpose of the cryptographic hardware features that are available for IBM z16 are listed in Table 6-1.

Table 6-1 Cryptographic features for IBM z16 A01

Feature Code	Description
3863	<p>CP Assist for Cryptographic Function (CPACF) enablement</p> <p>This feature is a prerequisite to use CPACF (except for SHA-1, SHA-224, SHA-256, SHA-384, and SHA-512) and the PCIe Crypto Express features.</p>
0908	<p>Crypto Express8S feature (dual HSM)^a</p> <p>These features are optional. The 2-port feature contains two IBM 4770 PCIe Cryptographic Coprocessors (HSMs), which can be independently defined as Coprocessor or Accelerator. New feature. Not supported on previous generations IBM Z systems.</p> <p>A TKE, smart card Reader and latest available level smart cards are required to operate the Crypto adapter card in EP11 mode.</p>
0909	<p>Crypto Express8S feature (single HSM)^a</p> <p>These features are optional. The 2-port feature contains two IBM 4770 PCIe Cryptographic Coprocessors (HSMs), which can be independently defined as Coprocessor or Accelerator. New feature. Not supported on previous generations IBM Z systems.</p> <p>A TKE, Smart Card Reader and latest available level smart cards are required to operate the Crypto adapter card in EP11 mode.</p>
0898	<p>Crypto Express7S feature (2-port)^a</p> <p>Carry forward from IBM z15. This feature contains two IBM 4769 PCIe Cryptographic Coprocessors (HSMs), which can be independently defined as Coprocessor or Accelerator. Supported on IBM z15 and IBM z16.</p>
0899	<p>Crypto Express7S feature (1-port)^a</p> <p>Carry forward from IBM z15. This feature contains one IBM 4769 PCIe Cryptographic Coprocessor (HSM), which can be defined as Coprocessor or Accelerator. Supported on IBM z15 and IBM z16.</p>
0893	<p>Crypto Express6S adapter^a</p> <p>This feature is available as a carry forward MES from IBM z14. This feature is optional. Each feature one IBM 4768 PCIe Cryptographic Coprocessor (HSM). This feature is supported in IBM z16, IBM z15, and IBM z14.</p>
0058	<p>TKE tower workstation</p> <p>A TKE provides basic key management (key identification, exchange, separation, update, and backup) and security administration. It is optional for running a Crypto Express feature in CCA mode in non PCI-compliant environment. It is required for running in EP11 mode and CCA mode with full PCI compliance. The TKE workstation has one 1000BASE-T Ethernet port, and supports connectivity to an Ethernet local area network (LAN). Up to 10 features combined (0057/0058) can be ordered per IBM z16.</p>

Feature Code	Description
0057	<p>TKE rack-mounted workstation</p> <p>The rack-mounted version of the TKE, which needs a customer-provided standard 19-inch rack. It features a 1u TKE unit and an (optional) 1u console tray (screen, keyboard, and pointing device). When smart card readers are used, another customer-provided tray is needed. Up to 10 features combined (0057/0058) can be ordered per IBM z16.</p>
0882	<p>TKE 10.0 Licensed Internal Code (LIC)</p> <p>Included with the TKE tower workstation FC 0058 and the TKE rack-mounted workstation FC 0057 for IBM z16. Earlier versions of TKE features (feature codes: 0087, 0088, 0085, and 0086) also can be upgraded to TKE 10.0 LIC, adding FC 0851 (IBM 4770 PCIeCC) if the TKE is assigned to an IBM z16 and manages Crypto Express8S.</p>
0851	<p>4770 TKE Crypto Adapter (IBM PCIeCC)</p> <p>The stand-alone crypto adapter is required for TKE upgrade from FC 0085 and FC 0086 TKE tower, or FC 0087 and FC 0088 TKE Rack Mount when carry forward these features to IBM z16.</p>
0144	<p>TKE Tower carry forward to IBM z16</p> <p>TKE Tower FC 0088 can be carried forward to IBM z16. It requires IBM 4770 PCIeCC (FC 0851) for compatibility with TKE LIC 10.0 (FC 0882) and for managing Crypto Express8S (FC 0144 = FC 0088 + FC 0851 + FC 0882).</p>
0145	<p>TKE Rack Mount carry forward to IBM z16</p> <p>TKE Rack Mount FC 0087 can be carried forward to IBM z16. It requires IBM 4770 PCIeCC (FC 0851) for compatibility with TKE LIC 10.0 (FC 0882) and for managing Crypto Express8S (FC 0145 = FC 0087 + FC 0851 + FC 0882).</p>
0233	<p>TKE Rack Mount carry forward to IBM z16</p> <p>TKE Rack Mount FC 0085 can be carried forward to IBM z16. It requires IBM 4770 PCIeCC (FC 0851) for compatibility with TKE LIC 10.0 (FC 0882) and for managing Crypto Express8S (FC 0233 = FC 0085 + FC 0851 + FC 0882).</p>
0234	<p>TKE Tower Carry forward to IBM z16</p> <p>TKE Tower FC 0086 can be carried forward to IBM z16. It requires IBM 4770 PCIeCC (FC 0851) for compatibility with TKE LIC 10.0 (FC 0882) and for managing Crypto Express8S (FC 0234 = FC 0086 + FC 0851 + FC 0882).</p>
0891	<p>TKE Smart Card Reader</p> <p>Access to information in the smart card is protected by a PIN. One feature code includes two smart card readers, two cables to connect to the TKE workstation, and 20 smart cards. Existing smart cards can be used on TKE 9.2 with these readers.</p>
0885	<p>TKE Smart Card Reader carry forward</p> <p>Access to information in the smart card is protected by a PIN. Carry forward with existing cards (non-FIPS). Existing smart cards can be used on TKE 9.2 with these readers.</p>

Feature Code	Description
0900	New TKE smart cards (10 pack) This card allows the TKE to support zones with EC 521 key strength (EC 521 strength for Logon Keys, Authority Signature Keys, and EP11 signature keys).
0892	More TKE smart cards Carry forward only to IBM z16. Ten smart cards are included.

- a. The maximum number of combined features of all types cannot exceed 60 HSMs on an IBM z16 A01 (any combination of single and dual HSM Crypto Express features). Therefore, the maximum number for Feature Code 0908 is 30; for all other (single HSM) types, it is 16 for an IBM z16 system.

A TKE includes support for AES encryption algorithm with 256-bit master keys and key management functions to load or generate master keys to the cryptographic coprocessor.

If the TKE workstation is chosen to operate the Crypto Express8S adapter in an IBM z16, TKE workstation with the TKE 10.0 LIC is required. For more information, see 6.6, “Trusted Key Entry workstation” on page 243.

Important: Products that include any of the cryptographic feature codes contain cryptographic functions that are subject to special export licensing requirements by the US Department of Commerce. It is your responsibility to understand and adhere to these regulations when you are moving, selling, or transferring these products.

To access and use the cryptographic hardware devices that are provided by IBM z16, the application must use an application programming interface (API) that is provided by the operating system. In z/OS, the Integrated Cryptographic Service Facility (ICSF) provides the APIs and is managing the access to the cryptographic devices, as shown in Figure 6-3.

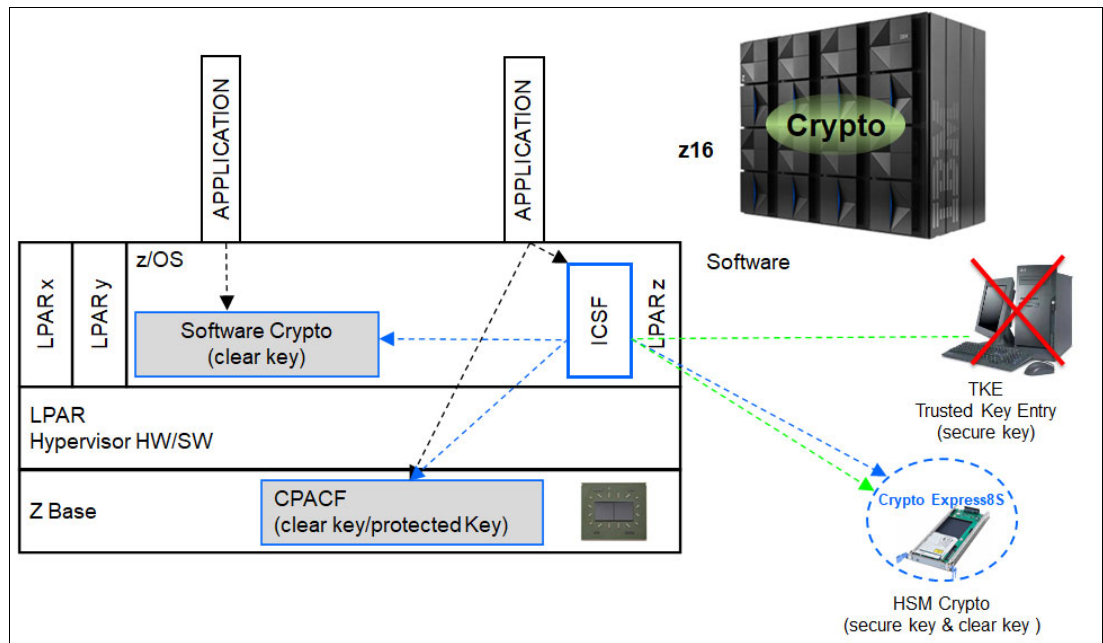


Figure 6-3 IBM z16 Cryptographic Support in z/OS

ICSF is a software component of z/OS. ICSF works with the hardware cryptographic features and the Security Server (IBM Resource Access Control Facility [IBM RACF] element) to provide secure, high-speed cryptographic services in the z/OS environment. ICSF provides the APIs by which applications request the cryptographic services, and from the CPACF and the Crypto Express features.

ICSF transparently routes application requests for cryptographic services to one of the integrated cryptographic engines (CPACF or a Crypto Express feature), depending on performance or requested cryptographic function. ICSF is also the means by which the secure Crypto Express features are loaded with master key values, which allows the hardware features to be used by applications.

The cryptographic hardware that is installed in IBM z16 determines the cryptographic features and services that are available to the applications.

The users of the cryptographic services call the ICSF API. Some functions are performed by the ICSF software without starting the cryptographic hardware features. Other functions result in ICSF going into routines that contain proprietary IBM Z crypto instructions. These instructions are run by a CPU engine and result in a work request that is generated for a cryptographic hardware feature.

6.4 CP Assist for Cryptographic Functions

Attached to every PU (core) of an IBM z16 system are two independent engines: one for compression and one for cryptographic functions, as shown in Figure 6-4.

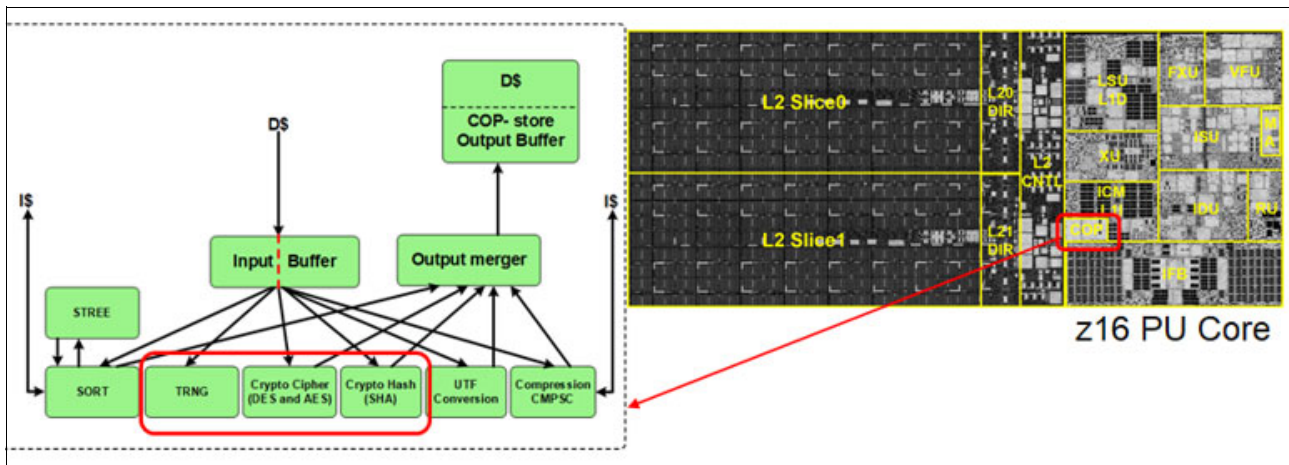


Figure 6-4 The cryptographic coprocessor CPACF

This cryptographic coprocessor, which is known as the *CPACF*, is not qualified as an HSM; therefore, it is not suitable for handling algorithms that use secret keys. However, the coprocessor can be used for cryptographic algorithms that use clear keys or protected keys. The CPACF works synchronously with the PU, which means that the owning processor is busy when its coprocessor is busy. This setup provides a fast device for cryptographic services.

CPACF supports pervasive encryption. Simple policy controls allow businesses to enable encryption to protect data in mission-critical databases without the need to stop the database or re-create database objects. Pervasive encryption includes z/OS Dataset Encryption, z/OS Coupling Facility Encryption, z/VM encrypted hypervisor paging, and z/TPF transparent database encryption, which use performance enhancements in the hardware.

The CPACF offers a set of symmetric cryptographic functions that enhances the encryption and decryption performance of clear key operations. These functions are for SSL, virtual private network (VPN), and data-storing applications that do not require FIPS 140-2 Level 4 security.

CPACF is designed to facilitate the privacy of cryptographic key material when used for data encryption through key wrapping implementation. It ensures that key material is not visible to applications or operating systems during encryption operations. For more information, see 6.4.2, “CPACF protected key” on page 226.

The CPACF feature provides hardware acceleration for the following cryptographic services:

- ▶ Symmetric ciphers:
 - DES
 - Triple-DES
 - AES-128
 - AES-192
 - AES-256 (all for clear and protected keys)
- ▶ Elliptic curves cryptography (ECC):
 - ECDSA, ECDH, support for the NIST P256, NIST P386, NIST P521
 - EdDSA for Ed25519, Ed448 Curves
 - ECDH for X25519, X448 Curves
 - Key generation for NIST, Ed, and X curves
- ▶ Hashes/MACs:
 - SHA-1
 - SHA-224 (SHA-2 or SHA-3 standard)
 - SHA-256 (SHA-2 or SHA-3 standard)
 - SHA-384 (SHA-2 or SHA-3 standard)
 - SHA-512 (SHA-2 or SHA-3 standard)
 - SHAKE-128
 - SHAKE-256
 - GHASH
- ▶ Random number generator:
 - PRNG (3DES based)
 - DRNG (NIST SP-800-90A SHA-512 based)
 - TRNG (true random number generator)

It provides high-performance hardware encryption, decryption, hashing, and random number generation support. The following instructions support the cryptographic assist function:

- ▶ KMAC: Compute Message Authentic Code
- ▶ KM: Cipher Message
- ▶ KMC: Cipher Message with Chaining
- ▶ KMF: Cipher Message with CFB
- ▶ KMCTR: Cipher Message with Counter
- ▶ KMO: Cipher Message with OFB

- ▶ KIMD: Compute Intermediate Message Digest
- ▶ KLMD: Compute Last Message Digest
- ▶ PCKMO: Provide Cryptographic Key Management Operation

These functions are provided as problem-state z/Architecture instructions that are directly available to application programs. These instructions are known as *Message-Security Assist* (MSA). When enabled, the CPACF runs at processor speed for every CP, IFL, and zIIP.

For more information about MSA instructions, see *z/Architecture Principles of Operation*, SA22-7832.

For activating these functions, the CPACF must be enabled by using Feature Code (FC) 3863, which is available at no charge. Support for hashing algorithms SHA-1, SHA-256, SHA-384, and SHA-512 always is enabled.

6.4.1 Cryptographic synchronous functions

Because the CPACF works synchronously with the PU, it provides cryptographic synchronous functions. For IBM and client-written programs, CPACF functions can be started by using the MSA instructions. z/OS ICSF callable services on z/OS, in-kernel crypto APIs, and a libica cryptographic functions library that is running on Linux on IBM Z also can start CPACF synchronous functions.

The following tools might benefit from the throughput improvements for IBM z16 CPACF:

- ▶ Db2/IMS encryption tool
- ▶ Db2 built-in encryption
- ▶ z/OS Communication Server: IPsec/IKE/AT-TLS
- ▶ z/OS System SSL
- ▶ z/OS Network Authentication Service (Kerberos)
- ▶ DFDSS Volume encryption
- ▶ z/OS Java SDK
- ▶ z/OS Encryption Facility
- ▶ Linux on IBM Z: Kernel, openssl, openCryptoki, and GSKIT

The IBM z16 hardware includes the implementation of algorithms as hardware synchronous operations. This configuration holds the PU processing of the instruction flow until the operation completes.

IBM z16 offers the following synchronous functions:

- ▶ Data encryption and decryption algorithms for data privacy and confidentiality:
 - Data Encryption Standard (DES):
 - Single-length key DES
 - Double-length key DES
 - Triple-length key DES (also known as Triple-DES)
 - Advanced Encryption Standard (AES) for 128-bit, 192-bit, and 256-bit keys

- ▶ Hashing algorithms for data integrity, such as SHA-1 and SHA-2.

New for IBM z14 ZR1 is SHA-3 support for SHA-224, SHA-256, SHA-384, and SHA-512 and the two extendable output functions as described by the standard SHAKE-128 and SHAKE-256.

- ▶ Message authentication code (MAC):
 - Single-length key MAC
 - Double-length key MAC

- ▶ Pseudo-Random Number Generator (PRNG), Deterministic Random Number Generation (DRNG), and True Random Number Generation (TRNG) for cryptographic key generation.
- ▶ Galois Counter Mode (GCM) encryption, which is enabled by a single hardware instruction.

For the SHA hashing algorithms and the random number generation algorithms, only clear keys are used. For the symmetric encryption and decryption DES and AES algorithms and clear keys, protected keys also can be used. On IBM z16, protected keys require a Crypto Express adapter that is running in CCA mode.

For more information, see 6.5.2, “Crypto Express8S as a CCA coprocessor” on page 232.

The hashing algorithms SHA-1, SHA-2, and SHA-3 support for SHA-224, SHA-256, SHA-384, and SHA-512, are enabled on all systems and do not require the CPACF enablement feature. For all other algorithms, the no-charge CPACF enablement feature (FC 3863) is required.

The CPACF functions are implemented as processor instructions and require operating system support for use. Operating systems that use the CPACF instructions include z/OS, z/VM, z/VSE, z/TPF, and Linux on IBM Z.

6.4.2 CPACF protected key

IBM z16 supports the protected key implementation. Secure keys are processed on the PCIeCC adapters (HSMs)³. This process requires an asynchronous operation to move the data and keys from the general-purpose central processor (CP) to the crypto adapters.

Clear keys process faster than secure keys because the process is done synchronously on the CPACF. Protected keys blend the security of Crypto Express8S, Crypto Express7S, or Crypto Express6S coprocessors and the performance characteristics of the CPACF. This process allows it to run closer to the speed of clear keys.

CPACF facilitates the continued privacy of cryptographic key material when used for data encryption. In Crypto Express8S, Crypto Express7S, or Express6S coprocessors, a secure key is encrypted under a master key. However, a protected key is encrypted under a wrapping key that is unique to each LPAR.

Because the wrapping key is unique to each LPAR, a protected key cannot be shared with another LPAR. By using key wrapping, CPACF ensures that key material is not visible to applications or operating systems during encryption operations.

CPACF code generates the wrapping key and stores it in the protected area of the hardware system area (HSA). The wrapping key is accessible only by firmware. It cannot be accessed by operating systems or applications.

DES/T-DES and AES algorithms are implemented in CPACF code with the support of hardware assist functions. Two variations of wrapping keys are generated: one for DES/T-DES keys and another for AES keys.

³ PCIeCC: IBM PCIe Cryptographic Coprocessor is the Hardware Security Module (HSM).

Wrapping keys are generated during the clear reset each time an LPAR is activated or reset. No customizable option is available at Support Element (SE) or Hardware Management Console (HMC) that permits or avoids the wrapping key generation. This function flow for the Crypto Express8S, Crypto Express7S, and Crypto Express6S adapters is shown in Figure 6-5.

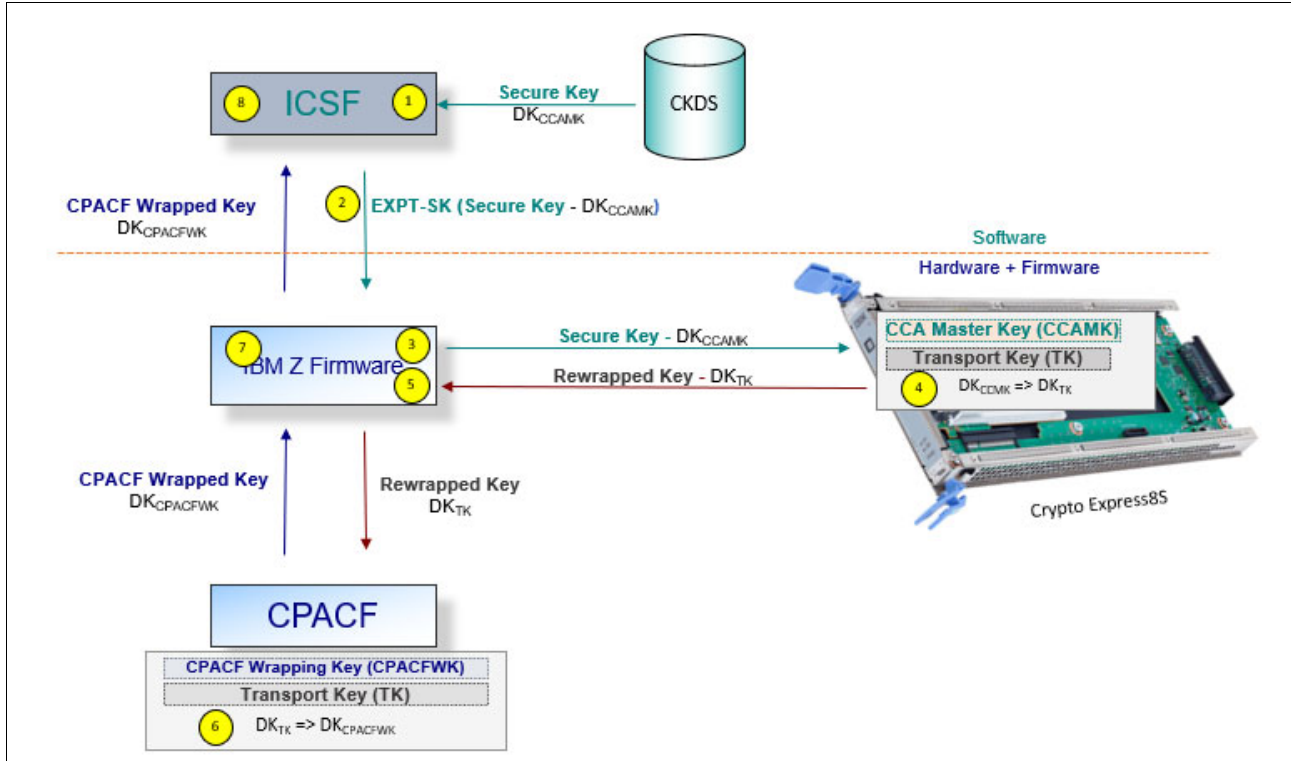


Figure 6-5 CPACF key wrapping for Crypto Express8S, Crypto Express7S, and Crypto Express6S

The key wrapping for Crypto Express8S is similar to Crypto Express7S or Crypto Express6S. The CPACF Wrapping Key and the Transport Key for use with Crypto Express7S or Crypto Express6S are in a protected area of the HSA that is not visible to operating systems or applications.

If a Crypto ExpressxS coprocessor (CEX8C, CEX7C, or CEX6C) is available, a protected key can begin its life as a secure key. Otherwise, an application is responsible for creating or loading a clear key value and then, uses the PCKMO instruction to wrap the key. ICSF is not called by the application if the CEXxC is not available.

A new segment in the profiles of the CSFKEYS class in IBM RACF® restricts which secure keys can be used as protected keys. By default, all secure keys are considered not eligible to be used as protected keys. The process that is shown in Figure 6-5 considers a secure key as the source of a protected key.

The source key in this case is stored in the ICSF Cryptographic Key Data Set (CKDS) as a secure key, which was encrypted under the master key. This secure key is sent to CEX8C, CEX7C, or CEX6C to be deciphered and then, sent to the CPACF in clear text.

At the CPACF, the key is wrapped under the LPAR wrapping key, and is then returned to ICSF. After the key is wrapped, ICSF can keep the protected value in memory. It then passes it to the CPACF, where the key is unwrapped for each encryption or decryption operation.

The protected key is designed to provide substantial throughput improvements for a large volume of data encryption and low latency for encryption of small blocks of data. A high-performance secure key solution, also known as a *protected key solution*, requires the ICSF HCR7770 as a minimum release.

6.5 Crypto Express8S

The Crypto Express8S feature (FC 0908 or FC 0909) is an optional feature that is exclusive to IBM z16 systems. Each feature FC 0909 has one IBM 4770 PCIe cryptographic adapter (hardware security module [HSM]), whereas FC 0908 has two IBM 4770 PCIe cryptographic adapters (two HSMs). The Crypto Express8S (CEX8S) feature occupies one I/O slot in an IBM z16 PCIe+ I/O drawer. This feature provides one or two HSMs and for a secure programming and hardware environment on which crypto processes are run.

Each cryptographic coprocessor includes a general-purpose processor, nonvolatile storage, and specialized cryptographic electronics. The Crypto Express8S feature provides tamper-sensing and tamper-responding, high-performance cryptographic operations.

Each Crypto Express8S PCI Express adapter (HSM) is available in one of the following configurations:

- ▶ Secure IBM CCA coprocessor (CEX8C) for FIPS 140-2 Level 4 certification. This configuration includes secure key functions. It is optionally programmable to deploy more functions and algorithms by using UDX.

For more information, see 6.5.2, “Crypto Express8S as a CCA coprocessor” on page 232.

A TKE workstation is required to support the administration of the Crypto Express8S when it is configured in CCA mode when in full Payment Card Industry (PCI)-compliant mode for the necessary certificate management in this mode. The TKE is optional in all other use cases for CCA.

- ▶ Secure IBM Enterprise PKCS #11 (EP11) coprocessor (CEX8P) implements an industry-standardized set of services that adheres to the PKCS #11 specification V2.20 and more recent amendments. It was designed for extended FIPS and Common Criteria evaluations to meet public sector requirements. This new cryptographic coprocessor mode introduced the PKCS #11 secure key function.

For more information, see 6.5.3, “Crypto Express8S as an EP11 coprocessor” on page 238.

A TKE workstation is always required to support the administration of the Crypto Express7S when it is configured in EP11 mode.

- ▶ Accelerator (CEX8A) for acceleration of public key and private key cryptographic operations that are used with SSL/TLS processing.

For more information, see 6.5.4, “Crypto Express8S as an accelerator” on page 239.

These modes can be configured by using the SE. The PCIe adapter must be configured offline to change the mode.

Attention: Switching between configuration modes erases all adapter secrets. The exception is when you are switching from Secure CCA to accelerator, and vice versa.

The Crypto Express8S feature is released for enhanced cryptographic performance. Customers who migrated to variable-length AES key tokens cannot take advantage of faster encryption speeds by using CPACF. Support is being added to translate a secure variable-length AES CIPHER token to a protected key token (protected by the system wrapping key). This support allows for faster AES encryption speeds when variable-length tokens are used while maintaining strong levels of security.

The Crypto Express8S feature does not include external ports and does not use optical fiber or other cables. It does not use channel path identifiers (CHPIDs), but requires one slot in the PCIe I/O drawer and one physical channel ID (PCHID) for each PCIe cryptographic adapter. Removal of the feature or adapter *zeroizes* its content. Access to the PCIe cryptographic adapter is controlled through the setup in the image profiles on the SE.

Adapter: Although PCIe cryptographic adapters include no CHPID type and are not identified as external channels, all logical partitions (LPARs) in all channel subsystems can access the adapter. In IBM z16, up to 85 LPARs are supported per adapter (HSM). Accessing the adapter requires a setup in the image profile for each partition. The adapter must be in the candidate list.

Each IBM z16 A01 supports up to 60 HSMs in total (combination of Crypto Express8S (1 or 2 HSMs), Crypto Express7S (1 or 2 ports, and Crypto Express6S). Crypto Express7S (1 or 2 ports) and Crypto Express6S features (single HSM) are *not* orderable for a new build IBM z16 A01 system, but can be carried forward from an IBM z14 or IBM z15 by using an MES. Configuration information for Crypto Express8S is listed in Table 6-2.

Table 6-2 Crypto Express8S features

Feature	Quantity
Minimum number of orderable features 0908 for IBM z16 A01	2
Minimum number of orderable features 0909 for IBM z16 ^a A01	2
Order increment (above two features for features 0908 and 0909)	1
Maximum number of HSMs for IBM z16 (combining all CEX8S, CEX7S, and CEX6S)	60 ^b
Number of PCIe cryptographic adapters for each feature 0908 (coprocessor or accelerator)	2
Number of PCIe cryptographic adapters for each feature 0909 (coprocessor or accelerator)	1
Number of cryptographic domains at IBM z16 for each PCIe adapter ^c	85

- a. The minimum initial order of Crypto Express8S feature 0909 is two. After the initial order, more Crypto Express8S features 0909 can be ordered individually.
- b. Crypto Express8S (dual HSM) has two hardware security modules (HSMs) per feature. The HSM is one IBM 4770 PCIe Cryptographic Coprocessor (PCIeCC). The maximum number of HSMs per A01 system (combining all cryptographic features) is 60. The maximum number of single HSM (port) cryptographic features is 16 (CEX8S [single HSM], CEX7S [1 port], and CEX6S).
- c. More than one partition, which is defined to the same channel subsystem (CSS) or to different CSSs, can use the same domain number when assigned to different PCIe cryptographic adapters.

The concept of *dedicated processor* does not apply to the PCIe cryptographic adapter. Whether configured as a coprocessor or an accelerator, the PCIe cryptographic adapter is made available to an LPAR. It is made available as directed by the domain assignment and the candidate list in the LPAR image profile. This availability is not changed by the shared or dedicated status that is given to the PUs in the partition.

When installed nonconcurrently, Crypto Express8S features are assigned PCIe cryptographic adapter numbers sequentially during the power-on reset (POR) that follows the installation. When a Crypto Express8S feature is installed concurrently, the installation can select an out-of-sequence number from the unused range. When a Crypto Express8S (Crypto Express7S or Crypto Express6S) feature is removed concurrently, the PCIe adapter numbers are automatically freed.

The definition of domain indexes and PCIe cryptographic adapter numbers in the candidate list for each LPAR must be planned to allow for nondisruptive changes. Consider the following points:

- ▶ Operational changes can be made by using the Change LPAR Cryptographic Controls task from the SE, which reflects the cryptographic definitions in the image profile for the partition. With this function, adding and removing the cryptographic feature without stopping a running operating system can be done dynamically.
- ▶ The same usage domain index can be defined more than once across multiple LPARs. However, the PCIe cryptographic adapter number that is coupled with the usage domain index that is specified must be unique across all active LPARs.

The same PCIe cryptographic adapter number and usage domain index combination can be defined for more than one LPAR (up to 85 for IBM z16). For example, you might define a configuration for backup situations. However, only one of the LPARs can be active at a time.

For more information, see 6.5.5, “Managing Crypto Express8S” on page 240.

6.5.1 Cryptographic asynchronous functions

The Crypto Express8S feature provides asynchronous cryptographic functions to IBM z16. More than 300 Cryptographic algorithms and modes are supported, including the following examples:

- ▶ DES/TDES with DES/TDES MAC/CMAC

The Data Encryption Standard is a widespread symmetrical encryption algorithm. DES, along with its double-length and triple length variations, TDES today are considered to be insufficiently secure for many applications. They were replaced by AES as the official US standard, but it is still used in the industry with the MAC and the Cipher-based Message Authentication Code (CMAC) for verifying the integrity of messages.

- ▶ AES, AESKW, AES GMAC, AES GCM, AES XTS, AES CIPHER mode, and CMAC

AES replaced DES as the official US standard in October 2000. The enhanced standards for AES Key Warp (AESKW), AES Galois Message Authentication Code (AES GMAC), and Galois/Counter Mode (AES GCM), the XEX-based tweaked-codebook mode with ciphertext stealing (AES XTS), and CMAC are supported.

- ▶ MD5, SHA-1, SHA-2, or SHA-3⁴ (224, 256, 384, and 512), and HMAC

The Secure Hash Algorithm (SHA-1 and the enhanced SHA-2 or SHA-3 for different block sizes), the older message-digest (MD5) algorithm, and the advanced keyed-hash method authentication code (HMAC) are used for verifying the data integrity and the authentication of a message.

- ▶ VFPE

A method of encryption in which the resulting cipher text features the same form as the input clear text, which is developed for use with credit cards.

⁴ SHA-3 was standardized by NIST in 2015. SHA-2 is still acceptable and no indication exists that SHA-2 is vulnerable or that SHA-3 is more or less vulnerable than SHA-2.

- ▶ RSA (512, 1024, 2048, and 4096)

RSA was published in 1977. It is a widely used asymmetric public-key algorithm, which means that the encryption key is public whereas the decryption key is kept secret. It is based on the difficulty of factoring the product of two large prime numbers. The number describes the length of the keys.

- ▶ ECDSA (192, 224, 256, 384, and 521 Prime/NIST)

ECC is a family of asymmetric cryptographic algorithms that are based on the algebraic structure of elliptic curves. ECC can be used for encryption, pseudo-random number generation, and digital certificates. The Elliptic Curve Digital Signature Algorithm (ECDSA) Prime/NIST method is used for ECC digital signatures, which are recommended for government use by NIST.

- ▶ ECDSA (160, 192, 224, 256, 320, 384, and 512 BrainPool)

ECC Brainpool is a work group of companies and institutions that collaborate on developing ECC algorithms. The ECDSA algorithms that are recommended by this group are supported.

- ▶ ECDH (192, 224, 256, 384, and 521 Prime/NIST)

Elliptic Curve Diffie-Hellman (ECDH) is an asymmetric protocol that is used for key agreement between two parties by using ECC-based private keys. The recommendations by NIST are supported.

- ▶ ECDH (160, 192, 224, 256, 320, 384, and 512 BrainPool)

ECDH according to the Brainpool recommendations.

- ▶ Montgomery Modular Math Engine

The Montgomery Modular Math Engine is a method for fast modular multiplication. Many crypto systems, such as RSA and Diffie-Hellman key Exchange, can use this method.

- ▶ Clear Key Fast Path (Symmetric and Asymmetric)

This mode of operation gives a direct hardware path to the cryptographic engine and provides high performance for public-key cryptographic functions.

- ▶ Random Number Generator (RNG)

- ▶ Prime Number Generator (PNG)

Several of these algorithms require a secure key and must run on an HSM. Some of these algorithms can also run with a clear key on the CPACF. Many standards are supported only when Crypto Express8S is running in CCA mode. Others are supported only when the adapter is running in EP11 mode.

The three modes for Crypto Express8S are described next. For more information, see 6.7, "Cryptographic functions comparison" on page 246.

6.5.2 Crypto Express8S as a CCA coprocessor

A Crypto Express8S adapter that is running in CCA mode supports IBM CCA. CCA is an architecture and a set of APIs. It provides cryptographic algorithms, secure key management, and many special functions that are required for banking. Over 129 APIs with more than 600 options are provided, with new functions and algorithms always being added.

The IBM CCA provides functions for the following tasks⁵:

- ▶ Encryption of data (DES/TDES/AES)
- ▶ Key management:
 - ▶ Using TDES or AES keys
 - ▶ Using RSA or Elliptic Curve keys
- ▶ Message authentication for MAC/HMAC/AES-CMAC
- ▶ Key generation
- ▶ Digital signatures
- ▶ Random number generation
- ▶ Hashing (SHA, MD5, and others)
- ▶ ATM PIN generation and processing
- ▶ Credit card transaction processing
- ▶ Visa Data Secure Platform (DSP) Point to Point Encryption (P2PE)
- ▶ Europay, MasterCard, and Visa (EMV) card transaction processing
- ▶ Card personalization
- ▶ Other financial transaction processing
- ▶ Integrated role-based access control system
- ▶ Compliance support for:
 - All DES services
 - AES services
 - RSA services, including full use of X.509 certificates
- ▶ TR-34 Remote Key Load

User-defined extensions support

User-defined extension (UDX) allows a developer to add customized operations to IBM's CCA Support Program. UDXs to the CCA support customized operations that run within the Crypto Express features when defined as a coprocessor.

UDX is supported under a special contract through an IBM or approved third-party service offering. The Crypto Cards website directs your request to an IBM representative for your geographic location. A special contract is negotiated between IBM and you for the development of the UDX code by IBM according to your specifications and an agreed-upon level of the UDX.

A UDX toolkit for IBM Z is tied to specific versions of the CCA code and the related host code. UDX is available for the Crypto Express8S, Crypto Express7S, and Crypto Express6S (Secure IBM CCA coprocessor mode only) features. An UDX migration is no more disruptive than a normal Microcode Change Level (MCL) or ICSF release migration.

⁵ List is not exhaustive; new functions are added continuously

In IBM z16, up to four UDX files can be imported. These files can be imported from a USB media stick or an FTP server. The UDX configuration window is updated to include a Reset to IBM Default button.

Consideration: CCA features a new code level starting with z13 systems, and the UDX clients require a new UDX.

On IBM z16 A01, Crypto Express8S is delivered with CCA Level 8.0 firmware. A new set of cryptographic functions and callable services is provided by the IBM CCA LIC to enhance the functions that secure financial transactions and keys. The Crypto Express8S includes the following features:

- ▶ Greater than 16 domains support up to 85 LPARs on IBM z16 A01.
- ▶ PCI PIN Transaction Security (PTS) HSM Certification that is available to IBM z16 in combination with CEX8S, CEX7S, or CEX6S features, to z15 in combination with CEX7S or CEX6S features, and to IBM z14 with CEX6S features.
- ▶ VFPE support, which was introduced with z13/z13s systems.
- ▶ AES PIN support for the German banking industry.
- ▶ PKA Translate UDX function into CCA.
- ▶ Verb Algorithm Currency.

CCA improvements

The following CCA improvements were made:

- ▶ CCA Quantum Safe Algorithm enhancements:
 - Updated support for Dilithium signatures:
 - Round 2: Level 2 (6 5) and 3 (8 7)
 - Round 3: Level 3 (6 5) and 5 (8 7)
 - Added support for Kyber key encapsulation in Round 2: Level 5 (1024)
- ▶ Quantum Safe protected key support for CCA
Host Firmware and CCA now employ a hybrid scheme combining ECDH and Kyber to accomplish a quantum safe transport key exchange for protected key import.

CCA 8.0

The following CCA 8.0 improvements were made:

- ▶ Performance enhancement for mixed workloads: better performance when one partition focuses on RSA/ECC and another partition focuses on AES/DES/TDES or financial operations
- ▶ Hardware accelerated key unwrap for AES wrapped keys
 - Trusted Key Entry workstation (TKE) controlled selection of WRAPENH3 as the default TDES key token wrapping method for easier management.

CCA 7.2 and CCA 6.5

The following CCA 7.2 and 6.5 improvements were made:

- ▶ AES DUKPT unique key per transaction for AES-based PIN and transaction protection
- ▶ ISO 4 enhanced support for adding AES protected PIN block support to all remaining services that process PIN blocks
- ▶ Format Preserving Encryption (FPE) supports three algorithms that are standardized by NIST and in X9.124: FF1, FF2, and FF2.1

- ▶ Elliptic Curve support for the Koblitz curve secp256k1, to all ECC services including native support for X.509 certificates

CCA 7.3, CCA 6.6

WRAPENH3 Enhanced Wrapping Method for TDES key tokens was added.

CCA 7.4 and CCA 6.7

The following CCA 7.4 and 6.7 improvements were made:

- ▶ German banking API updates for program currency
- ▶ X9.23 random padding for AES encryption for important cryptographic operation protection
- ▶ Enhanced triple length TDES PIN encryption key support for PIN change workloads
- ▶ New service to compare encrypted PINs, which is required for ISO 4 PIN block verification inside the HSM
- ▶ EC SDSA signature support, which is useful for new EMV certificate formats
- ▶ PKCS#11 update to CCA API export of AES and RSA keys by using RSA public key and AES ephemeral keys for key exchange with Cloud service key management APIs
- ▶ Australian Payment Network Acquirer function for key derivation and MAC chaining added for interoperability with Australian audited payment networks

CCA 7.1

The following CCA 7.1 improvements were made:

- ▶ Supported curves:
 - NIST Prime Curves: P192, P224, P256, P384, and P521
 - Brainpool Curves: 160, 192, 224, 256, 320, 384, and 512
- ▶ Support in the CCA coprocessor for Edwards curves ED25519 (128-bit security strength) and ED448 (224-bit security strength)

Although ED25519 is faster, ED448 is more secure. Practically though, 128-bit security strength is very secure.

Edwards curves are used for digitally signing documents and verifying those signatures.

Edwards curves are less susceptible to side channel attacks when compared to Prime and Brainpool curves.

- ▶ ECC Protected Keys

Crypto Express8S and Crypto Express7S provide support in CCA coprocessors to take advantage of fast DES and AES data encryption speeds in CPACF while maintaining high levels of security for the secure key material. The key remains encrypted and the key encrypting key never appears in host storage.

When CCA ECC services are used, ICSF can now take advantage of ECC support in CPACF (protected key support) for the following curves:

- Prime: P256, P384, P521
- Edwards: ED25519, ED448

CPACF can achieve much faster crypto speeds compared to the coprocessor.

The translation to protected key happens automatically after the attribute is set in the key token. No application change is required.

► New signatures

Support for the Cryptographic Suite for Algebraic Lattices signatures algorithm with the largest key sizes (MODE=3):

- Public Key size: 1760 bytes
- Private Key Size: 3856 bytes
- Signature Size: 3366 bytes

Lattice-based cryptographic keys are protected by the 256-bit AES MK. The lattice-based key has a security strength of 128 bits.

► TR-31 for Hash-based Message Authentication Code (HMAC)

HMAC keys are used to verify the integrity and authenticity of a message. This support provides a standard method of exchanging HMAC keys with a partner that uses symmetric key techniques. The key is exchanged in the standard TR-31 key block format, which can be used by any crypto system that supports the standard.

CCA Version 6.3 improvements⁶

The following CCA Version 6.3 improvements were made:

- Compliance support for:
 - All DES services
 - AES services
 - RSA services, including full use of X.509 certificates
- TR-34 Remote Key Load

Greater than 16 domains support

IBM z16 A01 supports up to 85 LPARs. The IBM Z crypto architecture supports 16 domains, which matched the LPAR maximum at the time. Before z13 systems, crypto workload separation can be complex in customer environments where the number of LPARs was larger than 16. These customers mapped a large set of LPARs to a small set of crypto domains.

Starting with IBM z14, the IBM Z crypto architecture can support up to 256 domains in an adjunct processor (AP) with the AP extended addressing (APXA) facility that is installed. As such, the Crypto Express adapters are enhanced to handle 256 domains.

The IBM Z firmware provides up to 85 domains for IBM z16 to customers (to match the current LPAR maximum). Customers can map individual LPARs to unique crypto domains or continue to share crypto domains across LPARs.

The following requirements must be met to support 85 domains:

- Hardware: IBM z16 A01 and Crypto Express8S, Crypto Express7S, or Crypto Express6S
- Operating systems:
 - z/OS:
 - New ICSF support is required to administer a CEX8 coprocessor by using a TKE workstation because of the exploitation of quantum algorithms. Otherwise, workloads run on IBM z16 without requiring ICSF support.
 - Exploitation of new function is supplied in ICSF PTFs on z/OS V2.2 V2.4 (Web deliverable HCR77D1) or V2.5 (base, which is HCR77D2).
 - When using new Quantum Safe Algorithms and sharing a KDS in a sysplex, ensure all ICSF PTFs are installed on all systems.

⁶ A TKE is required to manage a PCI-compliant coprocessor and for certificate management.

Tip: All supported levels of ICSF automatically detect what hardware cryptographic capabilities are available where it is running; then, it enables functions accordingly. No toleration of new hardware is necessary. If you want to use new capabilities, ICSF support is necessary.

- z/VM Version 7.1 or newer for guest use.

Payment Card Industry-HSM certification

PCI standards are developed to help ensure security in the PCI. PCI defines their standards as a set of security standards that is designed to ensure that all companies that accept, process, store, or transmit credit card information is maintained a secure environment.

Compliance with the PCI-HSM standard is valuable for customers, particularly those customers who are in the banking and finance industry. This certification is important to clients for the following fundamental reasons:

- ▶ Compliance is increasingly becoming mandatory
- ▶ The requirements in PCI-HSM make the system more secure.

Industry requirements for PCI-HSM compliance

The PCI organization cannot require compliance with its standards. Compliance with PCI standards is enforced by the payment card brands, such as Visa, MasterCard, American Express, JCB International, and Discover.

If you are a bank, acquirer, processor, or other participant in the payment card systems, the card brands can impose requirements on you if you want to process their cards. One set of requirements they are increasingly enforcing is the PCI standards.

The card brands work with PCI in developing these standards, and they focused first on the standards they considered most important, particularly the PCI Data Security Standard (PCI-DSS). Some of the other standards were written or required later, and PCI-HSM is one of the last standards to be developed. In addition, the standards themselves were increasing the strength of their requirements over time. Some requirements that were optional in earlier versions of the standards are now mandatory.

In general, the trend is for the card brands to enforce more of the PCI standards and to enforce them more rigorously. The trend in the standards is to impose more and stricter requirements in each successive version. The net result is that companies subject to these requirements can expect that they eventually must comply with all of the requirements.

Improved security through use of PCI-HSM

PCI-HSM was developed primarily to improve security in payment card systems. It imposes requirements in key management, HSM API functions, and device physical security. It also controls during manufacturing and delivery, device administration, and several other areas. It prohibits many things that were in common use for many years, but are no longer considered secure.

The result of these requirements is that applications and procedures often must be updated because they used some of the things that are now prohibited. Although this issue is inconvenient and imposes some costs, it does increase the resistance of the systems to attacks of various kinds. Updating a system to use PCI-HSM compliant HSMs is expected to reduce the risk of loss for the institution and its clients.

The following requirements must be met to use PCI-HSM:

- ▶ Hardware: IBM z16⁷ systems and Crypto Express8S, Crypto Express7S, or Crypto Express6S
- ▶ Operating systems:
 - z/OS - ICSF Web deliverable 19 (HCR77D1), unless otherwise noted. WD19 supports z/OS V2R2, V2R3, and V2R4.
WD 20 supports z/OS V2R5 (base, which is HCR77D2)
 - z/VM Version 7.1 or newer for guest use

Visa Format Preserving Encryption

VFPE refers to a method of encryption in which the resulting cipher text features the same form as the input clear text. The form of the text can vary according to use and application.

One of the classic examples is a 16-digit credit card number. After VFPE is used to encrypt a credit card number, the resulting cipher text is another 16-digit number. This process helps older databases contain encrypted data of sensitive fields without having to restructure the database or applications.

VFPE allows customers to add encryption to their applications in such a way that the encrypted data can flow through their systems without requiring a massive redesign of their application. In our example, if the credit card number is VFPE-encrypted at the point of entry, the cipher text still behaves as a credit card number. It can flow through business logic until it meets a back-end transaction server that can VFPE-decrypt it to get the original credit card number to process the transaction.

Note: VFPE technology forms part of Visa, Inc.'s, Data Secure Platform (DSP). The use of this function requires a service agreement with Visa. You must maintain a valid service agreement with Visa when you use DSP/FPE.

AES PIN support for the German banking industry

The German banking industry organization, DK, defined a new set of PIN processing functions to be used on the internal systems of banks and their servers. CCA is designed to support the functions that are essential to those parts of the German banking industry that are governed by DK requirements. The functions include key management support for new AES key types, AES key derivation support, and several DK-specific PIN and administrative functions.

This support includes PIN method APIs, PIN administration APIs, new key management verbs, and new access control points support that is needed for DK-defined functions.

Support for the updated German Banking standard (DK)

Update support requires ICSF WD19 (HCR77D1) for z/OS V2R2, V2R3, and V2R4.

⁷ Always check the latest information about security certification status for your specific model.

PKA Translate UDX function into CCA

UDX is custom code that allows the client to add unique operations or extensions to the CCA firmware. Specific UDX functions are integrated into the base CCA code over time to accomplish the following tasks:

- ▶ Remove headaches and challenges that are associated with UDX management and currency.
- ▶ Make available popular UDX functions to a wider audience to encourage adoption.

UDX is integrated into the base CCA code to support translating an external RSA CRT key into new formats. These formats use tags to identify key components. Depending on which new rule array keyword is used with the PKA Key Translate callable service, the service TDES encrypts those components in CBC or ECB mode. In addition, AES CMAC support is delivered.

Verb Algorithm Currency

Verb Algorithm Currency is a collection of CCA verb enhancements that are related to customer requirements, with the intent of maintaining currency with cryptographic algorithms and standards. It is also intended for customers who want to maintain the following latest cryptographic capabilities:

- ▶ Secure key support AES GCM encryption
- ▶ Key Check Value (KCV) algorithm for service CSNBKYT2 Key Test 2
- ▶ Key derivation options for CSNDEDH EC Diffie-Hellman service

6.5.3 Crypto Express8S as an EP11 coprocessor

A Crypto Express8S adapter that is configured in Secure IBM Enterprise PKCS #11 (EP11) coprocessor mode provides PKCS #11 secure key support for public sector requirements. Before EP11, the ICSF PKCS #11 implementation supported only clear keys.

In EP11, keys can now be generated and securely wrapped under the EP11 Master Key. The secure keys never leave the secure coprocessor boundary decrypted.

The secure IBM Enterprise PKCS #11 (EP11) coprocessor runs the following tasks:

- ▶ Encrypt and decrypt (AES, DES, TDES, and RSA)
- ▶ Sign and verify (DSA, RSA, and ECDSA)
- ▶ Generate keys and key pairs (DES, AES, DSA, ECC, and RSA)
- ▶ HMAC (SHA1, SHA2 or SHA3 [SHA224, SHA256, SHA384, and SHA512])
- ▶ Digest (SHA1, SHS2 or SHA3 [SHA224, SHA256, SHA384, and SHA512])
- ▶ Wrap and unwrap keys
- ▶ Random number generation
- ▶ Get mechanism list and information
- ▶ Attribute values
- ▶ Key Agreement (Diffie-Hellman)

Note: The function extension capability through UDX is not available to the EP11.

When defined in EP11 mode, the TKE workstation is required to manage the Crypto Express features.

Enterprise PKCS #11 (EP11) with IBM z16 provides the following updates⁸:

- ▶ Quantum Safe Algorithm enhancements provide:
 - Updated support for Dilithium signatures:
 - Round 2: Level 2 (6 5) and 3 (8 7)
 - Round 3: Level 2 (4 4), 3 (6 5) and 5 (8 7)
 - Add support for Kyber key encapsulation: Round 2: Level 3 (768) and 5 (1024)
- ▶ Quantum Safe protected key support for EP11
Host Firmware and EP11 now use a hybrid scheme that combines ECDH and Kyber to accomplish a quantum safe transport key exchange for protected key import.
- ▶ Quantum Safe host firmware management support for EP11
Host Firmware and EP11 now use a hybrid scheme for authenticating management functions that are started from the SE/HMC.
- ▶ EP11 for all of CEX8S (5.8.x), CEX7S (4.8.x) and CEX6S (3.8.x):
 - Support for HSM backed Hierarchical Deterministic Wallets for Bitcoin (BIP 0032 and SLIP 0010)
 - Hash collision resistant Schnorr signature scheme BSI TR 03111, two variants:
 - Plain BSI TR 03111
 - With compressed keys and signing party's public key as extra input
 - Support for Edwards and Montgomery elliptic curves: EdDSA (Ed25519, Ed448) and ECDH (X25519, X448) (8s and 7s)
 - RSA OAEP with SHA 2 and SHA 3 (8s and 7s only)
 - Extensive IBM Cloud Crypto support:
 - Domains fully manageable by clients without cloud admins assistance
 - Do not Disturb: Actively prohibit cloud administrators from domain management
 - HSM internal re encrypt support for block-based cipher modes
- ▶ EP11 for CEX8S (5.8.x) only
 - Three new compliance modes: FIPS2021, FIPS2024, and Administrative FIPS2021 (first of its kind)
 - Enhanced concurrent update support now includes kernel modules
 - Enhanced maximum performance for digest and random number generation
 - Allow for regular extractable keys to be tagged as protected key exportable

6.5.4 Crypto Express8S as an accelerator

A Crypto Express8S adapter that is running in accelerator mode supports only RSA clear key and SSL Acceleration. A request is processed fully in hardware.

The Crypto Express accelerator is a coprocessor that is reconfigured by the installation process so that it uses only a subset of the coprocessor functions at a higher speed. Reconfiguration is disruptive to coprocessor and accelerator operations. The coprocessor or accelerator must be deactivated before you begin the reconfiguration.

FIPS 140-2 certification is not relevant to the accelerator because it operates with clear keys only. The function extension capability through UDX is not available to the accelerator.

⁸ At the time of this writing (August 2022)

The functions that remain available when the Crypto Express8S feature is configured as an accelerator are used for the acceleration of modular arithmetic operations. That is, the RSA cryptographic operations are used with the SSL/TLS protocol. The following operations are accelerated:

- ▶ PKA Decrypt (CSNDPKD) with PKCS-1.2 formatting
- ▶ PKA Encrypt (CSNDPKE) with zero-pad formatting
- ▶ Digital Signature Verify

The RSA encryption and decryption functions support key lengths of 512 - 4,096 bits in the Modulus-Exponent (ME) and Chinese Remainder Theorem (CRT) formats.

6.5.5 Managing Crypto Express8S

Each cryptographic coprocessor has 85 physical sets of registers or queue registers, which corresponds to the maximum number of LPARs that are running on an IBM z16 A01, which is also 85. Each of these sets belongs to the following domains:

- ▶ A cryptographic domain index, in the range of 0 - 84 for IBM z16 A01, is allocated to a logical partition in its image profile. The same domain also must be allocated to the ICSF instance that is running in the logical partition that uses the Options data set.
- ▶ Each ICSF instance accesses only the Master Keys or queue registers that correspond to the domain number that is specified in the logical partition image profile at the SE and in its Options data set. Each ICSF instance sees a logical cryptographic coprocessor that consists of the physical cryptographic engine and the unique set of registers (the domain) that is allocated to this logical partition.

The installation of CP Assist for Cryptographic Functions (CPACF) DES/TDES enablement (FC 3863) is required to use the Crypto Express7S feature.

Each Crypto Express8S FC 0908 includes two IBM 4770 PCIe Cryptographic Coprocessors (PCIeCC), which is a hardware security module (HSM); FC 0909 includes one IBM 4770 PCIeCC. The adapters are available in the following configurations:

- ▶ IBM Enterprise Common Cryptographic Architecture (CCA) Coprocessor (CEX8C)
- ▶ IBM Enterprise Public Key Cryptography Standards #11 (PKCS) Coprocessor (CEX8P)
- ▶ IBM Crypto Express7S Accelerator (CEX8A)

During the feature installation, the PCI-X adapter is configured by default as the CCA coprocessor.

The configuration of the Crypto Express8S adapter as EP11 coprocessor requires a TKE workstation (FC 0057/0058) with TKE 10.0 (FC 0882) LIC. The same requirement applies to CCA mode for a full PCI-compliant environment.

The Crypto Express8S feature does not use CHPIDs from the channel subsystem pool. However, the Crypto Express8S feature requires one slot in a PCIe I/O drawer, and one PCHID for each PCIe cryptographic adapter.

For enabling an LPAR to use a Crypto Express8S adapter, the following cryptographic resources in the image profile must be defined for each partition:

- ▶ Usage domain index
- ▶ Control domain index
- ▶ PCI Cryptographic Coprocessor Candidate List
- ▶ PCI Cryptographic Coprocessor Online List

This task is accomplished by using the Customize/Delete Activation Profile task, which is in the Operational Customization Group, from the HMC or from the SE. Modify the cryptographic initial definition from the Crypto option in the image profile, as shown in Figure 6-6.

Important: After this definition is modified, any change to the image profile requires a DEACTIVATE and ACTIVATE of the logical partition for the change to take effect. Therefore, this cryptographic definition is disruptive to a running system.

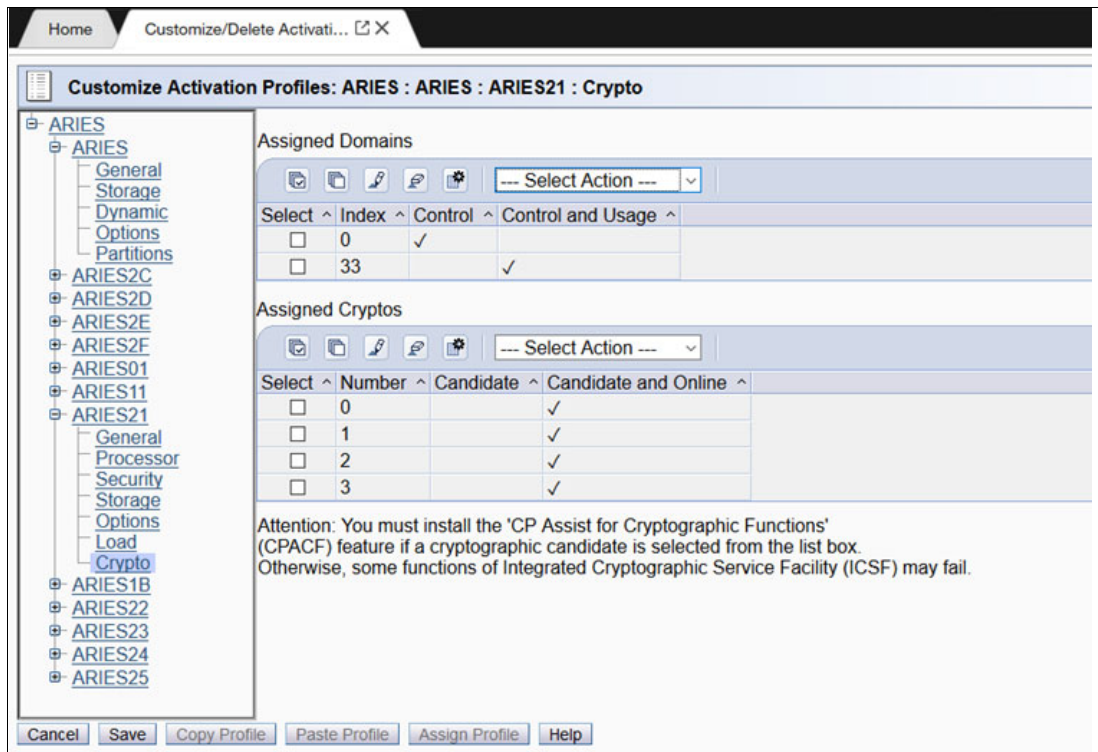


Figure 6-6 Customize Image Profiles: Crypto

The following cryptographic resource definitions are used:

► Control Domain

Identifies the cryptographic coprocessor domains that can be administered from this logical partition if it is set up as the TCP/IP host for the TKE.

If you are setting up the host TCP/IP in this logical partition to communicate with the TKE, the partition is used as a path to other domains' Master Keys. Indicate all the control domains that you want to access (including this partition's own control domain) from this partition.

► Control and Usage Domain

Identifies the cryptographic coprocessor domains that are assigned to the partition for all cryptographic coprocessors that are configured on the partition. The usage domains cannot be removed if they are online. The numbers that are selected must match the domain numbers that are entered in the Options data set when you start this partition instance of ICSF.

The same usage domain index can be used by multiple partitions, regardless to which CSS they are defined. However, the combination of PCIe adapter number and usage domain index number must be unique across all active partitions.

► Cryptographic Candidate list

Identifies the cryptographic coprocessor numbers that can be accessed by this logical partition. From the list, select the coprocessor numbers (in the range 0 - 15) that identify the PCIe adapters to be accessed by this partition.

► Cryptographic Online list

Identifies the cryptographic coprocessor numbers that are automatically brought online during logical partition activation. The numbers that are selected in the online list must also be part of the candidate list.

After they are activated, the active partition cryptographic definitions can be viewed from the HMC. Select the CPC, and click **View LPAR Cryptographic Controls** in the CPC Operational Customization window. The resulting window displays the definition of Usage and Control domain indexes, and PCI Cryptographic candidate and online lists, as shown in Figure 6-7. (Information is provided for active logical partitions only.)

View LPAR Cryptographic Controls - ARIES

Installed Crypto Express7S: 00 01 02 03 04 05 06 07

Cryptographic Candidates

Partition	Active	Crypto Numbers	Conflicts
ARIES01	No		
ARIES02	Yes		
ARIES03	Yes		
ARIES04	Yes		
ARIES05	Yes		
ARIES06	No		

Usage Domain Indexes

Partition	Active	Indexes	Conflicts
ARIES01	No	0	
ARIES02	Yes		
ARIES03	Yes		
ARIES04	Yes		
ARIES05	Yes		
ARIES06	No		

Summary

- ARIES02
- ARIES03
- ARIES04
- ARIES05
- ARIES1B
- ARIES12
- ARIES13
- ARIES14
- ARIES15
- ARIES16
- ARIES17
- ARIES2A

Figure 6-7 View LPAR Cryptographic Controls

Operational changes can be made by using the Change LPAR Cryptographic Controls task, which reflects the cryptographic definitions in the image profile for the partition. With this function, the cryptographic feature can be added and removed dynamically, without stopping a running operating system.

For more information about the management of Crypto Express8S, see *IBM z16 Configuration Setup*, [SG24-8960](#).

6.6 Trusted Key Entry workstation

The TKE workstation is an optional feature that offers key management functions. It can be a TKE tower workstation (FC 0058) or TKE rack-mounted workstation (FC 0077) for IBM z16 systems to manage Crypto Express8S, Crypto Express7S, or Crypto Express6S.

The TKE contains a combination of hardware and software. A mouse, keyboard, flat panel display, PCIe adapter, and a writable USB media to install the TKE Licensed Internal Code (LIC) are included with the system unit. The TKE workstation requires an IBM 4770 crypto adapter.

A TKE workstation is part of a customized solution for the use of the Integrated Cryptographic Service Facility for z/OS (ICSF for z/OS) or Linux for IBM Z. This program provides a basic key management system for the cryptographic keys of an IBM z16 system that has Crypto Express features installed.

The TKE provides a secure, remote, and flexible method of providing Master Key Part Entry, and to remotely manage PCIe cryptographic coprocessors. The cryptographic functions on the TKE run by one PCIe cryptographic coprocessor. The TKE workstation communicates with the IBM Z system through a TCP/IP connection. The TKE workstation is available with Ethernet LAN connectivity only. Up to 10 TKE workstations can be ordered.

TKE FCs 0057 and 0058 can be used to control any supported Crypto Express feature on IBM z16, IBM z15, IBM z14 systems, and the Crypto adapters on older, still supported systems.

The TKE 10.0 LIC (FC 0882) feature requires a 4770 HSM. The following features are supported:

- ▶ Managing the Crypto Express8S HSMs (CCA normal mode, CCA PCI mode, and EP11)
- ▶ Quantum Safe Cryptography (QSC) used when:
 - TKE authenticates Crypto Express8S HSMs
 - Deriving a Transport Key between TKE's HSM and target Crypto Express8S HSM
 - On-demand HSM dual validation check.
- ▶ Domain groups limitations All HSM in group must:
 - Support QSC (can include Crypto Express8S HSMs only)
 - Not support QSC (cannot include Crypto Express8S HSMs)
- ▶ Configuration migration tasks support:
 - Can collect and apply data to a Crypto Express8S HSM
 - Can apply data from a pre-Crypto Express8S HSM.
- ▶ New default wrapping method for the Crypto Express8S HSM
- ▶ New AES DUKPT key attribute on AES DKYGENKY parts

Tip: For more information about handling a TKE, see the [TKE Introduction video](#).

6.6.1 Logical partition, TKE host, and TKE target

If one or more LPARs are configured to use Crypto Express coprocessors, the TKE workstation can be used to manage DES, AES, ECC, and PKA master keys. This management can be done for all cryptographic domains of each Crypto Express coprocessor feature that is assigned to the LPARs that are defined to the TKE workstation.

Each LPAR in the same system that uses a domain that is managed through a TKE workstation connection is a TKE host or TKE target. An LPAR with a TCP/IP connection to the TKE is referred to as the *TKE host*; all other partitions are *TKE targets*.

The cryptographic controls that are set for an LPAR through the SE determine whether the workstation is a TKE host or a TKE target.

6.6.2 Optional smart card reader

An optional smart card reader (FC 0891) can be added to the TKE workstation. One FC 0891 includes two smart card readers, two cables to connect them to the TKE workstation, and 20 smart cards. The reader supports the use of smart cards that contain an embedded microprocessor and associated memory for data storage. The memory can contain the keys to be loaded into the Crypto Express features. These readers can be used only with smart cards that have applets that were loaded from a TKE 8.1 or later. These cards are FIPS certified.

Smart card readers from FC 0885 or FC 0891 also can be carried forward. Smart cards can be used on TKE 10.0 with these readers. Access to and use of confidential data on the smart card are protected by a user-defined PIN. Up to 990 other smart cards can be ordered for backup (the extra smart card feature code is FC 0900). When one feature code is ordered, 10 smart cards are included. The order increment is 1 - 99 (10 - 990 blank smart cards).

If smart cards with applets that are not supported by the new smart card reader are reused, new smart cards on TKE 8.1 or later must be created and the content from the old smart cards to the new smart cards must be copied. The new smart cards can be created and copied on a TKE 8.1 system. If the copies are done on TKE 9.0, the source smart card must be placed in an older smart card reader from feature code 0885 or 0891.

A new smart card for the Trusted Key Entry (TKE) allows stronger Elliptic Curve Cryptography (ECC) levels. More TKE Smart Cards (FC 0900, packs of 10, FIPS certified blanks) require TKE 9.1 LIC or up.

6.6.3 TKE hardware support and migration information

The new TKE 10.0 LIC (FC 0882) is originally shipped with a new IBM z16 server. The following TKE workstations can be ordered with a new IBM z16:

- ▶ TKE 10.0 tower workstation (FC 0058)
- ▶ TKE 10.0 rack-mounted workstation (FC 0057)

Note: Several options for ordering the TKE with or without ordering Keyboard, Mouse, and Display are available. Ask your IBM Representative for more information about which option is the best option for you.

The TKE 10.0 LIC requires the 4770 crypto adapter. The TKE 9.x and TKE 8.x workstations can be upgraded to the TKE 10.0 tower workstation by purchasing a 4770 crypto adapter.

The Omnikey Cardman 3821 smart card readers can be carried forward to any TKE 10.0 workstation. Smart cards 45D3398, 74Y0551, and 00JA710 can be used on TKE 10.0.

When performing a MES upgrade from TKE 8.x, or TKE 9.x to a TKE 10.0 installation, the following steps must be completed:

1. Save Upgrade Data on an old TKE to USB memory to save client data.
2. Replace the 4767 crypto adapter with the 4768 crypto adapter.
3. Upgrade the firmware to TKE 10.0.
4. Install the Frame Roll to apply Save Upgrade Data (client data) to the TKE 10.0 system.
5. Run the TKE Workstation Setup wizard.

TKE upgrade considerations

The TKE LIC does *not* need to be upgraded if you are migrating your configuration with Crypto Express6S and TKE Release 9.x to an IBM z16.

Note: If your IBM z16 includes Crypto Express7S or Crypto Express6S, you can use TKE V9.2, which requires the 4768 cryptographic adapter.

For more information about TKE hardware support, see Table 6-3. For some functions, requirements must be considered; for example, the characterization of a Crypto Express adapter in EP 11 mode always requires the use of a TKE.

Table 6-3 TKE Compatibility Matrix

TKE workstation	TKE Release LIC	8.0 ^a	8.1 ^a	9.0 ^a	9.1 ^a	9.2 ^a	10.0
	HW Feature Code	0847	0847 or 0097	0085 or 0086	0085 or 0086	0087 or 0088	0057 or 0058
	LICC	0877	0878	0879	0880	0881	0882
	Smart Card Reader	0891	0891	0895	0895	0895	0891
	Smart Card	0892	0892	0892	0892	0892	0900
Manage Host Crypto Module	CEX8C (CCA)	No	No	No	No	No	Yes
	CEX8P (EP11)	No	No	No	No	No	Yes
	CEX7C (CCA)	No	No	No	No	Yes	Yes
	CEX7P (EP11)	No	No	No	No	Yes	Yes
	CEX6C (CCA)	No	No	Yes	Yes	Yes	Yes
	CEX6P (EP11)	No	No	Yes	Yes	Yes	Yes

a. The TKE workstation can be upgraded to TKE LIC V10.0 by adding a 4770 cryptographic adapter.

Attention: The TKE is unaware of the CPC type where the host crypto module is installed. That is, the TKE does not consider whether a Crypto Express is running on IBM z16, IBM 15, or IBM z14 system. Therefore, the LIC can support any CPC where the coprocessor is supported, but the TKE LIC must support the specific crypto module.

6.7 Cryptographic functions comparison

The functions or attributes on IBM z16 for the two cryptographic hardware features are listed in Table 6-4, where “X” indicates that the function or attribute is supported.

Table 6-4 Cryptographic functions on IBM z16

Functions or attributes	CPACF	CEX8C	CEX8P	CEX8A
Supports z/OS applications that use CSF	X	X	X	X
Supports Linux on IBM Z CCA applications	X	X	-	X
Encryption and decryption by using secret-key algorithm	-	X	X	-
Provides the highest SSL/TLS handshake performance	-	-	-	X
Supports SSL/TLS functions	X	X	X	X
Provides the highest symmetric (clear key) encryption performance	X	-	-	-
Provides the highest asymmetric (clear key) encryption performance	-	-	-	X
Provides the highest asymmetric (encrypted key) encryption performance	-	X	X	-
Nondisruptive process to enable ^a	-	X	X	X
Requires IOCDs definition	-	-	-	-
Uses CHPID numbers	-	-	-	-
Uses PCHIDs (one PCHID)	-	X	X	X
Requires CPACF enablement (FC 3863) ^b	X	X	X	X
Requires ICSF to be active	-	X	X	X
Offers UDX	-	X	-	-
Usable for data privacy: Encryption and decryption processing	X	X	X	-
Usable for data integrity: Hashing and message authentication	X	X	X	-
Usable for financial processes and key management operations	-	X	X	-
Crypto performance IBM RMF monitoring	-	X	X	X
Requires system master keys to be loaded	-	X	X	-
System (master) key storage	-	X	X	-
Retained key storage	-	X	-	-
Tamper-resistant hardware packaging	-	X	X	X ^c
Designed for FIPS 140-2 Level 4 certification	-	X	X	X

Functions or attributes	CPACF	CEX8C	CEX8P	CEX8A
Supports Linux applications that perform SSL handshakes	-	-	-	X
RSA functions	-	X	X	X
High-performance SHA-1, SHA-2, and SHA-3	X	X	X	-
Clear key DES or triple DES	X	-	-	-
Advanced Encryption Standard (AES) for 128-bit, 192-bit, and 256-bit keys	X	X	X	-
True random number generator (TRNG)	X	X	X	-
Deterministic random number generator (DRNG)	X	X	X	-
Pseudo random number generator (PRNG)	X	X	X	-
Clear key RSA	-	-	-	X
Payment Card Industry (PCI) PIN Transaction (PTS) Hardware Security Module (HSM) PCI-HSM		X	X	
Europay, MasterCard, and Visa (EMV) support	-	X	-	-
Public Key Decrypt (PKD) support for Zero-Pad option for clear RSA private keys	-	X	-	-
Public Key Encrypt (PKE) support for Mod_Raised_to Power (MRP) function	-	X	X	-
Remote loading of initial keys in ATM	-	X	-	-
Improved key exchange with non-CCA systems	-	X	-	-
ISO 16609 CBC mode triple DES message authentication code (MAC) support	-	X	-	-
AES GMAC, AES GCM, AES XTS mode, CMAC	-	X	-	-
SHA-2, SHA-3 (384,512), HMAC	-	X	-	-
Visa Format Preserving Encryption	-	X	-	-
AES PIN support for the German banking industry	-	X	-	-
ECDSA (192, 224, 256, 384, 521 Prime/NIST)	-	X	-	-
ECDSA (160, 192, 224, 256, 320, 384, 512 BrainPool)	-	X	-	-
ECDH (192, 224, 256, 384, 521 Prime/NIST)	-	X	-	-
ECDH (160, 192, 224, 256, 320, 384, 512 BrainPool)	-	X	-	-
PNG (Prime Number Generator)	-	X	-	-

- a. To make adding the Crypto Express features nondisruptive, the logical partition must be predefined with the suitable PCI Express cryptographic adapter number. This number must be selected from its candidate list in the partition image profile.
- b. This feature is not required for Linux if only RSA clear key operations are used. DES or triple DES encryption requires CPACF to be enabled.
- c. This feature is physically present, but is not used when configured as an accelerator (clear key only).

6.8 Cryptographic operating system support for IBM z16

In this section, we provide an overview of the operating systems requirements in relation to cryptographic elements.

6.8.1 Crypto Express8S Toleration

Crypto Express8S (0908/0909) Toleration treats Crypto Express8S cryptographic coprocessors and accelerators as Crypto Express5 coprocessors and accelerators. The following minimum prerequisites must be met:

- ▶ z/OS V2.5; specific functions require WD 20 (HCR77D2)
- ▶ z/OS V2.4; specific functions require WD19 (HCR77D1)
- ▶ z/OS V2.3 with PTFs
- ▶ z/OS V2.2 with PTFs
- ▶ z/VM V7.1 and V7.2 for guest use
- ▶ z/VSE V6.2 with PTFs
- ▶ z/TPF V1.1 with PTFs
- ▶ Linux on IBM Z: IBM is working with its Linux distribution partners to provide support by way of maintenance or future releases for the following distributions:
 - SUSE Linux Enterprise Server 12 and SLES 11
 - Red Hat Enterprise Linux (RHEL) 8 and Red Hat Enterprise Linux 7
 - Ubuntu 16.04 LTS (or higher)
- ▶ The KVM hypervisor, which is offered supported Linux distributions. For more information about minimal and recommended distribution levels, see the [Tested platforms for Linux web page](#) of the IBM IT infrastructure website.

6.8.2 Crypto Express8S support of VFPE

The following minimum prerequisites must be met to use this element:

- ▶ z/OS V2.5, z/OS V2.4 with PTFs
- ▶ z/OS V2.3 with PTFs
- ▶ z/OS V2.2 with the Enhanced Cryptographic Support for z/OS V1.13-V2.2 web deliverable installed
- ▶ z/VM V7.2 for guest use
- ▶ z/VM V7.1 with PTFs for guest use
- ▶ Linux on IBM Z:
 - SUSE SLES 15 SP1 with service, SUSE SLES 12 SP4 with service, and SUSE SLES 11 SP4 with service.
 - Red Hat RHEL 8.0 with service, Red Hat RHEL 7.7 with service, and Red Hat RHEL 6.10 with service.
 - Ubuntu 18.04.1 LTS with service and Ubuntu 16.04.6 LTS with service.
 - The support statements for IBM z16 also cover the KVM hypervisor on distribution levels that have KVM support.

For more information about the minimum required and recommended distribution levels, see the [IBM Z website](#).

6.8.3 Crypto Express8S support of greater than 16 domains

The following prerequisites must be met to support more than 16 domains:

- ▶ z/OS V2.5
- ▶ z/OS V2.4 with PTFs
- ▶ z/OS V2.3 with PTFs
- ▶ z/OS V2.2 with the Enhanced Cryptographic Support for z/OS V1.13-V2.2 Web deliverable installed
- ▶ z/VM V7.1 and V7.2 for guest use
- ▶ z/VSE V6.2 with PTFs
- ▶ Linux on IBM Z:
 - SUSE SLES 15 SP1 with service, SUSE SLES 12 SP4 with service, and SUSE SLES 11 SP4 with service.
 - Red Hat RHEL 8.0 with service, Red Hat RHEL 7.7 with service, and Red Hat RHEL 6.10 with service.
 - Ubuntu 18.04.1 LTS with service and Ubuntu 16.04.6 LTS with service.
 - The support statements for IBM z16 also cover the KVM hypervisor on distribution levels that have KVM support.

For more information about the minimum that is required and recommended distribution levels, see the [IBM Z website](#).

For more information about the software support levels for cryptographic functions, see Chapter 7, “Operating system support” on page 251.



Operating system support

This chapter describes the minimum operating system requirements and support considerations for the IBM z16™ servers and their features. It addresses IBM z/OS, z/VM, z/VSE, z/TPF, Linux on IBM Z, and the KVM hypervisor.

Because this information is subject to continuous updating, for the most current information check the hardware fix categories for IBM z16 A01 IBM.Device.Server.IBM z16-3931.*.

Support of IBM z16 functions depends on the operating system and version and release.

This chapter includes the following topics:

- ▶ 7.1, “Operating systems summary” on page 252
- ▶ 7.2, “Support by operating system” on page 253
- ▶ 7.3, “IBM z16 features and function support overview” on page 256
- ▶ 7.4, “Support by features and functions” on page 269
- ▶ 7.5, “z/OS migration considerations” on page 321
- ▶ 7.6, “IBM z/VM migration considerations” on page 326
- ▶ 7.7, “z/VSE migration considerations” on page 327
- ▶ 7.8, “Software licensing” on page 327
- ▶ 7.9, “References” on page 330

7.1 Operating systems summary

The minimum operating system levels that are required on IBM z16 servers are listed in Table 7-1.

End of service operating systems: Operating system levels that are no longer in service are not covered in this publication.

Table 7-1 IBM z16 minimum operating systems requirements

Operating systems	Supported Version and release on IBM z16 ^a
z/OS	V2R2 ^b
z/VM	V7R1
z/VSE	V6.2
21 st Century Software z/VSE ^{n c}	V6.3
z/TPF	V1R1
Linux on IBM Z ^d	See Table 7-2 on page 255

a. Service is required.

b. z/OS V2R2 - Toleration mode only. The IBM Software Support Services for z/OS V2R2 offered as 1 October 2020, provides the ability for customers to purchase extended defect support service for z/OS V2.R2.

c. z/VSEⁿ is supported by 21st Century Software.

d. KVM hypervisor is supported by Linux distribution partners.

The use of specific features depends on the operating system. In all cases, program temporary fixes (PTFs) might be required with the operating system level that is indicated. Check the z/OS fix categories, or the subsets of the 3931DEVICE (IBM z16 A01) PSP buckets for z/VM and z/VSE.

The fix categories and the PSP buckets are continuously updated. They contain the latest information about maintenance.

Hardware and software buckets contain installation information, hardware and software service levels, service guidelines, and cross-product dependencies.

For more information about Linux on IBM Z distributions and KVM hypervisor, see the distributor's support information.

7.2 Support by operating system

IBM z16 systems introduced several new functions. This section describes the support of those functions by the current operating systems. Also included are some of the functions that were introduced in previous IBM Z servers and carried forward or enhanced in IBM z16 servers.

Features and functions that are available on previous servers, but no longer supported by IBM z16 servers, are *not* documented here.

For more information about supported functions that are based on operating systems, see 7.3, “IBM z16 features and function support overview” on page 256. Tables are built by function and feature classification to help you determine, by a quick scan, what is supported and the minimum operating system level that is required.

7.2.1 z/OS

z/OS Version 2 Release 3 is the earliest in-service release that supports IBM z16 servers. Consider the following points:

- ▶ Service support for z/OS Version 2 Release 2 ended in September of 2020; however, a fee-based extension for defect support (for up to three years) can be obtained by ordering IBM Software Support Services - Service Extension for z/OS V2.R2.
- ▶ IBM z16 capabilities differ depending on the z/OS release. Toleration support is provided on z/OS V2R2. Exploitation support is provided on z/OS V2R3 and later only¹.

How to get the latest fix information for z/OS systems

For the latest information about z/OS PTFs that apply to the IBM z16, consult the Fix Categories (FIXCATs).

Fixes are grouped into the following categories (for more information about IBM Fix Categories, see this IBM Support [web page](#)):

- ▶ Base support is provided by PTFs identified by:
`IBM.Device.Server.-3931.RequiredService`
Fixes that are required to run z/OS on the IBM z16 servers and must be installed before migration.
- ▶ Use of many functions is provided by PTFs identified by:
`IBM.Device.Server.-3931.Exploitation`
Fixes that are required to use the capabilities of the IBM z16. They must be installed only if you use the function.
- ▶ Recommended service is identified by:
`IBM.Device.Server.-3931.RecommendedService`
Fixes that are recommended to run z/OS on the IBM z16. These fixes also are listed in the Recommended Service section of the hardware PSP bucket. They represent fixes that were recommended by IBM Service. It is recommended that you review and install these PTFs.

For more information about supported functions and their minimum required support levels, see 7.3, “IBM z16 features and function support overview” on page 256.

¹ Use support for select features by way of PTFs. Toleration support for new hardware might also require PTFs.

7.2.2 z/VM

IBM z16 support is provided with PTFs for z/VM 7.1 and 7.2 including PTFs for IOCP, HCD, and HLASM. IBM z16 support will be included in the z/VM 7.3² base.

Note: At the time of this writing, z/VM V7.3 is planned for third quarter 2022 availability.

z/VM Compatibility Support enables guest use for several new facilities:

- ▶ Embedded Artificial Intelligence Acceleration
 - Designed to reduce the overall time required to execute CPU operations for neural networking processing functions, and help support real-time applications, such as fraud detection.
- ▶ Compliance-ready CPACF Counters support
 - Provides a means for guests to track crypto compliance and instruction usage.
- ▶ Breaking Event Address Register (BEAR) Enhancement Facility;
 - Facilitates debugging wild branches.
- ▶ Vector Packed Decimal Enhancements 2
 - New instructions intended to provide performance improvements.
- ▶ Reset DAT protection Facility
 - Provides a more efficient way to disable DAT protection, such as during copy-on-write or page change tracking operations.
- ▶ RoCE Express3 adapter
 - Allows guests to use Routable RoCE, Zero Touch RoCE, and SMC-R V2 support.
- ▶ Guest Enablement for the CEX8S crypto adapter and assorted crypto enhancements
 - Including Quantum Safe API Guest Exploitation Support that is available to dedicated guests.
- ▶ CPU/Core topology location information within z/VM monitor data
 - Provides a better picture of the system for diagnostic and tuning purposes.
- ▶ Consolidated Boot Loader for guest IPL from SCSI

The following IBM z16 support is not apparent to z/VM:

- ▶ Dynamic Partition Mode (DPM) enhancements SMC-R, SMC-D
- ▶ Dynamic Partition Mode (DPM) FICON CTC support for LPARs running on the same CPC
 - FICON CTC support is a prerequisite for establishing z/VM Single System Image (SSI) clustering. DPM FICON CTC support allows customers to create a z/VM SSI environment within the same CPC. SSI Clustering technology is required in order for customers to exploit Live Guest Relocation (LGR) to move running Linux guests across z/VM images.
- ▶ OSA-Express7S 1.2 GbE, 10 GbE, 1000BASE-T, OSA-Express7S 1.1 (25 GbE) Adapters
- ▶ Coupling Express2 LR Adapter
- ▶ 32 Gbps 2-port FICON Adapter
- ▶ Coupling facility scalability and performance improvements

For more information about supported functions and their minimum required support levels, see 7.3, “IBM z16 features and function support overview” on page 256.

² z/VM 7.3 preview announcement. See the [IBM z/VM continuous delivery page](#).

7.2.3 z/VSE

IBM z16 support is provided by z/VSE V6R2 and later, with the following considerations:

- ▶ z/VSE runs in z/Architecture mode only
- ▶ z/VSE supports 64-bit real and virtual addressing

For more information about supported functions and their minimum required support levels, see 7.3, “IBM z16 features and function support overview” on page 256.

7.2.4 21st Century Software z/VSEⁿ V6.3

21st Century Software VSEⁿ V6.3 was announced in March 2022 and is based on an IBM licensed copy of IBM z/VSE. For more information about this product, visit see the 21st Century Software [website](#).

7.2.5 z/TPF

IBM z16 support is provided by z/TPF V1R1 with PTFs. For more information about supported functions and their minimum required support levels, see 7.3, “IBM z16 features and function support overview” on page 256.

7.2.6 Linux on IBM Z

Generally, a new machine is not apparent to Linux on IBM Z. For IBM z16, toleration support is required for the following functions and features:

- ▶ IPL in “z/Architecture” mode
- ▶ Crypto Express8S cards
- ▶ RoCE Express3 adapters
- ▶ 8-byte LPAR offset

The service levels of SUSE, Red Hat, and Ubuntu releases that are supported at the time of this writing are listed in Table 7-2.

Table 7-2 Linux on IBM Z distributions

Linux on IBM Z distribution ^a	Supported Version and Release on IBM z16 ^b
SUSE Linux Enterprise Server	15 SP3 and later
SUSE Linux Enterprise Server	12 SP5 ^c
Red Hat RHEL	9
Red Hat RHEL	8.4 ^c and later with service
Red Hat RHEL	7.9 ^c with service
Ubuntu	22.04 LTS
Ubuntu	21.10 ^c
Ubuntu	20.04.1 LTS ^c
KVM Hypervisor ^d	Offered with the supported Linux distributions.

a. Only z/Architecture (64-bit mode) is supported. IBM testing identifies the minimum required level and the recommended levels of the tested distributions.

b. Fix installation is required for toleration.

- c. Maintenance is required.
- d. For more information about minimal and recommended distribution levels, see [the Linux on IBM Z website](#).

For more information about supported Linux distributions on IBM Z servers, see the [Tested platforms for Linux page](#) of the IBM IT infrastructure website.

IBM is working with Linux distribution Business Partners to provide further use of selected IBM z16 functions in future Linux on IBM Z distribution releases.

Consider the following guidelines:

- ▶ Use SUSE Linux Enterprise Server 15, Red Hat RHEL 9, or Ubuntu 22.10 LTS or newer in any new projects for IBM z16 servers.
- ▶ Update any Linux distribution to the latest service level before migrating to IBM z16 servers.
- ▶ Adjust the capacity of any Linux on IBM Z and z/VM guests, in terms of the number of IFLs and CPs, real or virtual, according to the PU capacity of the IBM z16 servers.

7.2.7 KVM hypervisor

KVM is offered through our Linux distribution partners to help simplify delivery and installation. Linux and KVM are provided from a single source. With KVM being included in the Linux distribution, ordering and installing KVM is easier.

For more information about KVM support, see [the IBM Z website](#).

7.3 IBM z16 features and function support overview

The following tables list the IBM z16 features and functions and their minimum required operating system support levels:

- ▶ Table 7-3 on page 257
- ▶ Table 7-4 on page 258
- ▶ Table 7-5 on page 260
- ▶ Table 7-6 on page 261
- ▶ Table 7-7 on page 262
- ▶ Table 7-8 on page 263
- ▶ Table 7-9 on page 265
- ▶ Table 7-10 on page 267
- ▶ Table 7-11 on page 268

Information about Linux on IBM Z refers exclusively to the suitable distributions of SUSE, Red Hat, and Ubuntu.

The tables in this section list but do not specifically mark all the features that require fixes that are required by the corresponding operating system for toleration or use.

All tables use the following conventions:

- ▶ **Y**: The function is supported.
- ▶ **N**: The function is not supported.
- ▶ **-**: The function is not applicable to that specific operating system.

7.3.1 Supported CPC functions

The supported Base CPC Functions or z/OS and z/VM are listed in Table 7-3.

Note: Consider the following points:

- ▶ In a future IBM Z hardware system family, the transactional execution and constrained transactional execution facility no longer will be supported. Users of the facility on current servers must always check the facility indications before use.
- ▶ z/OS V2R2 support ended on as of September 2020. No new function is provided for the use of the new hardware features (toleration support only). Although extended (fee-based) support for z/OS V2.R2 can be obtained, support for z/OS V2.R2 is not covered extensively in this document.

Table 7-3 Supported Base CPC Functions or z/OS and z/VM

Function ^a	z/OS V2R5	z/OS V2R4	z/OS V2R3	z/VM V7R3 ^b	z/VM V7R2	z/VM V7R1
IBM z16 servers	Y	Y	Y	Y	Y	Y
Maximum processor unit (PUs) per system image	200	200	200	80 ^c	80 ^c	80 ^c
Maximum main storage size	16 TB	4 TB	4 TB	4 TB ^d	4 TB ^d	2 TB
Dynamic PU add	Y	Y	Y	Y	Y	Y
Dynamic LPAR memory add	Y	Y	Y	Y	Y	Y
Dynamic LPAR memory removal	Y	Y	Y	Y	Y ^d	N
LPAR group absolute capping	Y	Y	Y	Y	Y	Y
Capacity Provisioning Manager	Y	Y	Y	N	N	N
Program-directed re-IPL	-	-	-	Y	Y	Y
Transactional Execution ^e	Y	Y	Y	Y ^f	Y ^f	Y ^f
Java Exploitation of Transactional Execution	Y	Y	Y	Y ^e	Y ^e	Y ^e
Simultaneous multithreading (SMT)	Y	Y	Y	Y	Y	Y
Single Instruction Multiple Data (SIMD)	Y	Y	Y	Y ^g	Y ^g	Y ^g
2 GB large page support	Y	Y	Y	N	N	N
Large page (1 MB) support	Y	Y	Y	Y ^h	Y ^h	Y ^h
Db2 exploitation of IBM Z zAIU	Y ⁱ	Y ⁱ	N	-	-	-
CPUMF (CPU measurement facility) for IBM z16	Y	Y	Y	Y	Y	Y
Flexible Capacity	Y	Y	Y	Y	Y	Y
IBM Virtual Flash Memory (VFM)	Y	Y	Y	N	N	N
1 MB pageable large pages	Y	Y	Y	N	N	N
Guarded Storage Facility (GSF)	Y	Y	Y	Y ^h	Y ^h	Y ^h
Instruction Execution Protection (IEP)	Y	Y	Y	Y ^h	Y ^h	Y ^h
Co-processor Compression Enhancements (CMPSC)	Y	Y ⁱ	Y ⁱ	N	N	N

Function ^a	z/OS V2R5	z/OS V2R4	z/OS V2R3	z/VM V7R3 ^b	z/VM V7R2	z/VM V7R1
IBM Integrated Accelerator for zEDC (on-chip compression)	Y	Y	Y	Y ^j	Y ^j	Y ^j
CPU MF Extended Counters	Y	Y	Y	Y	Y	Y
CF level 25 Enhancements	Y ^k	Y ^k	Y ^k	-	-	-
HiperDispatch Optimization	Y	Y	Y	Y ^h	Y ^h	Y ^h
System Recovery Boost Enhancements (IBM z16)	Y ^k	Y ^k	N/A	N/A	N/A	N/A
IBM Integrated Accelerator for Z SORT	Y	Y	Y ^k	Y ^h	Y ^h	Y ^h
ICSF Enhancements	Y	Y	Y	-	-	-
Guest support for Breaking Event Address Register (BEAR) Enhancement Facility	Y	Y	Y	Y	Y	Y
Guest support for Reset DAT protection Facility	Y	Y	Y	Y	Y	Y
zDNN library enablement for IBM Z Integrated Accelerator for AI	Y	Y ^l	N	-	-	-

- a. PTFs might be required for toleration support or use of IBM z16 features and functions.
- b. Planned GA for z/VM V7.3 is 3rd Q 2022.
- c. 80-way without multithreading; 40-way with multithreading enabled.
- d. With Service.
- e. Statement of Direction: In a future IBM Z hardware system family, the transactional execution and constrained transactional execution facility will no longer be supported. Users of the facility on current servers should always check the facility indications before use.
- f. Guests are informed that TX facility is available for use.
- g. Guests are informed that SIMD is available for use.
- h. Guest Exploitation support.
- i. With PTFs for use.
- j. Transparent for Guest support use of the gzip acceleration; guest support for z/OS Storage Compression.
- k. With Exploitation PTFs
- l. With Required PTFs

The supported base CPC functions for z/VSE, z/TPF, and Linux on IBM Z are listed in Table 7-4.

Table 7-4 Supported base CPC functions for z/VSE, z/TPF, and Linux on IBM Z

Function ^a	z/VSE V6R2	z/TPF V1R1	Linux on IBM Z ^b
IBM z16 servers	Y	Y	Y
Maximum processor unit (PUs) per system image	10	86	200 ^c
Maximum main storage size	32 GB	4 TB	16 TB ^d
Dynamic PU add	Y	N	Y
Dynamic LPAR memory upgrade	N	N	Y
LPAR group absolute capping	Y	N	N
Program-directed re-IPL	Y	N	Y
HiperDispatch	N	N	Y

Function ^a	z/VSE V6R2	z/TPF V1R1	Linux on IBM Z ^b
IBM Z Integrated Information Processors (zIIPs)	N	N	N
Java Exploitation of Transactional Execution	N	N	Y
Simultaneous multithreading (SMT)	N	N	Y ^e
Single Instruction Multiple Data (SIMD)	Y	N	Y
Hardware decimal floating point ^f	N	N	Y
2 GB large page support	N	Y	Y
Large page (1 MB) support	Y	Y	Y
CPUMF (CPU measurement facility) for IBM z16	N	Y	N ^g
AI accelerator exploitation	N	N	Y ^h
IBM Virtual Flash Memory (VFM)	N	N	Y
Guarded Storage Facility (GSF)	N	N	Y
Instruction Execution Protection (IEP)	N	N	Y
System Recovery Boost	Y ⁱ	Y ⁱ	N
Secure Boot (code integrity check)	-	-	Y ^j
Secure Execution Support for Linux	N/A	N/A	Y ^k
IBM Integrated Accelerator for zEDC (on-chip compression)	N	N	Y ^l
IBM Integrated Accelerator for Z SORT	N	N	N

- a. PTFs might be required for toleration support or exploitation of IBM z16 features and functions.
- b. Support statement varies based on Linux on IBM Z distribution and release.
- c. For SLES12/RHEL7/Ubuntu 16.04 and later, Linux kernel supports 256 cores without SMT and 128 cores with SMT (= 256 threads).
- d. IBM z16 A01 supports defining up to 32 TB per LPAR (OS support is required).
- e. On IFL only.
- f. Packed decimal conversion support.
- g. IBM is working with its Linux distribution Business Partners to provide this feature.
- h. Delivered with Linux distributions as a new package: libzdn.
- i. Subcapacity CP speed boost (no zIIP boost).
- j. For SCSI IPL.
- k. For second-level guests that are running under KVM.
- l. Requires Linux kernel exploitation support for gzip/zlib compression.

7.3.2 Coupling and clustering

The supported coupling and clustering functions for z/OS and z/VM are listed in Table 7-5.

Note: z/OS V2R2 support ended as of September 2020. No new function is provided for the use of the new hardware features (toleration support only). Although extended (fee-based) support for z/OS V2.R2 can be obtained, support for z/OS V2.R2 is not covered extensively in this document.

Table 7-5 Supported coupling and clustering functions for z/OS and z/VM

Function ^a	z/OS V2R5	z/OS V2R4	z/OS V2R3	z/VM V7R3	z/VM V7R2	z/VM V7R1
CFCC Level 25 ^b	Y	Y	Y	Y	Y	Y
CFCC Level 24 ^c	Y	Y	Y	Y	Y	Y
CFCC Level 23 ^d	Y	Y	Y	Y	Y	Y
CFCC Level 25 Coupling Facility Processor Scalability Enhancements	Y	Y	Y	Y	Y	Y
RMF coupling channel reporting	Y	Y	Y	N	N	N
z/VM Dynamic I/O support for ICA SR CHPIDs	-	-	-	Y	Y	Y
Asynchronous CF Duplexing for lock structures	Y	Y	Y	Y	Y	Y
Cache residency time metrics ^e	Y	Y	Y	N	N	N
Dynamic I/O activation for stand-alone CF ^f and for stand-alone Linux on Z and z/TPF ^g CPCs	Y	Y	Y	Y	Y	Y

a. PTFs are required for toleration support or use of IBM z16 features and functions.

b. CFCC Level 25 with Driver 51 (IBM z16).

c. CFCC Level 24 with Driver 41 (IBM z15).

d. CFCC Level 23 with Driver 36 (IBM z14).

e. With APAR OA60650.

f. Requires HMC 2.14.1(Driver 36) or newer and various OS fixes (HCD, HCM, IOS, IOCP)

g. Requires 2.3 or higher z/OS partition with APAR OA65559 applied, be running on an IBM z16, and Linux on Z and z/TPF also running on IBM z16. Both z16 CPCs require proper firmware level (Bundle S24 or higher). This configuration continues to support stand-alone CF Dynamic I/O activations.

In addition to operating system support that is listed in Table 7-5, Server Time Protocol is supported on z/TPF V1R1 and Linux on IBM Z. Also, CFCC Level 23, Level 24, and Level 25 are supported for z/TPF V1R1.

7.3.3 Storage connectivity

The supported storage connectivity functions for z/OS and z/VM are listed Table 7-6.

Table 7-6 Supported storage connectivity functions for z/OS and z/VM

Function ^a	z/OS V2R5	z/OS V2R4	z/OS V2R3	z/VM V7R3	z/VM V7R2	z/VM V7R1
zHyperLink Read Support for Db2 and VSAM	Y	Y	Y ^b	N	N	N
zHyperLink Write Support for Db2 logs	Y	Y	Y ^b	N	N	N
zHyperLink Writes support for asynchronous mirroring ^c	Y	Y ^b	Y ^b	N	N	N
zHyperLink Consistent read from metro mirror secondary ^d	Y	Y ^b	Y ^b	N	N	N
z/VM Dynamic I/O support for FICON FC and FCP CHPIDs	-	-	-	Y	Y	Y
CHPID (Channel-Path Identifier) type FC						
FICON support for zHPF (IBM Z High-Performance FICON)	Y	Y	Y	Y ^e	Y ^e	Y ^e
IBM Fibre Channel Endpoint Security ^f	Y	Y	Y	Y	Y	Y
FICON when using CTC (channel-to-channel)	Y	Y	Y	Y ^g	Y ^g	Y ^g
IPL from an alternative subchannel set	Y	Y	Y	N	N	N
32 K subchannels for FICON Express	Y	Y	Y	Y	Y	Y
Request node identification data (RNID)	Y	Y	Y	N	N	N
FICON link incident reporting	Y	Y	Y	N	N	N
CHPID (Channel-Path Identifier) type FCP						
FICON Express support of SCSI devices	-	-	-	Y	Y	Y
FICON Express support of hardware data router	-	-	-	Y ^e	Y ^e	Y ^e
FICON Express support of T10 Data Integrity Field (DIF)	-	-	-	Y ^e	Y ^e	Y ^e
N_Port ID Virtualization (NPIV)	-	-	-	Y	Y	Y
Worldwide port name tool	-	-	-	Y	Y	Y

a. PTFs might be required for toleration support or exploitation of IBM z16 features and functions.

b. With PTFs.

c. DS8900F only, 9.1 release with z/OS PTFs, does not include XRC.

d. DS8900F only, 9.2 release with z/OS PTFs.

e. For guest use.

f. FC 1146 (optional) is available for IBM z16 A01 and IBM z15 T01 only. Minimum, DS8910 or DS8890 storage, CPACF enablement and FICON Express16SA or FICON FICON Express32S LX/SX.

g. CTC channel type is now supported when CPC is managed in DPM mode. See 7.2.2, "z/VM" on page 254.

The supported storage connectivity functions for z/VSE, z/TPF, and Linux on IBM Z are listed in Table 7-7.

Table 7-7 Supported storage connectivity functions for z/VSE, z/TPF, and Linux on IBM Z

Function ^a	z/VSE V6R2	z/TPF V1R1	Linux on IBM Z ^b
The 63.75-K subchannels	N	N	Y
Six logical channel subsystems (LCSSs)	Y	N	Y
Four subchannel set per LCSS	Y	N	Y
CHPID (Channel-Path Identifier) type FC			
FICON Express support of zHPF (IBM Z High-Performance FICON) ^c	Y	Y	Y
IBM Fibre Channel Endpoint Security ^d	Y ^e	Y ^e	Y ^e
MIDAW (Modified Indirect Data Address Word)	N	N	N
FICON Express support for CTC (channel-to-channel)	Y	Y	Y ^f
IPL from an alternative subchannel set	N	N	N
32 K subchannels for FICON Express	N	N	Y
Request node identification data (RNID)	N	N	N
CHPID (Channel-Path Identifier) type FCP			
FICON Express support of SCSI devices	Y	-	Y
FICON Express support of hardware data router	N	N	Y
FICON Express support of T10 Data Integrity Field (DIF)	N	N	Y
N_Port ID Virtualization (NPIV)	Y	N	Y
Worldwide port name tool	-	-	Y

- a. PTFs might be required for toleration support or exploitation of IBM z16 features and functions.
- b. Support statement varies based on Linux on IBM Z distribution and release.
- c. Transparent to operating systems.
- d. FC 1146 (optional) is available for IBM z16 A01 and IBM z15 T01 only. Minimum, DS8910 or DS8890 storage, CPACF enablement and FICON Express16SA or FICON Express32S LX/SX.
- e. Feature is operating system-independent (that is transparent to the operating system); operating system support is needed only for displaying, configuration, and monitoring (fixes might be required).
- f. CTC channel type is now supported when CPC is managed in DPM mode.

7.3.4 Network connectivity

The supported network connectivity functions for z/OS and z/VM are listed in Table 7-8.

Statements of Direction^a: Consider the following points:

- ▶ IBM z16 is the last IBM Z server to support the OSE CHPID type.
- ▶ IBM z16 is the last IBM Z server to support OSA Express 1000BASE-T hardware adapters.
- ▶ z/OS V2R2 support ended as of September 2020. No new function is provided for the use of the hardware features (toleration support only). Although extended (fee-based) support for z/OS V2.R2 can be obtained, support for z/OS V2.R2 is not covered extensively in this document.

a. Statements by IBM regarding its plans, directions, and intent are subject to change or withdrawal without notice at the sole discretion of IBM.

Table 7-8 Supported network connectivity functions for z/OS and z/VM

Function ^a	z/OS V2R4	z/OS V2R3	z/OS V2R2	z/VM V7R2	z/VM V7R1	z/VM V6R4
Checksum offload for IPV6 packets	Y	Y	Y	Y ^b	Y ^b	Y ^b
Checksum offload for LPAR-to-LPAR traffic with IPv4 and IPv6	Y	Y	Y	Y ^b	Y ^b	Y ^b
QDIO data connection isolation for z/VM	-	-	-	Y	Y	Y
QDIO interface isolation for z/OS	Y	Y	Y	-	-	-
QDIO OLM (Optimized Latency Mode)	Y	Y	Y	-	-	-
QDIO Diagnostic Synchronization	Y	Y	Y	N	N	N
IWQ (Inbound Workload Queuing) for OSA	Y	Y	Y	Y ^b	Y ^b	Y ^b
GARP VLAN Registration Protocol	Y	Y	Y	Y	Y	Y
Link aggregation support for z/VM	-	-	-	Y	Y	Y
Multi-vSwitch Link Aggregation	-	-	-	Y	Y	Y
Large send for IPV6 packets	Y	Y	Y	Y ^b	Y ^b	Y ^b
z/VM Dynamic I/O Support for OSA-Express OSD CHPIDs	-	-	-	Y	Y	Y
OSA Dynamic LAN idle	Y	Y	Y	N	N	N
OSA Layer 3 virtual MAC for z/OS environments	Y	Y	Y	-	-	-
Network Traffic Analyzer	Y	Y	Y	N	N	N
HiperSockets						
HiperSockets ^c	Y	Y	Y	Y	Y	Y
HiperSockets Completion Queue	Y	Y	Y	Y	Y	Y
HiperSockets Virtual Switch Bridge	-	-	-	Y	Y	Y
HiperSockets Multiple Write Facility	Y	Y	Y	N	N	N
HiperSockets support of IPV6	Y	Y	Y	Y	Y	Y

Function ^a	z/OS V2R4	z/OS V2R3	z/OS V2R2	z/VM V7R2	z/VM V7R1	z/VM V6R4
HiperSockets Layer 2 support	Y	Y	Y	Y	Y	Y
SMC-D and SMC-R						
SMC-D ^d over ISM (Internal Shared Memory)	Y	Y	Y	Y ^b	Y ^b	Y ^b
25 GbE and 10 GbE RoCE Express3 for SMC-R	Y	Y	Y	Y ^b	Y ^b	Y ^b
25 GbE and 10 GbE RoCE Express3 and Express2/2.1 for Ethernet communications ^e including Single Root I/O Virtualization (SR-IOV)	N	N	N	Y ^b	Y ^b	Y ^b
z/VM Dynamic I/O support for RoCE Express	-	-	-	Y	Y	Y
Shared RoCE environment	Y	Y	Y	Y	Y	Y
Open Systems Adapter (OSA)^f						
OSA-Express7S 1.2 1000BASE-T Ethernet ^g CHPID type OSC and OSD	Y	Y	Y	Y	Y	Y
OSA-Express7S 1000BASE-T Ethernet CHPID type OSC and OSD	Y	Y	Y	Y	Y	Y
OSA-Express6S 1000BASE-T Ethernet CHPID types OSC and OSD	Y	Y	Y	Y	Y	Y
OSA-Express7S 1.2 25 GbE CHPID type OSD	Y	Y	Y	Y	Y	Y
OSA-Express7S 25-Gigabit Ethernet Short Reach (SR and SR1.1) CHPID type OSD	Y	Y ^h	Y ^h	Y	Y ⁱ	Y ⁱ
OSA-Express7S 1.2 10 GbE CHPID type OSD	Y	Y	Y	Y	Y	Y
OSA-Express7S 10-Gigabit Ethernet Long Reach (LR) and Short Reach (SR) CHPID type OSD	Y	Y	Y	Y	Y	Y
OSA-Express6S 10-Gigabit Ethernet Long Reach (LR) and Short Reach (SR) CHPID type OSD	Y	Y	Y	Y	Y	Y
OSA-Express7S 1.2 GbE CHPID type OSD and OSC	Y	Y	Y	Y	Y	Y
OSA-Express7S GbE CHPID type OSD and OSC	Y	Y	Y	Y	Y	Y
OSA-Express6S GbE CHPID type OSD	Y	Y	Y	Y	Y	Y
OSA-Express7S 1.2 1000BASE-T Ethernet CHPID type OSE ^j	Y	Y	Y	Y	Y	Y
OSA-Express7S 1000BASE-T Ethernet CHPID type OSE ^j	Y	Y	Y	Y	Y	Y
OSA-Express6S 1000BASE-T Ethernet CHPID type OSE ^j	Y	Y	Y	Y	Y	Y

a. PTFs might be required for toleration support or use of IBM z16 features and functions.

b. For guest use or exploitation.

c. On IBM z16, the CHPID statement of HiperSockets devices requires the keyword VCHID. If you are migrating from a zEC12 or earlier, the IBM z16 IOCP definitions must be migrated to support the HiperSockets definitions (from CHPID type IQD). VCHID specifies the virtual channel identification number that is associated with the channel path (valid range is 7C0 - 7FF).

d. Shared Memory Communications - Direct Memory Access.

e. Does not require a peer OSA.

- f. CHPID types OSM, OSN, OSX are no longer supported.
- g. Statements of Direction: IBM z16 will be the last IBM Z server to support OSA Express 1000BASE-T hardware adapters.
- h. Require PTFs for APARs OA55256 (IBM VTAM) and PI95703 (TCP/IP).
- i. Require PTF for APAR PI99085.
- j. Statements of Direction: IBM z16 will be the last IBM Z server to support the OSE CHPID type.

The supported network connectivity functions for z/VSE, z/TPF, and Linux on IBM Z are listed in Table 7-9.

Table 7-9 Supported network connectivity functions for z/VSE, z/TPF, and Linux on IBM Z

Function ^a	z/VSE V6R2	z/TPF V1R1	Linux on IBM Z ^b
Checksum offload for IPV6 packets	N	N	Y
Checksum offload for LPAR-to-LPAR traffic with IPv4 and IPv6	N	N	Y
QDIO Diagnostic Synchronization	N	N	N
Inbound Workload Queuing (IWQ) for OSA	N	N	N
GARP VLAN Registration Protocol	N	N	Y ^c
Multi-vSwitch Link Aggregation	N	N	N
Large send for IPV6 packets	N	N	Y
OSA Dynamic LAN idle	N	N	N
HiperSockets			
HiperSockets ^d	Y	N	Y
HiperSockets Completion Queue	Y	N	Y
HiperSockets Virtual Switch Bridge	-	-	Y ^e
HiperSockets support of IPV6	Y	N	Y
HiperSockets Layer 2 support	Y	N	Y
HiperSockets Network Traffic Analyzer for Linux on IBM Z	N	N	Y
SMC-D and SMC-R			
SMC-D ^f over ISM (Internal Shared Memory)	N	N	Y ^g
10 GbE RoCE ^h Express	N	N	Y ^{gi}
25 GbE and 10 GbE RoCE Express3 for SMC-R	N	N	Y ^{gi}
25 GbE and 10 GbE RoCE Express3 for Ethernet communications ^j including Single Root I/O Virtualization (SR-IOV)	N	N	Y ^{gi}
Shared RoCE environment	N	N	Y
Open Systems Adapter (OSA)			
OSA-Express7S 1.2 1000BASE-T Ethernet ^k CHPID type OSC and OSD	Y	Y	Y
OSA-Express7S 1000BASE-T Ethernet CHPID type OSC and OSD	Y	Y	Y

Function ^a	z/VSE V6R2	z/TPF V1R1	Linux on IBM Z ^b
OSA-Express6S 1000BASE-T Ethernet CHPID types OSC and OSD	Y	Y	Y
OSA-Express7S 1.2 25-GbE CHPID type OSD	Y	Y	Y
OSA-Express7S 25-Gigabit Ethernet Short Reach (SR and SR1.1) CHPID type OSD	Y	Y	Y
OSA-Express7S 1.2 10-GbE CHPID type OSD	Y	Y	Y
OSA-Express7S 10-Gigabit Ethernet Long Reach (LR) and Short Reach (SR) CHPID type OSD	Y	Y	Y
OSA-Express6S 10-Gigabit Ethernet Long Reach (LR) and Short Reach (SR) CHPID type OSD	Y	Y	Y
OSA-Express7S 1.2 GbE CHPID type OSD and OSC	Y	Y	Y
OSA-Express7S GbE CHPID type OSD and OSC	Y	Y	Y
OSA-Express6S GbE CHPID type OSD	Y	Y	Y
OSA-Express7S 1.2 1000BASE-T Ethernet CHPID type OSE ^l	Y	N	N
OSA-Express7S 1000BASE-T Ethernet CHPID type OSE ^j	Y	N	N
OSA-Express6S 1000BASE-T Ethernet CHPID type OSE ^j	Y	N	N

- a. PTFs might be required for toleration support or use of IBM z16 features and functions.
- b. Support statement varies based on Linux on IBM Z distribution and release.
- c. By using VLANs.
- d. On IBM z16, the CHPID statement of HiperSockets devices requires the keyword VCHID. Therefore, the IBM z16 IOCP definitions must be migrated to support the HiperSockets definitions (CHPID type IQD). VCHID specifies the virtual channel identification number that is associated with the channel path (valid range is 7C0 - 7FF). VCHID is not valid on IBM Z servers before IBM z13.
- e. Applicable to guest operating systems.
- f. Shared Memory Communications - Direct Memory Access.
- g. SMC-R and SMC-D are supported on Linux kernel; see: <https://linux-on-z.blogspot.com/p/smc-for-linux-on-ibm-z.html>
- h. Remote Direct Memory Access (RDMA) over Converged Ethernet.
- i. Linux can also use RocE Express as a standard NIC (Network Interface Card) for Ethernet.
- j. Does not require a peer OSA.
- k. Statements of Direction: IBM z16 will be the last IBM Z server to support OSA Express 1000BASE-T hardware adapters.
- l. Statements of Direction: IBM z16 will be the last IBM Z server to support the OSE CHPID type.

7.3.5 Cryptographic functions

the IBM z16 supported cryptography functions for z/OS and z/VM are listed in Table 7-10.

Note: z/OS V2R2 support ended as of September 2020. No new function is provided for leveraging the new HW features (toleration support only). Although extended (fee-based) support for z/OS V2.R2 can be obtained, support for z/OS V2.R2 is not covered extensively in this document.

Table 7-10 Supported cryptography functions for z/OS and z/VM

Function ^a	z/OS V2R5	z/OS V2R4	z/OS V2R3	z/VM V7R3	z/VM V7R2	z/VM V7R1
CP Assist for Cryptographic Function (CPACF)	Y	Y	Y	Y ^b	Y ^b	Y ^b
Support for 85 Domains	Y	Y	Y	Y ^b	Y ^b	Y ^b
CPACF support for: <ul style="list-style-type: none"> ▶ Encryption (DES, TDES, AES) ▶ Hashing (SHA-1, SHA-2, SHA-3, SHAKE) ▶ Random Number Generation (PRNG, DRNG, TRNG) 	Y	Y	Y	Y ^b	Y ^b	Y ^b
Crypto Express8S	Y	Y	Y	Y ^b	Y ^b	Y ^b
Crypto Express7S	Y	Y	Y	Y ^b	Y ^b	Y ^b
Crypto Express7S Support for Visa Format Preserving Encryption	Y	Y	Y	Y ^b	Y ^b	Y ^b
Crypto Express7S Support for Coprocessor in PCI-HSM Compliance Mode ^c	Y	Y	Y	Y ^b	Y ^b	Y ^b
Crypto Express6S	Y	Y	Y	Y ^b	Y ^b	Y ^b
Crypto Express6S Support for Visa Format Preserving Encryption	Y	Y	Y	Y ^b	Y ^b	Y ^b
Crypto Express6S Support for Coprocessor in PCI-HSM Compliance Mode ^d	Y	Y	Y	Y ^b	Y ^b	Y ^b
Elliptic Curve Cryptography (ECC)	Y	Y	Y	Y ^b	Y ^b	Y ^b
Secure IBM Enterprise PKCS #11 (EP11) coprocessor mode	Y	Y	Y	Y ^b	Y ^b	Y ^b
z/OS Data Set Encryption	Y	Y	Y	-	-	-
z/VM Encrypted paging support	-	-	-	Y	Y	Y
RMF Support for Crypto Express8, Express7, and Express6	Y	Y	Y	-	-	-
z/OS SMF Enhancements for CPACF	Y ^e	Y ^e	N	-	-	-
z/OS encryption readiness technology (zERT)	Y	Y	Y	-	-	-
ICFSF New Function Support	Y	Y ^e	Y ^e	-	-	-
Quantum-Safe Cryptography (QSC) for signing and key negotiation	Y	Y ^f	Y ^f	Y	Y	Y

a. PTFs might be required for toleration support or use of IBM z16 features and functions.

b. For guest use or exploitation.

c. Requires TKE 9.1 or newer.

- d. Requires TKE 9.2 or newer.
- e. Requires z/OS Exploitation support by way of APAR
- f. Requires Web deliverable HCR77D1

the IBM z16 supported cryptography functions for z/VSE, z/TPF, and Linux on IBM Z are listed in Table 7-11.

Table 7-11 Supported cryptography functions for z/VSE, z/TPF, and Linux on IBM Z

Function ^a	z/VSE V6R2	z/TPF V1R1	Linux on IBM Z ^b
CP Assist for Cryptographic Function (CPACF)	Y	Y	Y
Support for 85 Domains	Y	N	Y
CPACF support for: <ul style="list-style-type: none"> ▶ Encryption (DES, TDES, AES) ▶ Hashing (SHA-1, SHA-2, SHA-3, SHAKE) ▶ Random Number Generation (PRNG, DRNG, TRNG) 	Y	Y ^{cd}	Y
CPACF protected key	N	N	N
Crypto Express8S	Y	Y	Y
Crypto Express7S	Y	Y	Y
Crypto Support for Visa Format Preserving Encryption	N	N	N
Crypto Support for Coprocessor in PCI-HSM Compliance Mode	N	N	N
Crypto Express6S	Y	Y	Y
Elliptic Curve Cryptography (ECC)	Y	N	Y
Secure IBM Enterprise PKCS #11 (EP11) coprocessor mode	N	N	Y
z/TPF transparent database encryption	-	Y	-

- a. PTFs might be required for toleration support or use of IBM z16 features and functions.
- b. Support statement varies based on Linux on IBM Z distribution and release.
- c. z/TPF supports only AES-128 and AES-256.
- d. z/TPF supports only SHA-1 and SHA-256.

7.4 Support by features and functions

This section addresses operating system support by function. Only the currently in-support releases are covered.

Tables in this section use the following convention:

- ▶ N/A: Not applicable
- ▶ NA: Not available

7.4.1 LPAR Configuration and Management

A single system image can control multiple processor units (PUs), such as CPs, zIIPs, or IFLs.

Note: z/OS V2R2 support ended as of September 2020. No new function is provided for the use of the new hardware features (toleration support only). Although extended (fee-based) support for z/OS V2.R2 can be obtained, support for z/OS V2.R2 is not covered extensively in this document.

Maximum number of PUs per system image

The maximum number of PUs that is supported by each operating system image and by special-purpose LPARs are listed in Table 7-12 on page 270.

Table 7-12 Maximum number of PUs per system image

Operating system	Maximum number of PUs per system image
z/OS V2R5	256 ^{ab}
z/OS V2R4	256 ^{ab}
z/OS V2R3	256 ^{ab}
z/VM V7R3	80 ^c
z/VM V7R2	80 ^d
z/VM V7R1	80 ^e
z/VSE V6.2 and later	z/VSE Turbo Dispatcher can use up to 4 CPs, and tolerates up to 10-way LPARs
z/TPF V1R1	86 CPs
CFCC Level 25	16 CPs or ICFs (CPs and ICFs cannot be mixed)
Linux on IBM Z	<ul style="list-style-type: none"> ▶ SUSE Linux Enterprise Server 12 and later: 256 CPs or IFLs. ▶ Red Hat RHEL 7 and later: 256 CPs or IFLs. ▶ Ubuntu 20.04.1 LTS and later: 256 CPs or IFLs.
KVM Hypervisor	<p>The KVM hypervisor is offered with the following Linux distributions -- 256CPs or IFLs--:</p> <ul style="list-style-type: none"> ▶ SLES 12 SP5 and later ▶ RHEL 7.9 and later ▶ Ubuntu 20.04.1 LTS and later
Secure Service Container	80
GDPS Virtual Appliance	80

- a. IBM z16 A01 LPARs support 200-way without multithreading; 128-way with multithreading (SMT).
- b. Total characterizable PUs, including zIIPs and CPs.
- c. 80-way without multithreading and 40-way with multithreading enabled.
- d. 80-way without multithreading and 40-way with multithreading enabled.
- e. An 80-way without multithreading and 40-way with multithreading enabled. Requires PTF for APAR VM66265.

Maximum main storage size

The maximum amount of main storage that is supported by current operating systems is listed in Table 7-13. A maximum of 16 TB of main storage can be defined for an LPAR on an IBM z16 server.

Table 7-13 Maximum memory that is supported by the operating system

Operating system	Maximum supported main storage ^a
z/OS	z/OS V2R5 supports 16 TB. Prior z/OS releases support 4 TB
z/VM	z/VM V7R1 supports 2 TB while z/VM 7.2 ^b and z/VM 7.3 support 4 TB
z/VSE	z/VSE V6R2 supports 32 GB
z/TPF	z/TPF supports 4 TB
CFCC	Levels 23, 24 and 25 support up to 3 TB
Secure Service Containers	Supports up to 16 TB ^a
Linux on IBM Z (64-bit)	16 TB ^{a,c}

a. On IBM z16 A01, LPAR storage definition supports 32 TB (IBM z16 A01 supports up to 40 TB of usable memory).

b. With fix for APAR VM66173.

c. Support might vary by distribution. Check with your distribution provider.

IBM z16 Model A01 - Up to 85 LPARs

The IBM z16 A01 can be configured with up to 85 LPARs (same as previous models). Because channel subsystems can be shared by up to 15 LPARs, it is necessary to configure six channel subsystems to reach the 85 LPAR limit.

Remember: A virtual appliance that is deployed in a Secure Service Container runs in a dedicated LPAR. When activated, it reduces the maximum number of available LPARs by one.

Dynamic PU add

Planning an LPAR configuration includes defining reserved PUs that can be brought online when extra capacity is needed. Operating system support is required to use this capability without an IPL; that is, nondisruptively. This support is available in z/OS for some time.

The dynamic PU add function enhances this support by allowing you to dynamically define and change the number and type of reserved PUs in an LPAR profile, which removes any planning requirements. The new resources are immediately made available to the operating system and in the case of z/VM, to its guests.

The supported operating systems are listed in Table 7-3 on page 257 and Table 7-4 on page 258.

Dynamic LPAR memory upgrade

An LPAR can be defined with an initial and a reserved amount of memory. At activation time, the initial amount is made available to the partition and the reserved amount can be added later, partially or totally. Although these two memory zones do not have to be contiguous in real memory, they appear as logically contiguous to the operating system that runs in the LPAR.

z/OS can take advantage of this support and nondisruptively acquire and release memory from the reserved area. z/VM V7R1 and later can acquire memory nondisruptively and immediately make it available to guests.

z/VM virtualizes this support to its guests, which now also can increase their memory nondisruptively if supported by the guest operating system. Currently, releasing memory from z/VM is supported on z/VM V7.2 with PTFs³. Releasing memory from the z/VM guest depends on the guest's operating system support.

Linux on IBM Z also supports acquiring and releasing memory nondisruptively. This feature is enabled for SUSE Linux Enterprise Server 12 and RHEL 7.9 and later releases.

LPAR group absolute capping

Group absolute capping allows you to limit the amount of physical processor capacity that is used by an individual LPAR when a PU that is defined as a CP or an IFL is shared across a set of LPARs. This facility is designed to provide a physical capacity limit that is enforced as an absolute (versus a relative) limit. It is not affected by changes to the logical or physical configuration of the system. This physical capacity limit can be specified in units of CPs or IFLs.

Capacity Provisioning Manager

The provisioning architecture enables clients to better control the configuration and activation of the On/Off CoD. For more information, see Chapter 8, "System upgrades" on page 331. This process is inherently more flexible and can be automated. This capability can result in easier, faster, and more reliable management of the processing capacity.

The Capacity Provisioning Manager, which is a feature that was first available with z/OS V1R9, interfaces with z/OS Workload Manager (WLM) and implements capacity provisioning policies. Several implementation options are available, from an analysis mode that issues only guidelines, to an autonomic mode that provides fully automated operations.

Replacing manual monitoring with autonomic management or supporting manual operation with guidelines can help ensure that sufficient processing power is available with the least possible delay. The supported operating systems are listed in Table 7-3 on page 257.

Program-directed re-IPL

Program directed re-IPL allows an operating system to re-IPL without operator intervention. This function is supported for SCSI and IBM extended count key data (IBM ECKD) devices.

The supported operating systems are listed in Table 7-3 on page 257 and Table 7-4 on page 258.

IOCP

All IBM Z servers require a description of their I/O configuration. This description is stored in I/O configuration data set (IOCDS) files. The I/O configuration program (IOCP) allows for the creation of the IOCDS file from a source file that is known as the I/O configuration source (IOCS).

The IOCS file contains definitions of LPARs and channel subsystems. It also includes detailed information for each channel and path assignment, control unit, and device in the configuration.

³ z/VM Dynamic Memory Downgrade (releasing memory from z/VM LPAR) made available with PTFs for APAR VM66271. For more information, see: <http://www.vm.ibm.com/newfunction/#dmd>

IOCP for IBM z16 provides support for the following features:

- ▶ IBM z16 Base machine definition
- ▶ PCI function adapter for zHyperLink (HYL)
- ▶ PCI function adapter for RoCE Express3 (CX6)
- ▶ New hardware (announced with Driver 51)
- ▶ IOCP Dynamic I/O support for stand-alone CF, Linux on Z and z/TPF, running on z16 CPCs.

IOCP required level for IBM z16 servers:

- ▶ z/OS V2.R4 and older releases use the same IOCP FMID HIO1104
- ▶ z/OS V2.R5 uses IOCP FMID HIO1105

For more information, see the following publications:

- ▶ *Stand-Alone Input/Output Configuration Program User's Guide*, SB10-7180
- ▶ *Input/Output Configuration Program User's Guide for ICP IOCP*, SB10-7177

Dynamic Partition Manager V5.0

Dynamic Partition Manager V5.0 is available for managing IBM z16 that are running Linux. DPM 5.0 is available with HMC Driver Level 51 (HMC Version 2.16.0). IOCP does not need to configure a server that is running in DPM mode.

For more information, see *IBM Dynamic Partition Manager (DPM) Guide*, SB10-7182.

7.4.2 Base CPC features and functions

In this section, we describe the features and functions of Base CPC.

HiperDispatch

The **HIPERDISPATCH=YES/NO** parameter in the IEAOPTxx member of SYS1.PARMLIB and on the **SET OPT=xx** command controls whether HiperDispatch is enabled or disabled for a z/OS image. It can be changed dynamically, without an IPL or any outage.

In z/OS, the IEAOPTxx keyword **HIPERDISPATCH** defaults to YES when it is running on an IBM z16, IBM z15, or IBM z14 system.

The use of SMT on IBM z16 systems requires that HiperDispatch is enabled on the operating system. For more information, see “Simultaneous multithreading” on page 277.

Also, any LPAR that is running with more than 64 logical processors is required to operate in HiperDispatch Management Mode.

The following rules control this environment:

- ▶ If an LPAR is defined at IPL with more than 64 logical processors, the LPAR automatically operates in HiperDispatch Management Mode, regardless of the HIPERDISPATCH= specification.
- ▶ If logical processors are added to an LPAR that has 64 or fewer logical processors and the extra logical processors raise the number of logical processors to more than 64, the LPAR automatically operates in HiperDispatch Management Mode, regardless of the HIPERDISPATCH=YES/NO specification. That is, even if the LPAR has the HIPERDISPATCH=NO specification, that LPAR is converted to operate in HiperDispatch Management Mode.

- ▶ An LPAR with more than 64 logical processors that are running in HiperDispatch Management Mode cannot be reverted to run in non-HiperDispatch Management Mode.

HiperDispatch on IBM z16 systems uses chip and CPC drawer configuration to improve the access cache performance. It optimizes the system PU allocation with Chip/cluster/drawer cache structure on IBM Z servers.

The base support for IBM z16 is provided by PTFs that are identified by:

```
IBM.device.server.IBM z16-3931.requireservice
```

PR/SM on IBM z16 servers preferentially assigns memory for a system in one CPC drawer that is striped across the clusters of that drawer to take advantage of the lower latency memory access in a drawer. Also, PR/SM tries to consolidate storage onto drawers with the most processor entitlement.

With HiperDispatch enabled, PR/SM seeks to assign logical processors of a partition to the smallest number of PU chips within a drawer in cooperation with operating system to optimize shared cache usage.

PR/SM automatically keeps a partition's memory and logical processors on the same CPC drawer where possible. This arrangement looks simple for a partition, but it is a complex optimization for multiple logical partitions because some must be split among processors drawers.

All IBM z16 processor types can be dynamically reassigned except IFPs.

To use HiperDispatch effectively, WLM goal adjustment might be required. Review the WLM policies and goals and update them as necessary.

WLM policies can be changed without turning off HiperDispatch. A health check is provided to verify whether HiperDispatch is enabled on a system image.

z/VM V7R3, V7R2 and V7R1

z/VM also uses the HiperDispatch facility for improved processor efficiency by better use of the processor cache to take advantage of the cache-rich PU chip, node, and drawer design of the IBM z16 system.

CPU polarization support in Linux on IBM Z

You can optimize the operation of a vertical SMP environment by adjusting the SMP factor based on the workload demands. For more information about CPU polarization support in Linux on IBM Z, see this [IBM Documentation web page](#).

z/TPF

z/TPF on IBM z16 can use more processors immediately without reactivating the LPAR or IPLing the z/TPF system.

When z/TPF is running in a shared processor configuration, the achieved MIPS is higher when z/TPF uses a minimum set of processors.

In low-use periods, z/TPF minimizes the processor footprint by compressing TPF workload onto a minimal set of I-streams (engines), which reduces the effect on other LPARs and allows the entire CPC to operate more efficiently.

As a consequence, z/OS and z/VM experience less contention from the z/TPF system when the z/TPF system is operating at periods of low demand.

The supported operating systems are listed in Table 7-3 on page 257 and Table 7-4 on page 258.

zIIP support

zIIPs do not change the model capacity identifier of IBM z16 servers. IBM software product license charges that are based on the model capacity identifier are not affected by the addition of zIIPs.

No changes to applications are required to use zIIPs. They can be used by the following applications:

- ▶ Db2 V8 and later for z/OS data serving for applications that use data Distributed Relational Database Architecture (DRDA) over TCP/IP, such as data serving, data warehousing, and selected utilities.
- ▶ z/OS XML services.
- ▶ z/OS CIM Server.
- ▶ z/OS Communications Server for network encryption (Internet Protocol Security [IPsec]) and for large messages that are sent by HiperSockets.
- ▶ IBM GBS Scalable Architecture for Financial Reporting.
- ▶ IBM z/OS Global Mirror (formerly XRC) and System Data Mover.
- ▶ IBM z/OS Container Extensions.
- ▶ IBM OMEGAMON® XE on z/OS, OMEGAMON XE on Db2 Performance Expert, and Db2 Performance Monitor.
- ▶ Any Java application that uses the current IBM SDK.
- ▶ Java IBM Semeru Runtime offloading enablement for DLC models that use Integrated Accelerator for AI.
- ▶ WebSphere Application Server V5R1 and later, and products that are based on it, such as WebSphere Portal, WebSphere Enterprise Service Bus (WebSphere ESB), and WebSphere Business Integration (WBI) for z/OS.
- ▶ CICS/TS V2R3 and later.
- ▶ Db2 UDB for z/OS Version 8 and later.
- ▶ IMS Version 8 and later.
- ▶ zIIP Assisted HiperSockets for large messages.
- ▶ z/OSMF (z/OS Management Facility).
- ▶ IBM z/OS Platform for Apache Spark.
- ▶ IBM Watson® Machine Learning for z/OS.
- ▶ z/OS System Recovery Boost.
- ▶ Approved third-party vendor products.

The use of a zIIP is transparent to application programs. The supported operating systems are listed in Table 7-3 on page 257.

On IBM z16 servers, the zIIP processor is designed to run in SMT mode, with up to two threads per processor. This function is designed to help improve throughput for zIIP workloads and provide appropriate performance measurement, capacity planning, and SMF accounting data. zIIP support is available on all currently supported z/OS versions.

Use the **PROJECTCPU** option of the IEAOPTxx parmlib member to help determine whether zIIPs can be beneficial to the installation. Setting PROJECTCPU=YES directs z/OS to record the amount of eligible work for zIIPs in SMF record type 72 subtype 3.

The field APPL% IIPCP of the Workload Activity Report listing by WLM service class indicates the percentage of a processor that is zIIP eligible. Because of the zIIP's lower price as compared to a CP, even a utilization as low as 10% can provide cost benefits.

Transactional Execution⁴

Transactional Execution (TX) is known in academia and industry as *hardware transactional memory*. Transactional execution is implemented on IBM Z servers.

This feature enables software to indicate to the hardware the beginning and end of a group of instructions that must be treated in an atomic way. All of their results occur or none occur, in true transactional style. The execution is optimistic.

The hardware provides a memory area to record the original contents of affected registers and memory as instruction execution occurs. If the transactional execution group is canceled or must be rolled back, the hardware transactional memory is used to reset the values. Software can implement a fallback capability.

This capability increases the software's efficiency by providing a way to avoid locks (lock elision). This advantage is of special importance for speculative code generation and highly parallelized applications.

TX is used by IBM Java virtual machine (JVM) and might be used by other software. The supported operating systems are listed in Table 7-3 on page 257 and Table 7-4 on page 258.

System Recovery Boost

System Recovery Boost is a feature that was implemented on the IBM z15 system. The feature provides more temporary processor capacity and delivers substantially faster system shutdown and restart and critical system operations, such as stand-alone dump, short duration Recovery process boost for sysplex events, and fast catch-up of an accumulated backlog of critical workload after a planned or unplanned event.

⁴ Statement of Direction: In a future IBM Z hardware system family, the transactional execution and constrained transactional execution facility will no longer be supported. Users of the facility on current servers should always check the facility indications before use.

Added or increased IBM software costs are *not* incurred by using System Recovery Boost. With the IBM z16 system, more Recovery process boost scenarios are supported that allow the customer to define some boost granularity (see Table 7-14). For more information, see *IBM Z System Recovery Boost*, [REDP-5563](#).

Table 7-14 Operating system support for System Recovery Boost

Boost type ^a	z/OS V2R5	z/OS V2R4	z/OS V2R3	z/VM V7R3	z/VM V7R2	z/VM V7R1	z/TPF V1R1	z/VSE V6R2	Linux on IBM Z
Subcapacity Boost for IPL, Shutdown ^b	Y	Y	Y ^c	Y	Y	Y ^{cd}	Y ^c	Y ^c	N
zIIP boost ^e for IPL, shutdown, and dump events	Y	Y	Y ^c	N	N	N	N	N	N
Subcapacity and zIIP Boost for process recovery boost in a sysplex ^f .	Y	Y ^c	Y ^c	N	N	N	N	N	N
Recovery process boosts (IBM z16).	Y ^c	Y ^c	N	N	N	N	N	N	N

- a. Boost must be enabled for LPARs to opt in.
- b. Subcapacity Boost also is available for stand-alone memory dump on z/OS and z/VSE.
- c. With Fixes.
- d. Subcapacity boost might be available during the boost period to guest operating systems, except for z/OS.
- e. Allows CP work to be dispatched on zIIPs. zIIP processor capacity boost is available only if the customer has at least one active processor that is characterized as zIIP. For IBM z16l A01 and IBM z15 T01 only, more zIIPs can be used if obtained through eBOD (temporary zIIP boost records).
- f. Process recovery boosts support subcapacity CPs speed boost and entitled (purchased) customer zIIPs only; zIIPs that are provided by FC 9930 and FC 6802 cannot be used for process recovery boosts.

Automation

The client's automation product can be used to automate and control the following System Recovery Boost activities:

- ▶ To activate and deactivate the eBod temporary capacity record to provide more physical zIIPs for an IPL or Shutdown Boost.
- ▶ To dynamically modify LPAR weights, as might be needed to modify sharing physical zIIP capacity during a Boost period.
- ▶ To drive the invocation of the PROC that indicates the beginning of a shutdown process (and the start of the shut-down Boost).
- ▶ To take advantage of new composite hardware API reconfiguration actions.
- ▶ To control the level of parallelism that is present in the workload at startup (for example, starting middleware regions) and shutdown (for example, performing an orderly shutdown of middleware).

Simultaneous multithreading

SMT is the hardware capability to process up to two simultaneous threads in a single core, which shares the resources of the core, such as cache, translation lookaside buffer (TLB), and execution resources. This sharing improves system capacity and efficiency by reducing processor delays, which increases the overall throughput of the system.

SMT⁵ is supported for zIIPs and IFLs.

⁵ SMT is also enabled (not user configurable) by default for SAPs.

Note: For zIIPs and IFLs, SMT must be enabled on z/OS, z/VM, or Linux on IBM Z instances. An operating system with SMT support can be configured to dispatch work to a thread on a zIIP (for eligible workloads in z/OS) or an IFL (for z/VM) core in single-thread or SMT mode.

The supported operating systems are listed in Table 7-3 on page 257 and Table 7-4 on page 258.

An operating system that uses SMT controls each core and is responsible for maximizing its throughput and meeting workload goals with the smallest number of cores. In z/OS, consider HiperDispatch cache optimization when you must choose the two threads to be dispatched in the same processor.

HiperDispatch attempts to dispatch guest virtual CPUs on the same logical processor on which they ran. PR/SM attempts to dispatch a vertical low logical processor in the same physical processor. If that process is not possible, it attempts to dispatch it in the same node, or then the same CPC drawer where it was dispatched before to maximize cache reuse.

From the perspective of an application, SMT is transparent and no changes are required in the application for it to run in an SMT environment, as shown in Figure 7-1.

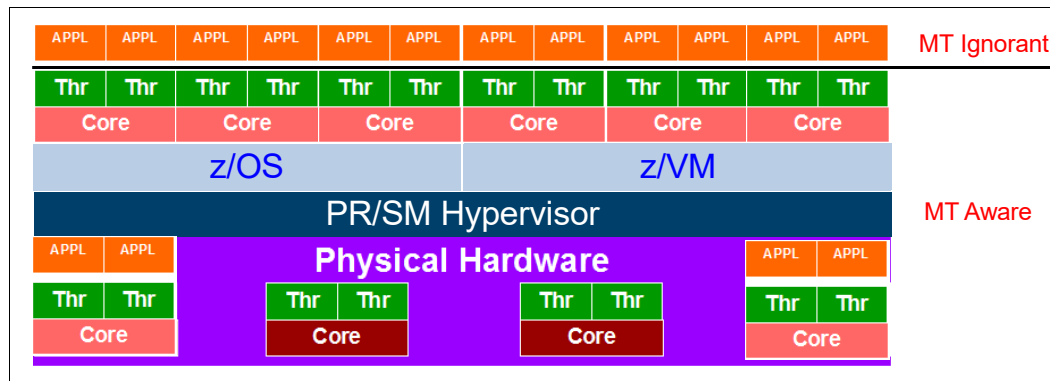


Figure 7-1 Simultaneous multithreading

z/OS

The use of SMT on z/OS requires enabling HiperDispatch, and defining the processor view (**PROCVIEW**) control statement in the LOADxx parmlib member and the **MT_ZIIP_MODE** parameter in the IEAOPTxx parmlib member.

The **PROCVIEW** statement is defined for the life of IPL, and can have the following values:

- ▶ **CORE:** This value specifies that z/OS should configure a processor view of core, in which a core can include one or more threads. The number of threads is limited by IBM z16 to two threads. If the underlying hardware does not support SMT, a core is limited to one thread.
- ▶ **CPU:** This value is the default. It specifies that z/OS should configure a traditional processor view of CPU and not use SMT.
- ▶ **CORE,CPU_OK:** This value specifies that z/OS should configure a processor view of core (as with the **CORE** value) but the **CPU** parameter is accepted as an alias for applicable commands.

When **PROCVIEW CORE** or **CORE,CPU_OK** are specified in z/OS that is running on an IBM z16, HiperDispatch is forced to run as enabled, and you cannot disable HiperDispatch. The **PROCVIEW** statement cannot be changed dynamically; therefore, you must re-IPL after changing it to make the new setting effective.

The **MT_ZIIP_MODE** parameter in the IEAOPTxx controls zIIP SMT mode. It can be 1 (the default), where only one thread can be running in a core, or 2, where up two threads can be running in a core. If **PROCVIEW CPU** is specified, the **MT_ZIIP_MODE** is always 1. Otherwise, the use of SMT to dispatch two threads in a single zIIP logical processor (**MT_ZIIP_MODE=2**) can be changed dynamically by using the **SET OPT=xx** setting in the IEAOPTxx parmlib. Changing the MT mode for all cores can take some time to complete.

PROCVIEW CORE requires **DISPLAY M=CORE** and **CONFIG CORE** to display the core states and configure an entire core.

With the introduction of Multi-Threading support for SAPs, a maximum of 88 logical SAPs can be used. RMF is updated to support this change by implementing page break support in the I/O Queuing Activity report that is generated by the RMF Post processor.

z/VM V7R3, V7R2, and V7R1

The use of SMT in z/VM is enabled by using the **MULTITHREADING** statement in the system configuration file. Multithreading is enabled only if z/VM is configured to run with the HiperDispatch vertical polarization mode enabled and with the dispatcher work distribution mode set to reshuffle.

The default in z/VM is multithreading disabled. Dynamic SMT enables dynamically varying the active threads per core. The number of active threads per core can be changed dynamically without a system outage and potential capacity gains going from SMT-1 to SMT-2 (one to two threads per core) can be achieved dynamically.

z/VM V7R3, V7R2, and V7R1 support up to 40 multithreaded cores (80 threads) for IFLs, and each thread is treated as an independent processor. z/VM dispatches virtual IFLs on the IFL logical processor so that the same or different guests can share a core. Each core has a single dispatch vector, and z/VM attempts to place virtual sibling IFLs on the same dispatch vector to maximize cache reuses.

z/VM guests have no awareness of SMT, and cannot use it directly. z/VM SMT use does not include guest support for multithreading. The value of this support for guests is that the first-level z/VM host of the guests can achieve higher throughput from the multi-threaded IFL cores.

Linux on IBM Z and the KVM hypervisor

The Linux kernel features [SMT functions](#) that were developed by the Linux on IBM Z development team. SMT is supported on LPAR only (not as a second-level guest).

The following *minimum* releases of Linux on IBM Z distributions are supported on IBM z16 (native SMT support):

- ▶ SUSE:
 - SLES 16
 - SLES 15 SP3 with service
 - SUSE SLES 12 SP5 with service

- ▶ Red Hat:
 - Red Hat RHEL 9.0
 - Red Hat RHEL 8.4 with service
 - Red Hat RHEL 7.9 with service
- ▶ Ubuntu:
 - Ubuntu 22.04 LTS
 - Ubuntu 21.10
 - Ubuntu 20.04.1 LTS with service

The KVM hypervisor is supported on the same Linux on IBM Z distributions in this list.

For more information about the most current support, see the Linux on IBM Z Tested platforms [website](#).

Single-instruction multiple-data

The SIMD feature introduces a new set of instructions to enable parallel computing that can accelerate code with string, character, integer, and floating point data types. The SIMD instructions allow many operands to be processed with a single complex instruction.

IBM z16 is equipped with a set of instructions to improve the performance of complex mathematical models and analytic workloads through vector processing and complex instructions, which can process numerous data with a single instruction. This set of instructions, which is known as SIMD, enables more consolidation of analytic workloads and business transactions on IBM Z servers.

SIMD on IBM z16 has support for enhanced math libraries that provide performance improvements for analytical workloads by processing more information with a single CPU instruction.

The supported operating systems are listed in Table 7-3 on page 257 and Table 7-4 on page 258. Operating System support includes the following features⁶:

- ▶ Enablement of vector registers.
- ▶ A math library with an optimized and tuned math function (Mathematical Acceleration Subsystem [MASS]) that can be used in place of some of the C standard math functions. It includes a SIMD vectorized and nonvectorized version.
- ▶ A specialized math library, which is known as Automatically Tuned Linear Algebra Software (ATLAS), that is optimized for the hardware.
- ▶ IBM Language Environment® for C runtime function enablement for ATLAS.
- ▶ DBX to support the disassembly of the new vector instructions, and to display and set vector registers.
- ▶ XML SS exploitation to use new vector processing instructions to improve performance.

MASS and ATLAS can reduce the time and effort for middleware and application developers. IBM provides compiler built-in functions for SIMD that software applications can use as needed, such as for using string instructions.

⁶ The features that are listed here might not be available on all operating systems that are listed in the tables.

The use of new hardware instructions require the z/OS V2R5 XL C/C++ compiler with ARCH(14) and TUNE(14) options for targeting IBM z16 instructions. The ARCH(14) compiler option allows the compiler to use any new IBM z16 instructions where suitable. The TUNE(14) compiler option allows the compiler to tune for any IBM z16 micro-architecture.

Vector programming support is extended for IBM z16 to provide access to the new instructions that were introduced by the VEF 2⁷ specification.

Older levels of z/OS XL C/C++ compilers do not provide IBM z16 exploitation; however, the z/OS V2R5 XL C/C++ compiler can be used to generate code for the older levels of z/OS running on IBM z16.

The followings compilers include built-in functions for SIMD:

- ▶ IBM Java
- ▶ XL C/C++
- ▶ Enterprise COBOL
- ▶ Enterprise PL/I

Code must be developed to use the SIMD functions. Applications with SIMD instructions abend if they run on a lower hardware level system that do not support SIMD. Some mathematical function replacement can be done without code changes by including the scalar MASS library before the standard math library.

Because the MASS and standard math library include different accuracies, assess the accuracy of the functions in the context of the user application before deciding whether to use the MASS and ATLAS libraries.

The SIMD functions can be disabled in z/OS partitions at IPL time by using the **MACHMIG** parameter in the LOADxx member. To disable SIMD code, use the MACHMIG VEF hardware-based vector facility. If you do not specify a **MACHMIG** statement, which is the default, the system not limited in its use of the Vector Facility for z/Architecture (SIMD).

Hardware decimal floating point

Industry support for decimal floating point is growing, with IBM leading the open standard definition. Examples of support for the draft standard IEEE 754r include Java BigDecimal, C#, XML, C/C++, GCC, COBOL, and other key software vendors, such as Microsoft and SAP.

IBM z16 introduces COBOL optimization for Hexadecimal Floating Point (HFP) <--> Binary Coded Decimal (BCD) conversion, and Numeric Editing, and Zoned Decimal operations.

The supported operating systems are listed in Table 7-3 on page 257 and Table 7-4 on page 258. For more information, see 7.5.8, “z/OS XL C/C++ considerations” on page 325.

Out-of-order execution

Out-of-order (OOO) execution yields significant performance benefits for compute-intensive applications by reordering instruction execution, which allows later (newer) instructions to be run ahead of a stalled instruction, and reordering storage accesses and parallel storage accesses. OOO maintains good performance growth for traditional applications.

The supported operating systems are listed in Table 7-3 on page 257 and Table 7-4 on page 258. For more information, see “3.4.3, “Out-of-Order execution” on page 83.

⁷ Hardware-based Vector-extension facility 2.

z/OS DFSORT exploitation of IBM Integrated Accelerator for Z Sort

The Integrated Accelerator for Z Sort is an on chip hardware feature that is available on IBM z15 and newer servers. It is driven by the SORT LISTS (SORTL) instruction.

z/OS DFSORT takes advantage of Z Sort, and provides users with significant performance boosts for their sort workloads. With z/OS DFSORT's Z Sort algorithm, clients can see batch sort job elapsed time improvements of up to 20 - 30% (depending on record size) and CPU time improvements of up to 40% compared to IBM z14.

The function is used on z/OS V2.R5 and enabled on z/OS V2.R4 and V2.R3 with PTFs for APAR PH03207.

The sort jobs must meet certain eligibility criteria. For the full list and other considerations, see the DFSORT User Guide for PH03207.

CPU Measurement Facility

Also known as Hardware Instrumentation Services (HIS), CPU Measurement Facility (CPUMF) data can be collected by z/OS System Measurement Facility on SMF 113 records to gain insight into the interaction of workload and hardware on which it runs.

The supported operating systems are listed in Table 7-3 on page 257.

For more information about this function, see this [IBM Support web page](#).

For more information about the CPU Measurement Facility, see this [IBM Support web page](#).

For more information, see “12.2, “IBM z16 Large System Performance Reference ratio” on page 480.

z/OS SMF Enhancements for CPACF

SMF 0 records were enhanced to indicate the number of crypto counters that are supported by the current IBM Z hardware.

SMF 30 records were enhanced to include new crypto counter sections that contain counters for CPACF cryptographic instructions that are used by a job in a specific period. These sections are produced only for those instructions that are used.

These counters are correlated with z/OS jobs and users for the determination of the algorithms, bit lengths, and key security that is used by a specific workload. This data can aid in compliance, performance, and configuration.

The SMF 30 self-defining section indicates the length and number of crypto counter sections.

The SMF 30 product and subsystem section indicates whether the crypto counters are active.

This feature is supported on z/OS 2.4 and later. It requires APAR OA61511.

Large page support

In addition to the 1-MB large pages, 4-KB pages, and page frames, IBM z16 servers support pageable 1-MB large pages, large pages that are 2 GB, and large page frames.

z/OS V2.R5 allows 2 GB LFAREA to exceed the 4 TB limit, up to 16 TB. All online real storage over 4 TB is part of the 2 GB LFAREA, in addition to what was specified in LFAREA.

Real memory is available for 2 GB pages only.

Applications that make use of 2 GB frames should be reviewed to use more frames if applicable (for example, Java and Db2).

The supported operating systems are listed in Table 7-3 on page 257 and Table 7-4 on page 258.

AI accelerator exploitation

With the IBM z16 Integrated Accelerator for AI, customers can benefit from the acceleration of AI operations, such as fraud detection, customer behavior predictions, and streamlining of supply chain operations; all in real time. AI accelerator is designed to deliver AI inference in real time, at large scale and rate, with no transaction left behind so that customers can instantly derive the valuable insights from their data.

The AI capability is applied directly into the running transaction, shifting the traditional paradigm of applying AI to the transactions that were completed. This innovative technology can be used for intelligent IT workloads placement algorithms and contribute to better overall system performance. The co-processor is driven by the new Neural Networks Processing Assist (NNPA) instruction.

NNPA is a new nonprivileged Complex Instruction Set Computer (CISC) memory-to-memory instruction that operates on tensor objects that are in client application program memory. AI functions and macros are abstracted by way of NNPA.

Virtual Flash Memory

IBM Virtual Flash Memory (FC 0644) offers up to 6.0 TB of memory for IBM z16 A01. VFM is provided for improved application availability and to handle paging workload spikes.

IBM Virtual Flash Memory is designed to help improve availability and handling of paging workload spikes when running z/OS. With this support, z/OS is designed to help improve system availability and responsiveness by using VFM across transitional workload events, such as market openings, and diagnostic data collection. z/OS also helps improve processor performance by supporting middleware use of pageable large (1 MB) pages.

VFM can help organizations meet their most demanding service level agreements and compete more effectively. VFM is easily configurable, and provides rapid time to value.

The supported operating systems are listed in Table 7-3 on page 257 and Table 7-4 on page 258.

Guarded Storage Facility

Also known as *less-pausing garbage collection*, Guarded Storage Facility (GSF) is an architecture that was introduced with IBM z14 to enable enterprise scale Java applications to run without periodic pause for garbage collection on larger heaps.

z/OS

GSF support allows an area of storage to be identified such that an Exit routine assumes control if a reference is made to that storage. GSF is managed by new instructions that define Guarded Storage Controls and system code to maintain that control information across undispach and redispach.

Enabling a less-pausing approach improves Java garbage collection. Function is provided on IBM z14 and subsequent servers that are running z/OS V2.R2 and later with APAR OA51643 installed. The **MACHMIG** statement in **LOADxx** of **SYS1.PARMLIB** disables the function.

z/VM

GSF is designed to improve the performance of garbage-collection processing by various languages, in particular Java.

The supported operating systems are listed in Table 7-3 on page 257 and Table 7-4 on page 258.

Instruction Execution Protection

Instruction Execution Protection (IEP) is a hardware function that enables software, such as Language Environment, to mark specific memory regions (for example, a heap or stack), as nonexecutable to improve the security of programs that are running on IBM Z servers against stack-overflow or similar attacks.

Through enhanced hardware features (based on DAT table entry bit) and specific software requests to obtain memory areas as nonexecutable, areas of memory can be protected from unauthorized execution. A Protection Exception occurs if an attempt is made to fetch an instruction from an address in such an element or if an address in such an element is the target of an execute-type instruction.

z/OS

To use IEP, Real Storage Manager (RSM) is enhanced to request nonexecutable memory allocation. Use new keyword **EXECUTABLE=YES|NO** on **STORAGE OBTAIN** or **IARV64** to indicate whether memory that is to be used contains executable code. Recovery Termination Manager (RTM) writes LOGREC record of any program-check that results from IEP.

IEP support is for z/OS V2.R2 and later running on IBM z16 with APARs OA51030 and OA51643 installed.

z/VM

Guest exploitation support for the Instruction Execution Protection Facility is provided with APAR VM65986.

The supported operating systems are listed in Table 7-3 on page 257 and Table 7-4 on page 258.

Secure Boot

Secure Boot verification ensures that the Linux distribution kernel comes from an official provider and was not compromised. If the signature of the distribution cannot be verified, the process of booting the operating system is stopped.

The Secure Boot feature requires operating system support.

IBM Integrated Accelerator for zEnterprise Data Compression

The IBM Integrated Accelerator for zEnterprise Data Compression (zEDC) is implemented as on-chip data compression accelerator; that is, Nest Compression Accelerator (NXU) and supports Deflate/gzip/zlib algorithms.

For more information, see Appendix C, “IBM Integrated Accelerator for zEnterprise Data Compression” on page 511.

Each PU chip includes one on-chip compression unit, which is designed to replace the zEnterprise Data Compression (zEDC) Express PCIe feature that is available on IBM z14 and earlier.

Note: The zEDC Express feature that is available on older systems is *not* carried forward to IBM z16.

The IBM Integrated Accelerator for zEDC maintains software compatibility with zEDC Express use cases. For more information, see [Integrated Accelerator for zEnterprise Data Compression](#).

The z/OS zEDC capability is a software-priced feature that is designed to support compression capable hardware. With IBM z16, the zEDC feature is implemented in the on-chip compression accelerator unit, but the software (z/OS) component is required to maintain the same functions as previous PCIe-based zEDC features.

All data interchange with zEDC compressed data remains compatible as IBM z16 and zEDC capable machines coexist (accessing same data). Data that is compressed and written with zEDC can be read and decompressed by IBM z16 well into the future.

The on-chip compression unit has the following operating modes:

- ▶ Synchronous execution in Problem State, where user application starts instruction in its virtual address space. This mode provides low latency and high-bandwidth compression and decompression operations. It does not require any special hypervisor support, which removes the virtualization layer (sharing the zEDC Express PCIe adapter among LPARs requires virtualization support).
- ▶ Asynchronous optimization for Large Operations under z/OS. The authorized application (for example, BSAM/QSAM) issues I/O for asynchronous execution and SAP (PU) starts instruction (synchronously) on behalf of application. The on-chip accelerator enables load balancing of high compression loads and low latency and high bandwidth compared to zEDC Express, while maintaining current user experience on compression.

Function support for the IBM Integrated Accelerator for zEDC is listed in Table 7-3 on page 257 and Table 7-4 on page 258.

For more information, see Appendix C, “IBM Integrated Accelerator for zEnterprise Data Compression” on page 511.

7.4.3 Coupling and clustering features and functions

In this section, we describe the coupling and cluster features.

Coupling facility and CFCC considerations

Coupling facility (CF) connectivity to an IBM z16 is supported on the z16, IBM z14, or another IBM z16. The CFCC levels that are supported on IBM Z are listed in Table 7-15.

Table 7-15 IBM Z CFCC code-levels

IBM Z server	Code level
IBM z16 A01	CFCC Level 25
IBM z15 T01 and T02	CFCC Level 24
IBM z14M0x and IBM z14ZR1	CFCC Level 23 ^a

a. CFCC Level 22 is not supported when an IBM z16 participates in the sysplex

Consideration: Because coupling link connectivity on IBM z16, IBM z15, and IBM z14 ZR1 do not support InfiniBand, you must carefully plan your configuration if IBM z14 M0x systems with InfiniBand coupling are present in your configuration. Also, consider the level of CFCC. For more information, see “Migration considerations” on page 194.

CFCC Level 25

CFCC Level 25 is delivered on IBM z16 servers with driver level 51 and introduces the following enhancements:

- ▶ Scalability Improvements

Processing and dispatching enhancements that result in meaningful scaling of effective throughput up to the limit of 16 ICF processors.

- ▶ Request latency/performance improvements

CFCC and coupling link firmware and hardware improvements to reduce link latency.

- ▶ Elimination of VSAM RLS orphaned cast-out lock problems and improved VSAM RLS Structure Full recovery processing.

Addresses reoccurring problems that are encountered by installations running VSAM RLS data sharing.

Retry Buffer support that is used on list and lock commands is extended to nonidempotent cache commands and optimized lock commands.

The new support also allows connectors to lock structures to specify a percentage of record data entries to be reserved. These reserved entries are off limits to normal requests to the coupling facility and can be used only if a new keyword is used on lock requests that generate record data entries.

- ▶ Cache residency time metrics

The CF calculates in microseconds by way of a moving weighted average the elapsed time a data area or directory entry resides in a storage class before it is reclaimed. XES returns this information on an IXLCACHE REQUEST=READSTGSTATS and IXLMG STRNAME=stname,STGCLASS=stgclass request.

- ▶ DYNDISP=ONIOFF is deprecated

For CFCC Level 25, DYNDISP=THIN is the only available behavior for shared-engine CF dispatching.

Specifying OFF or ON in CF commands and the CF configuration file is preserved for compatibility, but a warning message is issued to indicate that these options are no longer supported, and that DYNDISP=THIN behavior is to be used.

Before you begin the migration process, install the compatibility and coexistence PTFs. A planned outage is required when you upgrade the CF or CF LPAR to CFCC Level 25.

CFCC Level 24

CFCC Level 24 is delivered on IBM z16 servers with driver level 41. CFCC Level 24 introduced the following enhancements:

- ▶ CFCC Fair Latch Manager

This enhancement to the internals of the Coupling Facility (CFCC) dispatcher provides CF work management efficiency and processor scalability improvements. It also improves the “fairness” of arbitration for internal CF resource latches across tasks

► CFCC Message Path Resiliency

CF Message Paths use a z/OS-provided system identifier (SYID) to uniquely identify which z/OS system image (and instance of that system image) is sending requests over a message path to the CF. With IBM z15, we are providing a new resiliency mechanism that transparently recovers for this “missing” message path deactivate (if and when that deactivation ever occurs).

During path initialization, the CF provides more information to z/OS about every message path that appears active, including the SYID for the path. Whenever z/OS interrogates the state of the message paths to the CF, z/OS checks this SYID information for currency and correctness, and if incorrect, gather diagnostic information and reactivates the path to correct the problem.

► CF monopolization avoidance

z/OS takes advantage of current CF support in CFLEVEL 24 (IBM z15 T01/T02) to deliver improved z/OS support for handling CF monopolization.

With IBM z15 T01/T02, the CF dispatcher monitors in real-time the number of CF tasks that have a command assigned to them for a specific structure on a structure-by-structure basis.

When the number of CF tasks that is used by any structure exceeds a model-dependent CF threshold, and a global threshold on the number of active tasks also is exceeded, the structure is considered to be “monopolizing” the CF. z/OS is informed of this monopolization.

New support in z/OS observes the monopolization state for a structure, and starts to selectively queue and throttle incoming requests to the CF on a structure-specific basis. Other requests for other “non-monopolizing” structures and workloads are unaffected.

z/OS dynamically manages the queue of requests for the “monopolizing” structures to limit the number of active CF requests (parallelism) to them, and monitors the CF’s monopolization state information so as to observe the structure becoming “non-monopolized” again, so that request processing can eventually revert back to a non-throttled mode of operation.

The overall goal of z/OS anti-monopolization support is to protect the ability of ALL well-behaved structures and workloads to access the CF, and get their requests processed in the CF in a timely fashion. At the same time, it implements queuing and throttling mechanisms in z/OS to hold back the specific abusive workloads that are causing problems for other workloads.

z/OS XCF/XES use of APAR support is required to provide this function.

► CFCC Change Shared-Engine *CF Default* to **DYNDISP=THIN**

Coupling Facility images can run with shared or dedicated processors. Shared processor CFs can operate with different Dynamic Dispatching (DYNDISP) models:

- **DYNDISP=OFF**: LPAR timeslicing controls the CF processor.
- **DYNDISP=ON**: An optimization over pure LPAR timeslicing, in which the CFCC code manages timer interrupts to share processors more efficiently.
- **DYNDISP=THIN**: An interrupt-driven model in which the CF processor is dispatched in response to a set of events that generate Thin Interrupts.

Thin Interrupt support was available since zEC12/zBC12,. It is proven to be efficient and well-performing in numerous different test and customer shared-engine coupling facility configurations.

Therefore, IBM z15 made **DYNDISP=THIN** the *default mode* of operation for coupling facility images that use shared processors.

CFCC Level 23

CFCC Level 23 is delivered on IBM z14 servers with driver level 36. In addition to CFCC Level 22 enhancements, it introduces the following enhancements:

- ▶ Asynchronous cross invalidation (XI) for CF cache structures
This enhancement requires z/OS fixes for APARs OA54688 (exploitation) and OA54985 (toleration). It also requires specific data manager support (Db2 V12 with PTFs).
- ▶ Coupling Facility hang detection
These enhancements provide a significant reduction in failure scope and client disruption (CF-level to structure-level), with no loss of FFDC collection capability. With this support, the CFCC dispatcher significantly reduces the CF hang detection interval to only 2 seconds, which allows more timely detection and recovery from such events.
When a hang is detected, in most cases the CF confines the scope of the failure to “structure damage” for the single CF structure the hung command was processing against, captures diagnostics with a nondisruptive CF dump, and continues operating without stopping or rebooting the CF image.
- ▶ Coupling Facility granular latching
This enhancement eliminates the performance degradation that is caused by structure-wide latching. With this support, most CF list and lock structure ECR processing no longer uses structure-wide latching. It serializes its execution by using the normal structure object latches that all mainline commands use. However, a few “edge conditions” in ECR processing still require structure-wide latching.

For more information about CFCC code levels, see [the Parallel Sysplex page](#) of the IBM IT infrastructure website.

For more information about the latest CFCC code levels, see [the current exception letter](#) that is published on Resource Link website (login is required).

CF structure sizing changes are expected when upgrading from a previous CFCC Level to CFCC Level 25. In fact, CFLEVEL 25 can have more noticeable CF structure size increases associated with it, especially for smaller structures, because of task-related memory increases that are associated with the increased number of CF tasks in CFLEVEL 25

Review the CF LPAR size by using the [CFSizer tool](#).

Alternatively, the batch [SIZER utility](#) also can be used for re-sizing your CF structures as needed. Make sure to update CFRM Policy INITISIZE or SIZE values as needed.

Coupling links support

Integrated Coupling Adapter (ICA) Short Reach and Coupling Express2 Long Reach (CE2 LR) coupling link options provide high-speed connectivity at short and longer distances over fiber optic interconnections.

For more information, see 4.6.4, “Parallel Sysplex connectivity” on page 190.

Integrated Coupling Adapter

PCIe Gen3 coupling fan-out, which is also known as Integrated Coupling Adapter Short Reach (ICA SR, ICA SR1.1), supports a maximum distance of 150 meters (492 feet) and is defined as CHPID type CS5 in IOCP.

***Coupling Express2 Long Reach*⁸**

The CE LR link provides point-to-point coupling connectivity at distances of 10 km (6.21 miles) unrepeated and defined as CHPID type CL5 in IOCP. The supported operating systems are listed in Table 7-5 on page 260.

Virtual Flash Memory use by CFCC

VFM can be used in coupling facility images to provide extended capacity and availability for workloads that use WebSphere MQ Shared Queues structures. The use of VFM can help availability by reducing latency from paging delays that can occur at the start of the workday or during other transitional periods. It also helps to eliminate delays that can occur when diagnostic data during failures is collected.

CFCC Coupling Thin Interrupts (required for IBM z16)

The Coupling Thin Interrupts improves the performance of a CF partition and the dispatching of z/OS LPARs that are awaiting the arrival of returned asynchronous CF requests when used in a shared engine environment.

For more information, see “**Coupling Thin Interrupts**” on page 104. The supported operating systems are listed in Table 7-5 on page 260.

Asynchronous CF Duplexing for lock structures

Asynchronous CF Duplexing enhancement is a general-purpose interface for any CF Lock structure user. It enables secondary structure updates to be performed asynchronously from primary CF updates. It offers performance advantages for duplexing lock structures and avoids the need for synchronous communication delays during the processing of every duplexed update operation.

Asynchronous CF Duplexing for lock structures requires the following software support:

- ▶ z/OS V2R5, V2R4
- ▶ z/OS V2R3 with PTFs for APAR OA47796 and OA49148
- ▶ z/VM V7R3, V7R2 or V7R1
- ▶ Db2 V12 with PTFs for APAR PI66689
- ▶ IRLM V2.R3 with PTFs for APAR PI68378

The supported operating systems are listed in Table 7-5 on page 260.

Asynchronous cross-invalidate for CF cache structures

Asynchronous cross-invalidate (XI) for CF cache structures enables improved efficiency in CF data sharing by adopting a more transactional behavior for cross-invalidate (XI) processing. This processing is used to maintain coherency and consistency of data managers' local buffer pools across the sysplex.

Instead of performing XI signals synchronously on every cache update request that causes them, data managers can “opt in” for the CF to perform these XIs asynchronously (and then synchronize them with the CF at or before the transaction is completed). Data integrity is maintained if all XI signals complete by the time transaction locks are released.

The feature enables faster completion of cache update CF requests, especially with the cross-site distance that is involved. It also provides improved cache structure service times and coupling efficiency. It requires specific data manager use or participation, which is not transparent to the data manager. No SMF data changes were made for CF monitoring and reporting.

⁸ Coupling Express LR features are *not* carried forward to IBM z16. Coupling Express2 LR is available.

The following requirements must be met:

- ▶ CFCC Level 23 or higher
- ▶ z/OS V2.R5 or V2.R4
- ▶ PTFs on every exploiting system in the sysplex: Fixes for APAR OA54688 - Exploitation support z/OS V2.R3
- ▶ Db2 V12 with PTFs for exploitation

z/VM Dynamic I/O support for ICA CHPIDs

z/VM dynamic I/O configuration support allows you to add, delete, and modify the definitions of channel paths, control units, and I/O devices to the server and z/VM without shutting down the system.

This function refers exclusively to the z/VM dynamic I/O support of InfiniBand⁹ and ICA coupling links. Support is available for the CIB and CS5 CHPID type in the z/VM dynamic commands, including the **change channel path** dynamic I/O command.

Specifying and changing the system name when entering and leaving configuration mode are also supported. z/VM does not use InfiniBand or ICA, and does not support the use of InfiniBand or ICA coupling links by guests. The supported operating systems are listed in Table 7-5 on page 260.

7.4.4 Storage connectivity-related features and functions

In this section, we describe the storage connectivity-related features and functions.

zHyperlink Express

IBM z14 introduced IBM zHyperLink Express as a brand new IBM Z input/output (I/O) channel link technology since FICON. The zHyperLink Express 1.1 feature is available with new IBM z16 systems and is designed to help bring data close to processing power, increase the scalability of transaction processing, and lower I/O latency.

zHyperLink Express is designed for up to 5x lower latency than High-Performance FICON for IBM Z (zHPF) by directly connecting the IBM Z central processor complex (CPC) to the I/O Bay of the DS8000 (DS8880 or later). This short distance (up to 150 m [492.1 feet]), direct connection is intended to speed Db2 for z/OS transaction processing and improve active log throughput.

The improved performance of zHyperLink Express allows the Processing Unit (PU) to make a synchronous request for the data that is in the DS8000 cache. This process eliminates the undispatch of the running request, the queuing delays to resume the request, and the PU cache disruption.

Support for zHyperLink Writes can accelerate Db2 log writes to help deliver superior service levels by processing high-volume Db2 transactions at speed. IBM zHyperLink Express requires compatible levels of DS8000/F hardware, firmware R8.5.1 or later, and Db2 12 with PTFs.

The supported operating systems are listed in Table 7-6 on page 261 and Table 7-7 on page 262.

⁹ InfiniBand coupling is *not* supported on IBM z16.

FICON Express32S

FICON Express32S (available for IBM z16 servers) supports a link data rate of 32 gigabits per second (Gbps) and auto negotiation to 16 and 8 Gbps for synergy with switches, directors, and storage devices. With support for native FICON, High-Performance FICON for Z (zHPF), and Fibre Channel Protocol (FCP), the IBM z16 server enables you to position your SAN for even higher performance, which helps you to prepare for an end-to-end 16 Gbps infrastructure to meet the lower latency and increased bandwidth demands of your applications.

The supported operating systems are listed in Table 7-6 on page 261 and Table 7-7 on page 262.

IBM Fibre Channel Endpoint Security

IBM z16 Model A01 supports IBM Fibre Channel Endpoint Security feature (FC 1146). FC 1146 provides FC/FCP link encryption and endpoint authentication. This optional priced feature requires the following components:

- ▶ FICON Express32S and FICON Express16SA (carry forward) for both link encryption and endpoint authentication
- ▶ FICON Express16S+ (carry forward) for endpoint authentication only
- ▶ Select DS8000 storage
- ▶ Supporting infrastructure: IBM Security Guardium Key Lifecycle Manager
- ▶ CPACF enablement (FC 3863)

For more information, see this [announcement letter](#).

FICON Express16SA

FICON Express16SA (carry forward to IBM z16 server) supports a link data rate of 16 gigabits per second (Gbps) and auto negotiation to 8 Gbps for synergy with switches, directors, and storage devices. With support for native FICON, High-Performance FICON for IBM Z (zHPF), and Fibre Channel Protocol (FCP), the IBM z16 server enables you to position your SAN for even higher performance, which helps you to prepare for an end-to-end 16 Gbps infrastructure to meet the lower latency and increased bandwidth demands of your applications.

The supported operating systems are listed in Table 7-6 on page 261 and Table 7-7 on page 262.

FICON Express16S+

FICON Express16S+ (carry forward to IBM z16) supports a link data rate of 16 Gbps and auto negotiation to 4 or 8 Gbps for synergy with switches, directors, and storage devices. With support for native FICON, High-Performance FICON for Z (zHPF), and Fibre Channel Protocol (FCP), the IBM Z enable you to position your SAN for even higher performance, which helps you to prepare for an end-to-end 16 Gbps infrastructure to meet the lower latency and increased bandwidth demands of your applications.

The new FICON Express16S+ channel works with your fiber optic cabling environment (single mode and multimode optical cables). The FICON Express16S+ feature running at end-to-end 16 Gbps link speeds provides reduced latency for large read/write operations and increased bandwidth compared to the FICON Express8S feature.

The supported operating systems are listed in Table 7-6 on page 261 and Table 7-7 on page 262.

Extended distance FICON

An enhancement to the industry-standard FICON architecture (FC-SB-3) helps avoid degradation of performance at extended distances by implementing a new protocol for persistent IU pacing. Extended distance FICON is transparent to operating systems and applies to all FICON Express32S, FICON Express16SA, and FICON Express16S+ features that carry native FICON traffic (CHPID type FC).

To use this enhancement, the control unit must support the new IU pacing protocol. IBM System Storage DS8000 series supports extended distance FICON for IBM Z environments. The channel defaults to current pacing values when it operates with control units that cannot use extended distance FICON.

High-performance FICON

High-performance FICON (zHPF) was first provided on IBM System z10®, and is a FICON architecture for protocol simplification and efficiency. It reduces the number of information units (IUs) that are processed. Enhancements were made to the z/Architecture and the FICON interface architecture to provide optimizations for online transaction processing (OLTP) workloads.

zHPF is available on the following servers:

- ▶ IBM z16
- ▶ IBM z15
- ▶ IBM z14
- ▶ IBM z13
- ▶ IBM z13s®
- ▶ IBM zEC12
- ▶ IBM zBC12

As of this writing, the FICON Express32S, FICON Express16SA, and FICON Express16S+(CHPID type FC) support the FICON protocol and the zHPF protocol in the server LIC.

When used by the FICON channel, the z/OS operating system, and the DS8000 control unit or other subsystems, the FICON channel processor usage can be reduced and performance improved. Suitable levels of Licensed Internal Code (LIC) are required.

Also, the changes to the architectures provide end-to-end system enhancements to improve reliability, availability, and serviceability (RAS).

zHPF is compatible with the following standards:

- ▶ Fibre Channel Framing and Signaling standard (FC-FS)
- ▶ Fibre Channel Switch Fabric and Switch Control Requirements (FC-SW)
- ▶ Fibre Channel Single-Byte-4 (FC-SB-4) standards

For example, the zHPF channel programs can be used by the z/OS OLTP I/O workloads, Db2, VSAM, the partitioned data set extended (PDSE), and the z/OS file system (zFS).

At the zHPF announcement, zHPF supported the transfer of small blocks of fixed size data (4 K) from a single track. This capability was extended, first to 64 KB, and then to multi-track operations. The 64 KB data transfer limit on multi-track operations was removed by z196. This improvement allows the channel to fully use the bandwidth of FICON channels, which results in higher throughputs and lower response times.

The multi-track operations extension applies to the FICON Express32S, FICON Express16SA, and FICON Express16S+, when configured as CHPID type FC and connecting to z/OS. zHPF requires matching support by the DS8000 series. Otherwise, the extended multi-track support is transparent to the control unit.

zHPF is enhanced to allow all large write operations (greater than 64 KB) at distances up to 100 km (62.13 miles) to be run in a single round trip to the control unit. This process does not elongate the I/O service time for these write operations at extended distances. This enhancement to zHPF removes a key inhibitor for customers that are adopting zHPF over extended distances, especially when the IBM HyperSwap capability of z/OS is used.

From the z/OS perspective, the FICON architecture is called *command mode* and the zHPF architecture is called *transport mode*. During link initialization, the channel node and the control unit node indicate whether they support zHPF.

Requirement: All FICON channel path identifiers (CHPIDs) that are defined to the same LCU must support zHPF. The inclusion of any non-compliant zHPF features in the path group causes the entire path group to support command mode only.

The mode that is used for an I/O operation depends on the control unit that supports zHPF and its settings in the z/OS operating system. For z/OS use, a parameter is available in the IECIOSxx member of SYS1.PARMLIB (**ZHPF=YES or NO**) and in the **SETIOS** system command to control whether zHPF is enabled or disabled. The default is ZHPF=NO.

Support also is added for the **D IOS,ZHPF** system command to indicate whether zHPF is enabled, disabled, or not supported on the server.

Similar to the existing FICON channel architecture, the application or access method provides the channel program (CCWs). How zHPF (transport mode) manages channel program operations is different from the CCW operation for the existing FICON architecture (command mode).

While in command mode, each CCW is sent to the control unit for execution. In transport mode, multiple channel commands are packaged together and sent over the link to the control unit in a single control block. Fewer processors are used compared to the existing FICON architecture. Specific complex CCW chains are not supported by zHPF.

The supported operating systems are listed in Table 7-6 on page 261 and Table 7-7 on page 262.

For more information about FICON channel performance, see the performance technical papers that are available [at the IBM Z I/O connectivity page](#) of the IBM IT infrastructure website.

Modified Indirect Data Address Word facility

The Modified Indirect Data Address Word (MIDAW) facility improves FICON performance. It provides a more efficient channel command word (CCW)/indirect data address word (IDAW) structure for specific categories of data-chaining I/O operations.

The MIDAW facility is a system architecture and software feature that is designed to improve FICON performance. This facility was first made available on IBM System z9® servers, and is used by the Media Manager in z/OS.

The MIDAW facility provides a more efficient CCW/IDAW structure for certain categories of data-chaining I/O operations.

MIDAW can improve FICON performance for extended format data sets. Nonextended data sets also can benefit from MIDAW.

MIDAW can improve channel use and I/O response time. It also reduces FICON channel connect time, director ports, and control unit processor usage.

IBM laboratory tests indicate that applications that use EF data sets, such as Db2, or long chains of small blocks can gain significant performance benefits by using the MIDAW facility.

MIDAW is supported on FICON channels that are configured as CHPID type FC. The supported operating systems are listed in Table 7-6 on page 261 and Table 7-7 on page 262.

MIDAW technical description

An IDAW is used to specify data addresses for I/O operations in a virtual environment.¹⁰ The IDAW design allows the first IDAW in a list to point to any address within a page. Subsequent IDAWs in the same list must point to the first byte in a page. Also, IDAWs (except the first and last IDAW) in a list must manage complete 2 K or 4 K units of data.

Figure 7-2 shows a single CCW that controls the transfer of data that spans noncontiguous 4 K frames in main storage. When the IDAW flag is set, the data address in the CCW points to a list of words (IDAWs). Each IDAW contains an address that designates a data area within real storage.

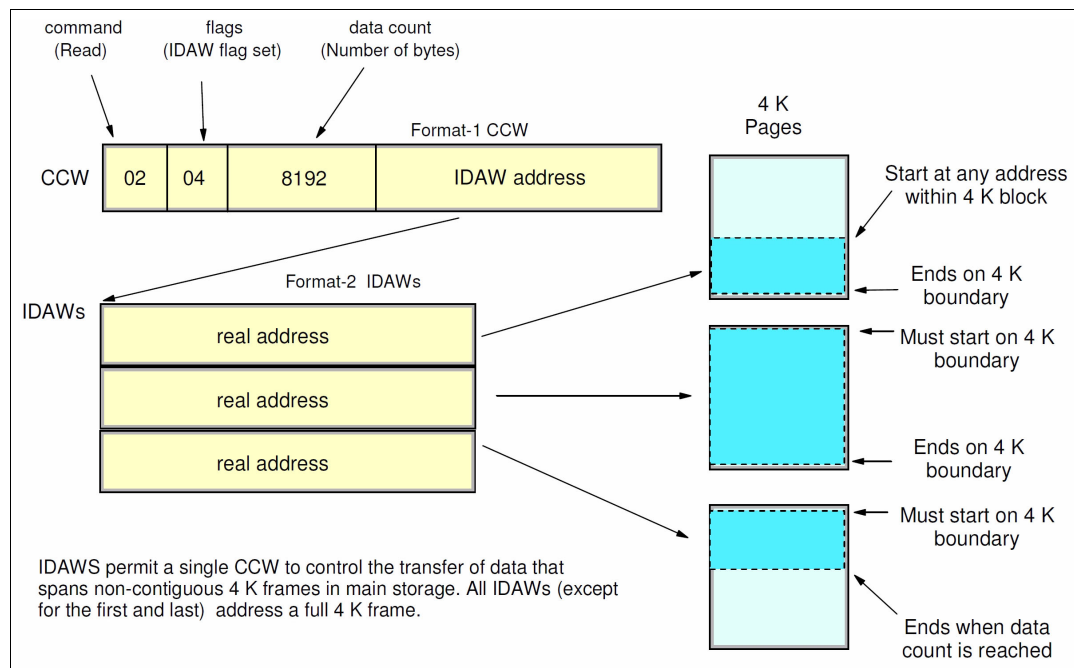


Figure 7-2 IDAW usage

The number of required IDAWs for a CCW is determined by the following factors:

- ▶ IDAW format as specified in the operation request block (ORB)
- ▶ Count field of the CCW
- ▶ Data address in the initial IDAW

¹⁰ Exceptions are made to this statement, and many details are omitted in this description. In this section, we assume that you can merge this brief description with an understanding of I/O operations in a virtual memory environment.

For example, three IDAWs are required when the following events occur:

- ▶ The ORB specifies format-2 IDAWs with 4 KB blocks.
- ▶ The CCW count field specifies 8 KB.
- ▶ The first IDAW designates a location in the middle of a 4 KB block.

CCWs with data chaining can be used to process I/O data blocks that have a more complex internal structure, in which portions of the data block are directed into separate buffer areas. This process is sometimes known as *scatter-read* or *scatter-write*. However, as technology evolves and link speed increases, data chaining techniques become less efficient because of switch fabrics, control unit processing and exchanges, and other issues.

The MIDAW facility is a method of gathering and scattering data from and into discontinuous storage locations during an I/O operation. The MIDAW format is shown in Figure 7-3. It is 16 bytes long and aligned on a quadword.

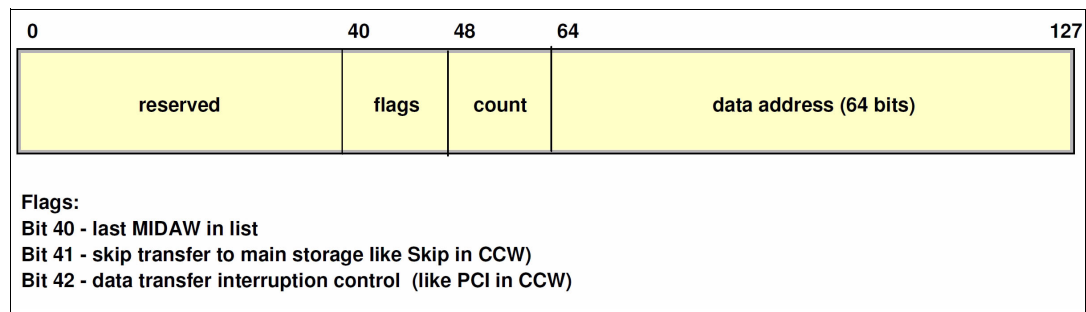


Figure 7-3 MIDAW format

An example of MIDAW usage is shown in Figure 7-4.

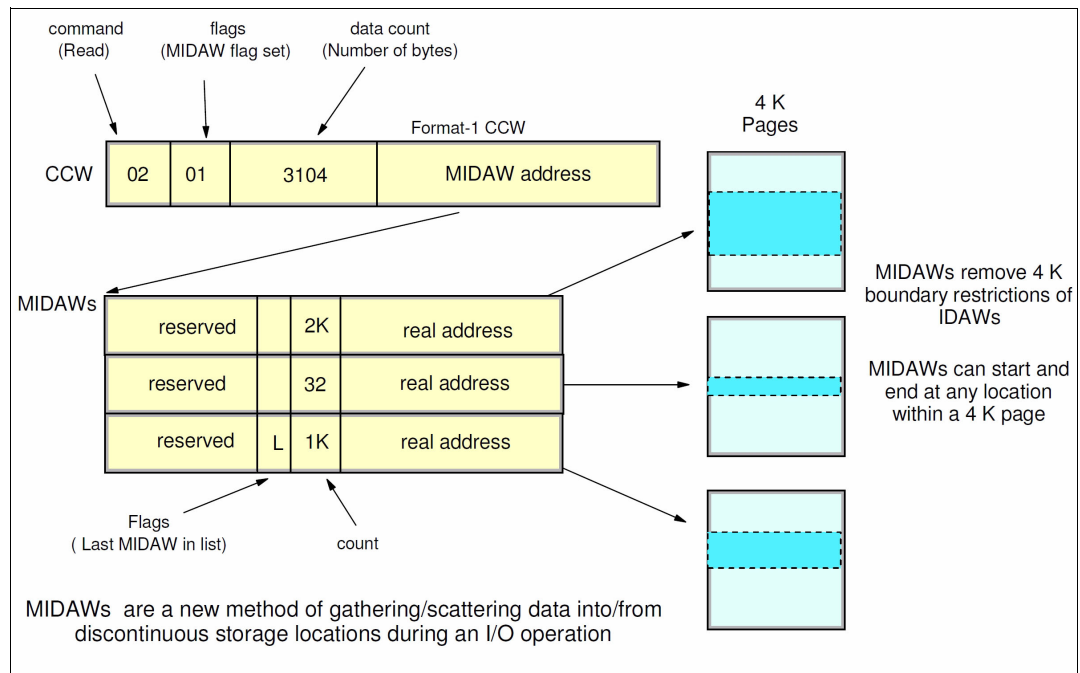


Figure 7-4 MIDAW usage

The use of MIDAWs is indicated by the MIDAW bit in the CCW. If this bit is set, the skip flag cannot be set in the CCW. The skip flag in the MIDAW can be used instead. The data count in the CCW must equal the sum of the data counts in the MIDAWs. The CCW operation ends when the CCW count goes to zero or the last MIDAW (with the last flag) ends.

The combination of the address and count in a MIDAW cannot cross a page boundary. Therefore, the largest possible count is 4 K. The maximum data count of all the MIDAWs in a list cannot exceed 64 K, which is the maximum count of the associated CCW.

The scatter-read or scatter-write effect of the MIDAWs makes it possible to efficiently send small control blocks that are embedded in a disk record to separate buffers from those that are used for larger data areas within the record. MIDAW operations are on a single I/O block, in the manner of data chaining. Do not confuse this operation with CCW command chaining.

Extended format data sets

z/OS extended format (EF) data sets use internal structures (often not visible to the application program) that require a scatter-read (or scatter-write) operation. Therefore, CCW data chaining is required, which produces less than optimal I/O performance. Because the most significant performance benefit of MIDAWs is achieved with EF data sets, a brief review of the EF data sets is included here.

VSAM and non-VSAM (DSORG=PS) sets can be defined as EF data sets. For non-VSAM data sets, a 32-byte suffix is appended to the end of every physical record (that is, block) on disk. VSAM appends the suffix to the end of every control interval (CI), which normally corresponds to a physical record.

A 32 K CI is split into two records to span tracks. This suffix is used to improve data reliability, and facilitates other functions that are described next. For example, if the DCB BLKSIZE or VSAM CI size is equal to 8192, the block on storage consists of 8224 bytes. The control unit does not distinguish between suffixes and user data. The suffix is transparent to the access method and database.

In addition to reliability, EF data sets enable the following functions:

- ▶ DFSMS striping
- ▶ Access method compression
- ▶ Extended addressability (EA)

EA is useful for creating large Db2 partitions (larger than 4 GB). Striping can be used to increase sequential throughput, or to spread random I/Os across multiple logical volumes. DFSMS striping is useful for the use of multiple channels in parallel for one data set. The Db2 logs are often striped to optimize the performance of Db2 sequential inserts.

Processing an I/O operation to an EF data set normally requires at least two CCWs with data chaining. One CCW is used for the 32-byte suffix of the EF data set. With MIDAW, the extra CCW for the EF data set suffix is eliminated.

MIDAWs benefit EF and non-EF data sets. For example, to read 12 4 K records from a non-EF data set on a 3390 track, Media Manager chains together 12 CCWs by using data chaining. To read 12 4 K records from an EF data set, 24 CCWs are chained (two CCWs per 4 K record). By using Media Manager track-level command operations and MIDAWs, an entire track can be transferred by using a single CCW.

Performance benefits

z/OS Media Manager includes I/O channel program support for implementing EF data sets, and automatically uses MIDAWs when appropriate. Most disk I/Os in the system are generated by using Media Manager.

Users of the Executing Fixed Channel Programs in Real Storage (EXCPVR) instruction can construct channel programs that contain MIDAWs. However, doing so requires that they construct an IOBE with the IOBEMIDA bit set. Users of the EXCP instruction cannot construct channel programs that contain MIDAWs.

The MIDAW facility removes the 4 K boundary restrictions of IDAWs and for EF data sets, which reduces the number of CCWs. Decreasing the number of CCWs helps to reduce the FICON channel processor use. Media Manager and MIDAWs do not cause the bits to move any faster across the FICON link. However, they reduce the number of frames and sequences that flow across the link and use the channel resources more efficiently.

The performance of a specific workload can vary based on the conditions and hardware configuration of the environment. IBM laboratory tests found that Db2 gains significant performance benefits by using the MIDAW facility in the following areas:

- ▶ Table scans
- ▶ Logging
- ▶ Utilities
- ▶ Use of DFSMS striping for Db2 data sets

Media Manager with the MIDAW facility can provide significant performance benefits when used in combination applications that use EF data sets (such as Db2) or long chains of small blocks.

For more information about FICON and MIDAW, see the following resources:

- ▶ The [I/O Connectivity page](#) of the IBM IT infrastructure website includes information about FICON channel performance
- ▶ *DS8000 Performance Monitoring and Tuning*, [SG24-8013](#)

ICKDSF

Device Support Facilities, ICKDSF, Release 17 is required on all systems that share disk subsystems with an IBM z16 processor.

ICKDSF supports a modified format of the CPU information field that contains a two-digit LPAR identifier. ICKDSF uses the CPU information field instead of CCW reserve/release for concurrent media maintenance. It prevents multiple systems from running ICKDSF on the same volume, and at the same time allows user applications to run while ICKDSF is processing. To prevent data corruption, ICKDSF must determine all sharing systems that might run ICKDSF. Therefore, this support is required for IBM z16.

Remember: The need for ICKDSF Release 17 also applies to systems that are not part of the same sysplex, or are running an operating system other than z/OS, such as z/VM.

z/OS Discovery and Auto-Configuration

z/OS Discovery and Auto Configuration (zDAC) is designed to automatically run several I/O configuration definition tasks for new and changed disk and tape controllers that are connected to a switch or director, when attached to a FICON channel.

The zDAC function is integrated into the hardware configuration definition (HCD). Clients can define a policy that can include preferences for availability and bandwidth that include parallel access volume (PAV) definitions, control unit numbers, and device number ranges. When new controllers are added to an I/O configuration or changes are made to existing controllers, the system discovers them and proposes configuration changes that are based on that policy.

zDAC provides real-time discovery for the FICON fabric, subsystem, and I/O device resource changes from z/OS. By exploring the discovered control units for defined logical control units (LCUs) and devices, zDAC compares the discovered controller information with the current system configuration. It then determines delta changes to the configuration for a proposed configuration.

All added or changed logical control units and devices are added into the proposed configuration. They are assigned proposed control unit and device numbers, and channel paths that are based on the defined policy. zDAC uses channel path chosen algorithms to minimize single points of failure. The zDAC proposed configurations are created as work I/O definition files (IODFs) that can be converted to production IODFs and activated.

zDAC is designed to run discovery for all systems in a sysplex that support the function. Therefore, zDAC helps to simplify I/O configuration on IBM z16 systems that run z/OS, and reduces complexity and setup time.

zDAC applies to all FICON features that are supported on IBM z16 when configured as CHPID type FC. The supported operating systems are listed in Table 7-6 on page 261 and Table 7-7 on page 262.

Platform and name server registration in FICON channel

The FICON Express32S, FICON Express16SA, and FICON Express16S+ features support platform and name server registration to the fabric for CHPID types FC and FCP.

Information about the channels that are connected to a fabric (if registered) allows other nodes or storage area network (SAN) managers to query the name server to determine what is connected to the fabric.

The following attributes are registered for the IBM z16 systems:

- ▶ Platform information
- ▶ Channel information
- ▶ Worldwide port name (WWPN)
- ▶ Port type (N_Port_ID)
- ▶ FC-4 types that are supported
- ▶ Classes of service that are supported by the channel

The platform and name server registration service are defined in the Fibre Channel Generic Services 4 (FC-GS-4) standard.

The 63.75-K subchannels

Servers before IBM z9 EC reserved 1024 subchannels for internal system use, out of a maximum of 64 K subchannels. Starting with IBM z9 EC, the number of reserved subchannels was reduced to 256, which increased the number of subchannels that are available. Reserved subchannels exist in subchannel set 0 only. One subchannel is reserved in each of subchannel sets 1, 2, and 3.

The informal name, 63.75-K subchannels, represents 65280 subchannels, as shown in the following equation:

$$63 \times 1024 + 0.75 \times 1024 = 65280$$

This equation is applicable for subchannel set 0. For subchannel sets 1, 2 and 3, the available subchannels are derived by using the following equation:

$$(64 \times 1024) - 1 = 65535$$

The supported operating systems are listed in Table 7-6 on page 261 and Table 7-7 on page 262.

Multiple subchannel sets

First introduced in IBM z9 EC, multiple subchannel sets (MSS) provide a mechanism for addressing more than 63.75 K I/O devices and aliases for FICON (CHPID types FC) on the IBM z16, IBM z15, IBM z14, IBM z13, IBM z13s, IBM zEC12, and IBM zBC12. IBM z196 introduced the third subchannel set (SS2). With IBM z13, one more subchannel set (SS3) was introduced, which expands the alias addressing by 64 K more I/O devices.

Current z/VM versions MSS support for mirrored direct access storage device (DASD) provides a subset of host support for the MSS facility to allow the use of an alternative subchannel set for Peer-to-Peer Remote Copy (PPRC) secondary volumes.

The supported operating systems are listed in Table 7-6 on page 261 and Table 7-7 on page 262. For more information about channel subsystem, see Chapter 5, “Central processor complex channel subsystem” on page 201.

Subchannel sets

IBM z16 A01 supports four subchannel sets (SS0, SS1, SS2, and SS3).

Subchannel sets SS1, SS2, and SS3 can be used for disk alias devices of primary and secondary devices, and as Metro Mirror secondary devices. This set helps facilitate storage growth and complements other functions, such as extended address volume (EAV) and Hyper Parallel Access Volumes (HyperPAV).

See Table 7-6 on page 261 and Table 7-7 on page 262 for list of supported operating systems.

IPL from an alternative subchannel set

IBM z16 supports IPL from subchannel set 1 (SS1), subchannel set 2 (SS2), or subchannel set 3 (SS3), in addition to subchannel set 0.

See Table 7-6 on page 261 and Table 7-7 on page 262 for list of supported operating systems. For more information, see “IPL from an alternative subchannel set” on page 299.

32 K subchannels

To help facilitate growth and continue to enable server consolidation, the IBM z16 supports up to 32 K subchannels per FICON Express32S, FICON Express16SA, and FICON Express16S+ channels (CHPID). More devices can be defined per FICON channel, which includes primary, secondary, and alias devices. The maximum number of subchannels across all device types that are addressable within an LPAR remains at 63.75 K for subchannel set 0 and 64 K (64 X 1024)-1 for subchannel sets 1, 2, and 3.

This support is available to the IBM z16, IBM z15, z14, IBM z13, and IBM z13s servers and applies to the FICON Express32S, FICON Express16SA, and FICON Express16S+ features (defined as CHPID type FC).

The supported operating systems are listed in Table 7-6 on page 261 and Table 7-7 on page 262.

Request node identification data

The request node identification data (RNID) function for native FICON CHPID type FC allows isolation of cabling-detected errors. The supported operating systems are listed in Table 7-6 on page 261.

FICON link incident reporting

FICON link incident reporting allows an operating system image (without operator intervention) to register link incident reports. The supported operating systems are listed in Table 7-6 on page 261.

Health Check for FICON Dynamic routing

Starting with IBM z13, the channel microcode was changed to support FICON dynamic routing. Although change is required in z/OS to support dynamic routing, I/O errors can occur if the FICON switches are configured for dynamic routing despite the missing support in the processor or storage controllers. Therefore, a health check is provided that interrogates the switch to determine whether dynamic routing is enabled in the switch fabric.

No action is required on z/OS to enable the health check; it is automatically enabled at IPL and reacts to changes that might cause problems. The health check can be disabled by using the **PARMLIB** or **SDSF** modify commands.

The supported operating systems are listed in Table 7-6 on page 261. For more information about FICON Dynamic Routing (FIDR), see Chapter 4, “Central processor complex I/O structure” on page 147.

Global resource serialization FICON CTC toleration

For some configurations that depend on ESCON CTC definitions, global resource serialization (GRS) FICON CTC toleration that is provided with APAR OA38230 is essential, especially after ESCON channel support was removed from IBM Z starting with IBM zEC12.

The supported operating systems are listed in Table 7-6 on page 261.

Increased performance for the FCP protocol

The FCP LIC is modified to help increase I/O operations per second for small and large block sizes, and to support 32-Gbps link speeds.

For more information about FCP channel performance, see [the performance technical papers that are available](#) at the IBM Z I/O connectivity page of the IBM IT infrastructure website.

The FCP protocol is supported by z/VM, z/VSE, and Linux on IBM Z. The supported operating systems are listed in Table 7-6 on page 261 and Table 7-7 on page 262.

T10-DIF support

American National Standards Institute (ANSI) T10 Data Integrity Field (DIF) standard is supported on IBM Z for SCSI end-to-end data protection on fixed block (FB) LUN volumes. IBM Z provides added end-to-end data protection between the operating system and the DS8870 unit. This support adds protection information that consists of Cyclic Redundancy Checking (CRC), Logical Block Address (LBA), and host application tags to each sector of FB data on a logical volume.

IBM Z support applies to FCP channels only. The supported operating systems are listed in Table 7-6 on page 261 and Table 7-7 on page 262.

N_Port ID Virtualization

N_Port ID Virtualization (NPIV) allows multiple system images (in LPARs or z/VM guests) to use a single FCP channel as though each were the sole user of the channel. First introduced with z9 EC, this feature can be used with supported FICON features on IBM z16 servers. The supported operating systems are listed in Table 7-6 on page 261 and Table 7-7 on page 262.

Worldwide port name tool

Part of the IBM z16 system installation is the planning of the SAN environment. IBM includes a stand-alone tool to assist with this planning before the installation.

The capabilities of the WWPN are extended to calculate and show WWPNs for virtual and physical ports ahead of system installation.

The tool assigns WWPNs to each virtual FCP channel or port by using the same WWPN assignment algorithms that a system uses when assigning WWPNs for channels that use NPIV. Therefore, the SAN can be set up in advance, which allows operations to proceed much faster after the server is installed. In addition, the SAN configuration can be retained instead of altered by assigning the WWPN to physical FCP ports when a FICON feature is replaced.

The WWPN tool takes a .csv file that contains the FCP-specific I/O device definitions and creates the WWPN assignments that are required to set up the SAN. A binary configuration file that can be imported later by the system is also created. The .csv file can be created manually or exported from the HCD/HCM. The supported operating systems are listed in Table 7-6 on page 261 and Table 7-7 on page 262.

The WWPN tool is applicable to all FICON channels that are defined as CHPID type FCP (for communication with SCSI devices) on IBM z16. It is available [for download at the Resource Link](#) at the following website (log in is required).

Note: An optional feature can be ordered for WWPN persistency before shipment to keep the same I/O serial number on the new CPC. Current information must be provided during the ordering process.

7.4.5 Networking features and functions

In this section, we describe the networking features and functions that are supported on IBM z16.

25 GbE RoCE Express3 SR and 25 GbE RoCE Express3 LR

The 25 GbE RoCE Express3 features (FC 0452 and FC 0453) are a RDMA/Ethernet technology refresh. The features now also support LR optics and 25 Gbit Ethernet switches with relaxed requirements. The features are installed in the PCIe+ I/O drawer and are supported on IBM z16 servers only.

The 25 GbE RoCE Express3 are native PCIe features that not use a CHPID and are defined by using the IOCP **FUNCTION** statement or in the hardware configuration definition (HCD).

The virtualization capabilities for IBM z16 are 63 Virtual Functions per port (126 VFs per feature/PCHID). One RoCE Express feature can be shared by up to 126 partitions (LPARs) (one adapter is one PCHID).

The 25 GbE RoCE Express3 SR (FC 0452) feature connects by using SR optics and multimode fiber that is terminated with LC connector. The 25 GbE RoCE Express3 LR (FC 0453) connects by using LR optics and single mode fiber that is terminated with LC connector.

Support for select Linux on IBM Z distributions is provided for Shared Memory Communications over Remote Direct Memory Access (SMC-R) by using RoCE Express features. For more information, see [this Linux on IBM Z Blogspot web page](#).

The RoCE Express3 features also can provide local area network (LAN) connectivity for Linux on IBM Z, and comply with IEEE standards. In addition, RoCE Express features assume several functions of the TCP/IP stack that normally are performed by the PU, which allows significant performance benefits by offloading processing from the operating system.

10 GbE RoCE Express3 SR and 10 GbE RoCE Express3 LR

The 10 GbE RoCE Express3 features (FC 0440 and FC 0441) are a RDMA/Ethernet technology refresh. The features support now also LR optics and 10 Gbit Ethernet switches with relaxed requirements. The features are installed in the PCIe+ I/O drawer and are supported on IBM z16 servers only.

The 10 GbE RoCE Express3 are native PCIe features that do not use a CHPID and are defined by using the IOCP **FUNCTION** statement or in the HCD.

The virtualization capabilities for IBM z16 are 63 Virtual Functions per port (126 VFs per feature/PCHID). One RoCE Express feature can be shared by up to 126 partitions (LPARs) (one adapter is one PCHID).

The 25 GbE RoCE Express3 SR (FC 0452) feature connects by using SR optics and multimode fiber that is terminated with LC connector. The 25 GbE RoCE Express3 LR (FC 0453) connects by using LR optics and single mode fiber that is terminated with LC connector.

25 GbE RoCE Express2.1 and 25 GbE RoCE Express2

Based on the RoCE Express2 generation hardware, the 25 GbE RoCE Express2 (FC 0430 and 0450) features provide two 25 GbE physical ports and require 25 GbE optics and Ethernet switch 25 GbE support. The switch port must support 25 GbE (negotiation down to 10 GbE is *not* supported).

The 25 GbE RoCE Express2 has one PCHID and the same virtualization characteristics and the 10 GbE RoCE Express2 (FC 0412 and FC 0432); that is, 126 Virtual Functions per PCHID.

z/OS requires fixes for APAR OA55686. RMF 2.2 and later also is enhanced to recognize the CX4 card type and properly display CX4 cards in the PCIe Activity reports.

25 GbE RoCE Express2 feature also are used by Linux on IBM Z for applications that are coded to the native RoCE verb interface or use Ethernet (such as TCP/IP). This native exploitation does not require a peer OSA.

Support for select Linux on IBM Z distributions is now provided for Shared Memory Communications over Remote Direct Memory Access (SMC-R) by using RoCE Express features. For more information, see [this Linux on IBM Z Blogspot web page](#).

The RoCE Express3 features also can provide LAN connectivity for Linux on IBM Z, and comply with IEEE standards. In addition, RoCE Express features assume several functions of the TCP/IP stack that normally are performed by the PU, which allows significant performance benefits by offloading processing from the operating system.

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

10 GbE RoCE Express2.1 and 10 GbE RoCE Express2

IBM 10 GbE RoCE Express2 provides a natively attached PCIe I/O Drawer-based Ethernet feature that supports 10 Gbps Converged Enhanced Ethernet (CEE) and RDMA over CEE (RoCE). The RoCE feature, with an OSA feature, enables shared memory communications between two CPCs by using a shared switch.

RoCE Express2 provides increased virtualization (sharing capability) by supporting 63 Virtual Functions (VFs) per physical port for a total of 126 VFs per PCHID. This configuration allows RoCE to be extended to more workloads.

z/OS Communications Server (CS) provides a new software device driver ConnectX4 (CX4) for RoCE Express2. The device driver is not apparent to the upper layers of the CS (the SMC-R and TCP/IP stack) and the application software (that uses TCP sockets). RoCE Express2 introduces a minor change in how the physical port is configured.

RMF 2.2 and later also is enhanced to recognize the new CX4 card type and correctly display CX4 cards in the PCIe Activity reports.

Support in select Linux on IBM Z distributions is now provided for Shared Memory Communications over Remote Direct Memory Access (SMC-R) by using the supported RoCE Express features. For more information, see [this Linux on IBM Z Blogspot web page](#).

The RoCE Express3 features also can provide LAN connectivity for Linux on IBM Z, and comply with IEEE standards. In addition, RoCE Express features assume several functions of the TCP/IP stack that normally are performed by the PU, which allows significant performance benefits by offloading processing from the operating system.

The 10 GbE RoCE Express2 feature also is used by Linux on IBM Z for applications that are coded to the native RoCE verb interface or use Ethernet (such as TCP/IP). This native use does not require a peer OSA.

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

Shared Memory Communication - Direct Memory Access

First introduced with IBM z13 servers, the Shared Memory Communication - Direct Memory Access (SMC-D) feature maintains the socket-API transparency aspect of SMC-R so that applications that use TCPI/IP communications can benefit immediately without requiring application software to undergo IP topology changes.

Similar to SMC-R, this protocol uses shared memory architectural concepts that eliminate TCP/IP processing in the data path, yet preserve TCP/IP Qualities of Service for connection management purposes.

Support in select Linux on IBM Z distributions is now provided for Shared Memory Communications over Direct Memory Access (SMC-D). For more information, see [this Linux on IBM Z Blogspot web page](#).

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

Shared Memory Communications Version 2

Shared Memory Communications v2 is available in z/OS V2R4 (with PTFs) and z/OS V2R5.

Because the initial version of SMC was limited to TCP/IP connections over the same layer 2 network, it was not routable across multiple IP subnets. The associated TCP/IP connection was limited to hosts within a single IP subnet that required the hosts to have direct access to the same physical layer 2 network (that is, the same Ethernet LAN over a single VLAN ID). The scope of eligible TCP/IP connections for SMC was limited to and defined by the single IP subnet.

SMC Version 2 (SMCv2) provides support for SMC over multiple IP subnets for both SMC-D and SMC-R and is referred to as SMC-Dv2 and SMC-Rv2. SMCv2 requires updates to the underlying network technology. SMC-Dv2 requires ISMv2 and SMC-Rv2 requires RoCEv2.

The SMCv2 protocol is downward compatible, which allows SMCv2 hosts to continue to communicate with SMCv1 previous hosts.

Although SMCv2 changes the SMC connection protocol to enable multiple IP subnet support, SMCv2 does not change how user TCP socket data is transferred, which preserves the benefits of SMC to TCP workloads.

TCP/IP connections that require IPsec are not eligible for any form of SMC.

HiperSockets Completion Queue

The HiperSockets Completion Queue function is implemented on IBM z16, IBM z15, and IBM z14. This function is designed to allow HiperSockets to transfer data synchronously (if possible) and asynchronously, if necessary. Therefore, it combines ultra-low latency with more tolerance for traffic peaks. HiperSockets Completion Queue can be especially helpful in burst situations.

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

HiperSockets Virtual Switch Bridge

The HiperSockets Virtual Switch Bridge is supported on IBM Z servers. With the HiperSockets Virtual Switch Bridge, z/VM virtual switch is enhanced to transparently bridge a guest virtual machine network connection on a HiperSockets LAN segment. This bridge allows a single HiperSockets guest virtual machine network connection to also directly communicate with the following components:

- ▶ Other guest virtual machines on the virtual switch
- ▶ External network hosts through the virtual switch OSA UPLINK port

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

HiperSockets Multiple Write Facility

The HiperSockets Multiple Write Facility allows the streaming of bulk data over a HiperSockets link between two LPARs. Multiple output buffers are supported on a single Signal Adapter (SIGA) write instruction. The key advantage of this enhancement is that it allows the receiving LPAR to process a much larger amount of data per I/O interrupt. This process is transparent to the operating system in the receiving partition. HiperSockets Multiple Write Facility with fewer I/O interrupts is designed to reduce processor use of the sending and receiving partitions.

Support for this function is required by the sending operating system. For more information, see “HiperSockets” on page 188. The supported operating systems are listed in Table 7-8 on page 263.

HiperSockets support of IPV6

IPv6 is a key element in the future of networking. The IPv6 support for HiperSockets allows compatible implementations between external networks and internal HiperSockets networks. The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

HiperSockets Layer 2 support

For flexible and efficient data transfer for IP and non-IP workloads, the HiperSockets internal networks on IBM Z servers can support two transport modes: Layer 2 (Link Layer) and the current Layer 3 (Network or IP Layer). Traffic can be Internet Protocol (IP) Version 4 or Version 6 (IPv4, IPv6) or non-IP (AppleTalk, DECnet, IPX, NetBIOS, or SNA).

HiperSockets devices are protocol-independent and Layer 3-independent. Each HiperSockets device features its own Layer 2 Media Access Control (MAC) address. This MAC address allows the use of applications that depend on the existence of Layer 2 addresses, such as Dynamic Host Configuration Protocol (DHCP) servers and firewalls.

Layer 2 support can help facilitate server consolidation. Complexity can be reduced, network configuration is simplified and intuitive, and LAN administrators can configure and maintain the mainframe environment the same way as they do a nonmainframe environment.

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

HiperSockets network traffic analyzer for Linux on IBM Z

HiperSockets network traffic analyzer (HS NTA) provides support for tracing Layer2 and Layer3 HiperSockets network traffic in Linux on IBM Z. This support allows Linux on IBM Z to control the trace for the internal virtual LAN to capture the records into host memory and storage (file systems).

Linux on IBM Z tools can be used to format, edit, and process the trace records for analysis by system programmers and network administrators.

OSA-Express7S 1.2 25 GbE LR and SR features

OSA-Express7S 1.2 features are an Ethernet technology refresh introduced with IBM z16.

OSA-Express7S 1.2 25 GbE SR (FC 0459) and OSA-Express7S 1.2 25 GbE LR (FC 0460) are installed in the PCIe+ I/O Drawer and have 25 GbE physical port. New with the generation is the Long Reach version, which uses single mode fiber and can be point to point connected to a distance of up to 10 km (6.2 miles). The features connect to a 25 GbE switch and do not support auto-negotiation to a different speed.

Consider the following points regarding operating system support:

- ▶ z/OS V2R2 and V2R3 require fixes for the following APARs: OA55256 (IBM VTAM®) and PI95703 (TCP/IP).
- ▶ V7R1 requires PTF for APAR PI99085.

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

OSA-Express7S 1.2 10 GbE LR and SR features

OSA-Express7S 1.2 features are an Ethernet technology refresh introduced with IBM z16.

OSA-Express7S 1.2 10 GbE SR (FC 0457) and OSA-Express7S 1.2 10 GbE LR (FC 0456) are installed in the PCIe+ I/O Drawer and have 10 GbE physical port. The features connect to a 10 GbE switch and do not support auto-negotiation to a different speed.

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

OSA-Express7S 1.2 GbE LX and SX features

OSA-Express7S 1.2 features are an Ethernet technology refresh that was introduced with IBM z16.

OSA-Express7S 1.2 GbE SX (FC 0455) and OSA-Express7S 1.2 10 GbE LX (FC 0454) are installed in the PCIe+ I/O Drawer and have two GbE physical ports. The features connect to a GbE switch and do not support auto-negotiation to a different speed.

Each adapter can be configured in the following modes:

- ▶ QDIO, with CHPID types OSD
- ▶ Local 3270 emulation, including OSA-ICC, with CHPID type OSC

Note: Operating system support is required to recognize and use the second port on the OSA-Express6S 1000BASE-T Ethernet feature.

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

OSA-Express7S 1.2 1000BASE-T features (FC 0458)

OSA-Express7S 1.2 features are an Ethernet technology that was refresh introduced with IBM z16. The performance characteristics are comparable to the OSA-Express7S and OSA-Express6S features and they also retain the same form factor and port granularity.

Removal of support for OSA-Express 1000BASE-T hardware adapters^a: IBM z16 is planned to be the last IBM Z server to support OSA-Express 1000BASE-T hardware adapters (FC 0426, 0446, and 0458) on new build servers. Defining all valid OSA CHPID types is allowed on OSA-Express GbE adapters only. IBM plans to continue moving forward with OSA CHPID types on higher bandwidth fiber Ethernet adapters on future servers.

- a. Statements by IBM regarding its plans, directions, and intent are subject to change or withdrawal without notice at the sole discretion of IBM.

Each adapter can be configured in the following modes:

- ▶ QDIO, with CHPID types OSD
- ▶ Non-QDIO, with CHPID type OSE
- ▶ Local 3270 emulation, including OSA-ICC, with CHPID type OSC

Notes: Consider the following points:

- ▶ Operating system support is required to recognize and use the second port on the OSA-Express7S 1.2 1000BASE-T Ethernet feature.
- ▶ OSA-Express7S 1.2 1000BASE-T Ethernet feature supports only 1000 Mbps duplex mode (no auto-negotiation to 100 or 10 Mbps)

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

OSA-Express7S 25 Gigabit Ethernet SR (carry forward to IBM z16)

OSA-Express7S 25 GbE SR1.1 (FC 0449) and OSA-Express7S 25 GbE (FC 0429) are installed in the PCIe I/O drawer and have one 25 GbE physical port and requires 25 GbE optics and Ethernet switch 25 GbE support (negotiation down to 10 GbE is not supported).

Consider the following points regarding operating system support:

- ▶ z/OS V2R1, V2R2, and V2R3 require fixes for the following APARs: OA55256 (VTAM) and PI95703 (TCP/IP).
- ▶ z/VM V6R4 and V7R1 require PTF for APAR PI99085.

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

OSA-Express7S 10-Gigabit Ethernet LR and SR (carry forward)

OSA-Express6S 10-Gigabit Ethernet features are installed in the PCIe I/O drawer, which is supported by the 16 GBps PCIe Gen3 host bus. The performance characteristics are comparable to the OSA-Express6S features and they also retain the same form factor and port granularity.

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

OSA-Express6S 10-Gigabit Ethernet LR and SR (carry forward)

OSA-Express6S 10-Gigabit Ethernet features are installed in the PCIe I/O drawer, which is supported by the 16 GBps PCIe Gen3 host bus. The performance characteristics are comparable to the OSA-Express5S features. They also retain the same form factor and port granularity. OSA-Express6S features were introduced with IBM IBM z14, can be carried forward to an IBM z15 (T01 and T02), and ordered with a new IBM z16 A01

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

OSA-Express7S Gigabit Ethernet LX and SX (carry forward)

IBM z16 introduces an Ethernet technology refresh with OSA-Express7S Gigabit Ethernet features to be installed in the PCIe I/O drawer, which is supported by the 16 GBps PCIe Gen3 host bus. The performance characteristics are comparable to the OSA-Express6S features and they also retain the same form factor and port granularity.

Each adapter can be configured in the following modes:

- ▶ QDIO, with CHPID types OSD
- ▶ Local 3270 emulation, including OSA-ICC, with CHPID type OSC

Note: Operating system support is required to recognize and use the second port on the OSA-Express6S 1000BASE-T Ethernet feature.

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

OSA-Express7S 1000BASE-T Ethernet (carry forward)

IBM z16 introduces an Ethernet technology refresh with OSA-Express7S 1000BASE-T Ethernet features to be installed in the PCIe I/O drawer, which is supported by the 16 GBps PCIe Gen3 host bus. The performance characteristics are comparable to the OSA-Express6S features and they also retain the same form factor and port granularity.

Each adapter can be configured in the following modes:

- ▶ QDIO, with CHPID types OSD
- ▶ Non-QDIO, with CHPID type OSE
- ▶ Local 3270 emulation, including OSA-ICC, with CHPID type OSC

Notes: Consider the following points:

- ▶ Operating system support is required to recognize and use the second port on the OSA-Express7S 1000BASE-T Ethernet feature.
- ▶ OSA-Express7S 1000BASE-T Ethernet feature supports only 1000 Mbps duplex mode (no auto-negotiation to 100 or 10 Mbps)

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

OSA-Express6S 1000BASE-T Ethernet (carry forward)

IBM z14 introduced an Ethernet technology refresh with OSA-Express6S 1000BASE-T Ethernet features to be installed in the PCIe I/O drawer, which is supported by the 16 GBps PCIe Gen3 host bus. The performance characteristics are comparable to the OSA-Express5S features and they also retain the same form factor and port granularity.

Each adapter can be configured in the following modes:

- ▶ QDIO, with CHPID types OSD
- ▶ Non-QDIO, with CHPID type OSE
- ▶ Local 3270 emulation, including OSA-ICC, with CHPID type OSC

Note: Operating system support is required to recognize and use the second port on the OSA-Express6S 1000BASE-T Ethernet feature.

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

OSA-Integrated Console Controller

The OSA-Express 1000BASE-T Ethernet features provide the Integrated Console Controller (OSA-ICC) function, which supports TN3270E (RFC 2355) and non-SNA DFT 3270 emulation. The OSA-ICC function is defined as CHPID type OSC and console controller, and includes multiple LPAR support as shared or spanned channels.

Removal of support for OSA-Express 1000BASE-T hardware adapters^a: IBM z16 is planned to be the last IBM Z server to support OSA-Express 1000BASE-T hardware adapters (FC 0426, 0446, and 0458) on new build servers. Defining all valid OSA CHPID types is allowed on OSA-Express GbE adapters only. IBM plans to continue moving forward with OSA CHPID types on higher bandwidth fiber Ethernet adapters on future servers.

a. Statements by IBM regarding its plans, directions, and intent are subject to change or withdrawal without notice at the sole discretion of IBM.

With the OSA-ICC function, 3270 emulation for console session connections is integrated in the IBM z16 through a port on the OSA-Express7S 1000BASE-T, OSA-Express7S GbE, OSA-Express6S 1000BASE-T, or OSA-Express5S 1000BASE-T.

OSA-ICC can be configured on a PCHID-by-PCHID basis, and is supported at any of the feature settings. Each port can support up to 120 console session connections.

To improve security of console operations and to provide a secure, validated connectivity, OSA-ICC supports Transport Layer Security/Secure Sockets Layer (TLS/SSL) with Certificate Authentication starting with IBM z13 GA2 (Driver level 27).

Note: OSA-ICC supports up to 48 *secure* sessions per CHPID (the overall maximum of 120 connections is unchanged).

OSA-ICC Enhancements

With HMC 2.14.1 and newer the following enhancements are available:

- ▶ The IPv6 communications protocol is supported by OSA-ICC 3270 so that clients can comply with regulations that require all computer purchases to support IPv6.
- ▶ TLS negotiation levels (the supported TLS protocol levels) for the OSA-ICC 3270 client connection can now be specified:
 - TLS 1.0 OSA-ICC 3270 server permits TLS 1.0, TLS 1.1, and TLS 1.2 client connections.
 - TLS 1.1 OSA-ICC 3270 server permits TLS 1.1 and TLS 1.2 client connections.
 - TLS 1.2 OSA-ICC 3270 server permits only TLS 1.2 client connections.
- ▶ Separate and unique OSA-ICC 3270 certificates are supported (for each PCHID) for the benefit of customers who host workloads across multiple business units or data centers where cross-site coordination is required. Customers can avoid interruption of all the TLS connections at the same time when having to renew expired certificates. OSA-ICC also continues to support a single certificate for all OSA-ICC PCHIDs in the system.

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

Checksum offload for in QDIO mode (CHPID type OSD)

Checksum offload provides the capability of calculating the Transmission Control Protocol (TCP), User Datagram Protocol (UDP), and IP header checksum. Checksum verifies the accuracy of files. By moving the checksum calculations to a Gigabit or 1000BASE-T Ethernet feature, host processor cycles are reduced and performance is improved.

Checksum offload provides checksum offload for several types of traffic and is supported by the following features when configured as CHPID type OSD (QDIO mode only):

- ▶ OSA-Express7S 1.2, OSA_Express7S 1.1, and OSA-Express7S 25 GbE
- ▶ OSA-Express7S and OSA-Express7S 1.2 10 GbE
- ▶ OSA-Express7S and OSA-Express7S 1.2 GbE
- ▶ OSA-Express7S and OSA-Express7S 1.2 1000BASE-T Ethernet
- ▶ OSA-Express6S 10 GbE
- ▶ OSA-Express6S GbE
- ▶ OSA-Express6S 1000BASE-T Ethernet

When checksum is offloaded, the OSA-Express feature runs the checksum calculations for Internet Protocol version 4 (IPv4) and Internet Protocol version 6 (IPv6) packets. The checksum offload function applies to packets that go to or come from the LAN.

When multiple IP stacks share an OSA-Express, and an IP stack sends a packet to a next hop address that is owned by another IP stack that is sharing the OSA-Express, OSA-Express sends the IP packet directly to the other IP stack. The packet does not have to be placed out on the LAN, which is termed LPAR-to-LPAR traffic. Checksum offload is enhanced to support the LPAR-to-LPAR traffic, which was not originally available.

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

Querying and displaying an OSA configuration

OSA-Express3 introduced the capability for the operating system to query and display directly the current OSA configuration information (similar to OSA/SF). z/OS uses this OSA capability by introducing the TCP/IP operator command `display OSAINFO`. z/VM provides this function with the `NETSTAT OSAINFO TCP/IP` command.

The use of `display OSAINFO` (z/OS) or `NETSTAT OSAINFO` (z/VM) allows the operator to monitor and verify the current OSA configuration and helps improve the overall management, serviceability, and usability of OSA-Express cards.

These commands apply to CHPID type OSD. The supported operating systems are listed in Table 7-8 on page 263.

QDIO data connection isolation for z/VM

The QDIO data connection isolation function provides a higher level of security when sharing an OSA connection in z/VM environments that use VSWITCH. The VSWITCH is a virtual network device that provides switching between OSA connections and the connected guest systems.

QDIO data connection isolation allows disabling internal routing for each QDIO connected. It also provides a means for creating security zones and preventing network traffic between the zones.

QDIO data connection isolation is supported by all OSA-Express features on IBM z16. The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

QDIO interface isolation for z/OS

Some environments require strict controls for routing data traffic between servers or nodes. In specific cases, the LPAR-to-LPAR capability of a shared OSA connection can prevent such controls from being enforced. With interface isolation, internal routing can be controlled on an LPAR basis. When interface isolation is enabled, the OSA discards any packets that are destined for a z/OS LPAR that is registered in the OSA Address Table (OAT) as isolated.

QDIO interface isolation is supported on all OSA-Express features on IBM z16. The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

QDIO optimized latency mode

QDIO optimized latency mode (OLM) can help improve performance for applications that feature a critical requirement to minimize response times for inbound and outbound data.

OLM optimizes the interrupt processing in the following manner:

- ▶ For inbound processing, the TCP/IP stack looks more frequently for available data to process. This process ensures that any new data is read from the OSA-Express features without needing more program-controlled interrupts (PCIs).
- ▶ For outbound processing, the OSA-Express cards also look more frequently for available data to process from the TCP/IP stack. Therefore, the process does not require a Signal Adapter (SIGA) instruction to determine whether more data is available.

The supported operating systems are listed in Table 7-8 on page 263.

QDIO Diagnostic Synchronization

QDIO Diagnostic Synchronization enables system programmers and network administrators to coordinate and simultaneously capture software and hardware traces. It allows z/OS to signal OSA-Express features (by using a diagnostic assist function) to stop traces and capture the current trace records.

QDIO Diagnostic Synchronization is supported by the OSA-Express features on IBM z16 when in QDIO mode (CHPID type OSD). The supported operating systems are listed in Table 7-8 on page 263.

Inbound workload queuing (IWQ) for OSA

Inbound workload queuing (IWQ) creates multiple input queues and allows OSA to differentiate workloads “off the wire.” It then assigns work to a specific input queue (per device) to z/OS.

Each input queue is a unique type of workload, and has unique service and processing requirements. The IWQ function allows z/OS to preassign the appropriate processing resources for each input queue. This approach allows multiple concurrent z/OS processing threads to process each unique input queue (workload), which avoids traditional resource contention.

IWQ reduces the conventional z/OS processing that is required to identify and separate unique workloads. This advantage results in improved overall system performance and scalability.

A primary objective of IWQ is to provide improved performance for business-critical interactive workloads by reducing contention that is created by other types of workloads. In a heavily mixed workload environment, this “off the wire” network traffic separation is provided by OSA-Express7S 1.2, OSA-Express7S, and OSA-Express6S¹¹ features that are defined as CHPID type OSD.

¹¹ Only OSA-Express6S and OSA-Express7S cards are supported on IBM z16 as carry forward.

OSA IWQ is shown in Figure 7-5.

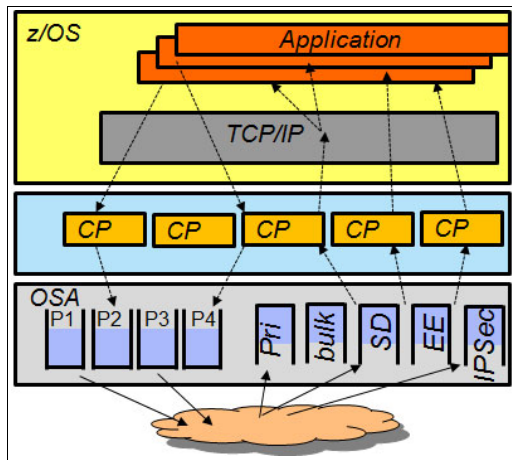


Figure 7-5 OSA inbound workload queuing

The following types of z/OS workloads are identified and assigned to unique input queues:

- ▶ z/OS Sysplex Distributor traffic
Network traffic that is associated with a distributed virtual Internet Protocol address (VIP) is assigned to a unique input queue. This configuration allows the Sysplex Distributor traffic to be immediately distributed to the target host.
- ▶ z/OS bulk data traffic
Network traffic that is dynamically associated with a streaming (bulk data) TCP connection is assigned to a unique input queue. This configuration allows the bulk data processing to be assigned the suitable resources and isolated from critical interactive workloads.
- ▶ EE (Enterprise Extender / SNA traffic)
IWQ for the OSA-Express features is enhanced to differentiate and separate inbound Enterprise Extender traffic to a dedicated input queue.

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

GARP VLAN Registration Protocol

All OSA-Express features support VLAN prioritization, which is a component of the IEEE 802.1 standard. GARP VLAN Registration Protocol (GVRP) support allows an OSA-Express port to register or unregister its VLAN IDs with a GVRP-capable switch and dynamically update its table as the VLANs change. This process simplifies the network administration and management of VLANs because manually entering VLAN IDs at the switch is no longer necessary.

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

Link aggregation support for z/VM

Link aggregation (IEEE 802.3ad) that is controlled by the z/VM Virtual Switch (VSWITCH) allows the dedication of an OSA-Express port to the z/VM operating system. The port must be participating in an aggregated group that is configured in Layer 2 mode.

Link aggregation (trunking) combines multiple physical OSA-Express ports into a single logical link. This configuration increases throughput, and provides nondisruptive failover if a port becomes unavailable. The target links for aggregation must be of the same type.

Link aggregation is applicable to CHPID type OSD (QDIO). The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

Multi-VSwitch Link Aggregation

Multi-VSwitch Link Aggregation support allows a port group of OSA-Express features to span multiple virtual switches within a single z/VM system or between multiple z/VM systems. Sharing a Link Aggregation Port Group (LAG) with multiple virtual switches increases optimization and use of the OSA-Express features when handling larger traffic loads.

Higher adapter use protects customer investments, which is increasingly important as 10 GbE deployments become more prevalent. The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

Large send for IPv6 packets

Large send for IPv6 packets improves performance by offloading outbound TCP segmentation processing from the host to an OSA-Express feature by using a more efficient memory transfer into it.

Large send support for IPv6 packets applies to the OSA-Express7S 1.2, OSA-Express7S, and OSA-Express6S¹¹ features (CHPID type OSD) on IBM z16, IBM z15, and IBM z14.

OSA-Express6S added TCP checksum on large send, which reduces the cost (CPU time) of error detection for large send.

The supported operating systems are listed in Table 7-8 on page 263 and Table 7-9 on page 265.

OSA Dynamic LAN idle

The OSA Dynamic LAN idle parameter helps reduce latency and improve performance by dynamically adjusting the inbound blocking algorithm. System administrators can authorize the TCP/IP stack to enable a dynamic setting that previously was static.

The blocking algorithm is modified based on the following application requirements:

- ▶ For latency-sensitive applications, the blocking algorithm is modified considering latency.
- ▶ For streaming (throughput-sensitive) applications, the blocking algorithm is adjusted to maximize throughput.

In all cases, the TCP/IP stack determines the best setting that is based on the current system and environmental conditions, such as inbound workload volume, processor use, and traffic patterns. It can then dynamically update the settings.

Supported OSA-Express features adapt to the changes, which avoids thrashing and frequent updates to the OAT. Based on the TCP/IP settings, OSA holds the packets before presenting them to the host. A dynamic setting is designed to avoid or minimize host interrupts.

OSA Dynamic LAN idle is supported by all OSA-Express features on IBM z16 when in QDIO mode (CHPID type OSD). The supported operating systems are listed in Table 7-8 on page 263.

OSA Layer 3 virtual MAC for z/OS environments

To help simplify the infrastructure and facilitate load balancing when an LPAR is sharing an OSA MAC address with another LPAR, each operating system instance can have its own unique logical or virtual MAC (VMAC) address. All IP addresses that are associated with a TCP/IP stack are accessible by using their own VMAC address instead of sharing the MAC address of an OSA port. This situation also applies to Layer 3 mode and to an OSA port spanned among channel subsystems.

OSA Layer 3 VMAC is supported by all OSA-Express features on IBM z16 when in QDIO mode (CHPID type OSD). The supported operating systems are listed in Table 7-8 on page 263.

Network Traffic Analyzer

IBM Z servers offer systems programmers and network administrators the ability to more easily solve network problems despite high traffic. With the OSA-Express Network Traffic Analyzer and QDIO Diagnostic Synchronization on the server, you can capture trace and trap data. This data can then be forwarded to z/OS tools for easier problem determination and resolution.

The Network Traffic Analyzer is supported by all OSA-Express features on IBM z16 when in QDIO mode (CHPID type OSD). The supported operating systems are listed in Table 7-8 on page 263.

7.4.6 Cryptography Features and Functions Support

IBM z16 provides the following major groups of cryptographic functions:

- ▶ Synchronous cryptographic functions, which are provided by CPACF
- ▶ Asynchronous cryptographic functions, which are provided by the Crypto Express8S feature

The minimum software support levels are described in the following sections. Review the current PSP buckets to ensure that the latest support levels are known and included as part of the implementation plan.

CP Assist for Cryptographic Function

Central Processor Assist for Cryptographic Function (CPACF), which is standard¹² on every IBM z16 core, now supports pervasive encryption. Simple policy controls allow business to enable encryption to protect data in mission-critical databases without stopping the database or re-creating database objects.

Database administrators can use z/OS Dataset Encryption, z/OS Coupling Facility Encryption, z/VM encrypted hypervisor paging, and z/TPF transparent database encryption, which use the performance enhancements in the hardware.

CPACF supports the following features in IBM z16:

- ▶ Processor Activity Instrumentation to count cryptographic operations
- ▶ Advanced Encryption Standard (AES, symmetric encryption)

¹² CPACF hardware is implemented on each IBM z15 core. CPACF functions are enabled with FC 3863.

- ▶ Data Encryption Standard (DES, symmetric encryption)
- ▶ Secure Hash Algorithm (SHA, hashing)
- ▶ SHAKE Algorithms
- ▶ True Random Number Generation (TRNG)
- ▶ Improved GCM (Galois Counter Mode) encryption (enabled by a single hardware instruction)

In addition, the IBM z16 and IBM z15 cores implement a Modulo Arithmetic unit in support of Elliptic Curve Cryptography.

CPACF is used by several IBM software product offerings for z/OS, such as IBM WebSphere Application Server for z/OS. For more information, see 6.4, “CP Assist for Cryptographic Functions” on page 223.

The supported operating systems are listed in Table 7-10 on page 267 and Table 7-11 on page 268.

Crypto Express8S (new on IBM z16)

Crypto Express8S includes a single- or dual- HSM adapter (single or dual IBM 4770 PCIe Cryptographic Co-processor [PCIeCC]) and complies with the following Physical Security Standards:

- ▶ FIPS 140-3 level 4
- ▶ Common Criteria EP11 EAL4+
- ▶ Payment Card Industry (PCI) HSM
- ▶ German Banking Industry Commission (GBIC, formerly DK)
- ▶ AusPayNet (APN)

Support of Crypto Express8S functions varies by operating system and release and by the way that the card is configured as a coprocessor or an accelerator. The supported operating systems are listed in Table 7-10 on page 267 and Table 7-11 on page 268.

Crypto Express7S (carry forward on IBM z16)

Introduced with IBM z15, Crypto Express7S includes a single- or dual-port adapter (single or dual IBM 4769 PCIe Cryptographic Co-processor [PCIeCC]) and complies with the following Physical Security Standards:

- ▶ FIPS 140-2 level 4
- ▶ Common Criteria EP11 EAL4
- ▶ Payment Card Industry (PCI) HSM
- ▶ German Banking Industry Commission (GBIC, formerly DK)

The supported operating systems are listed in Table 7-10 on page 267 and Table 7-11 on page 268.

Crypto Express6S (carry forward on IBM z16)

Introduced with IBM z14, Crypto Express6S includes one IBM 4768 PCIe Cryptographic Co-processor (PCIeCC) and complies with the following Physical Security Standards:

- ▶ FIPS 140-2 level 4
- ▶ Common Criteria EP11 EAL4
- ▶ Payment Card Industry (PCI) HSM
- ▶ German Banking Industry Commission (GBIC, formerly DK)

The supported operating systems are listed in Table 7-10 on page 267 and Table 7-11 on page 268.

Web deliverables

For more information about web-deliverable code on z/OS, see [the z/OS downloads website](#).

For Linux on IBM Z, support is delivered through IBM and the distribution partners. For more information, see [Linux on IBM Z on the IBM Developer website](#).

z/OS Integrated Cryptographic Service Facility

To achieve security in a distributed computing environment, a combination of elements must work together. A security policy should be based on an appraisal of the value of data and the potential threats to that data. This security policy provides the foundation for a secure environment.

IBM categorized the following security functions according to International Organization for Standardization (ISO) standard 7498-2:

- ▶ Identification and authentication: Includes the ability to identify users to the system and provide proof that they are who they claim to be.
- ▶ Access control: Determines which users can access which resources.
- ▶ Data confidentiality: Protects an organization's sensitive data from being disclosed to unauthorized persons.
- ▶ Data integrity: Ensures that data is in its original form and that nothing altered it.
- ▶ Security management: Administers, controls, and reviews a business security policy.
- ▶ Nonrepudiation: Assures that the suitable individual sent the message.

Only cryptographic services can provide the data confidentiality and the identity authentication that is required to protect business commerce on the internet¹³.

Integrated Cryptographic Service Facility (ICSF) is a base component of z/OS. It is designed to transparently use the available cryptographic functions (whether CPACF or Crypto Express) to balance the workload and help address the bandwidth requirements of the applications.

ICSF support for IBM z16 is provided with PTFs, not as previously was the case, through Web deliverables.

Supported levels of ICSF automatically detect what hardware cryptographic capabilities are available where it is running. Then, it enables functions accordingly. No toleration of new hardware is necessary because it is "just there". ICSF maintenance is necessary if you want to use new capabilities.

Use of new functions is supplied in ICSF PTFs on z/OS V2.R2-V2.R4 (Web deliverable HCR77D1) or V2.R5 (base, which is HCR77D2).

New function exploitation includes:

- ▶ CCA and EP11 CEX8 Coprocessor support
- ▶ CCA and EP11 Quantum Safe Algorithms (Kyber & Dilithium 8,7)
- ▶ EP11 mechanism for data reencryption and new ECC curve support
- ▶ Fully homomorphic encryption
- ▶ Usage counters that count classes of crypto operations (to meet audit requirements)

¹³ Quoted from z/OS V2.R5 publications.

When new Quantum Safe Algorithms are used and a KDS is shared in a sysplex, ensure that all ICSF PTFs are installed on all systems.

For more information about ICSF versions and FMID cross-references, see this [IBM Support web page](#).

RMF Support for Crypto Express

RMF enhances the Monitor I Crypto Activity data gatherer to recognize and use performance data for the new Crypto Express8S (CEX8), Crypto Express7S (CEX7), and CryptoExpress6S (CEX6) cards. RMF supports all valid card configurations on IBM z16 and provides CEX7 and CEX6 crypto activity data in the SMF type 70 subtype 2 records and RMF Postprocessor Crypto Activity Report.

Reporting can be done at an LPAR/domain level to provide more granular reports for capacity planning and diagnosing problems. This feature requires fix for APAR OA54952.

The supported operating systems are listed in Table 7-10 on page 267.

z/OS Data Set Encryption

Aligned with IBM Z Pervasive Encryption initiative, IBM provides application-transparent, policy-controlled dataset encryption in IBM z/OS.

Policy-driven z/OS Data Set Encryption enables users to perform the following tasks:

- ▶ De-couple encryption from data classification; encrypt data automatically independent of labor-intensive data classification work.
- ▶ Encrypt data immediately and efficiently at the time that it is written.
- ▶ Reduce risks that are associated with mis-classified or undiscovered sensitive data.
- ▶ Help protect digital assets automatically.
- ▶ Achieve application transparent encryption.

IBM Db2 for z/OS and IBM Information Management System (IMS) intend to use z/OS Data Set Encryption.

With z/OS, Data Set Encryption DFSMS enhances data security with support for data set level encryption by using DFSMS access methods. This function is designed to give users the ability to encrypt their data sets without changing their application programs.

DFSMS users can identify which data sets require encryption by using JCL, Data Class, or the RACF data set profile. Data set level encryption can allow the data to remain encrypted during functions, such as backup and restore, migration and recall, and replication.

z/OS Data Set Encryption requires CP Assist for Cryptographic Functions (CPACF).

Considering the significant enhancements that were introduced with z14, the encryption mode of XTS is used by access method encryption to obtain the best performance possible. It is not recommended to enable z/OS data set encryption until all sharing systems, fallback, backup, and DR systems support encryption.

In addition to applying PTFs enabling the support, ICSF configuration is required. The supported operating systems are listed in Table 7-10 on page 267.

Quantum-safe encryption with IBM z16 and Crypto Express8S

Quantum-safe cryptography strengthens the portfolio of pervasive encryption capabilities on IBM z16, which allows customers to encrypt the data with a quantum-safe cryptographic algorithm (AES with 256-bit keys) as is the case with prior IBM Z buy using quantum-safe algorithms for internal system protection of encryption keys.

The following Quantum-safe enhancements were introduced with IBM z16 to accomplish this encryption:

- ▶ Key generation
- ▶ Hybrid key exchange schemes
- ▶ Dual digital signature schemes

Crypto Analytics Tool for IBM Z

The IBM Crypto Analytics Tool (CAT) for IBM Z is an analytics solution that collects data on your z/OS cryptographic infrastructure, presents reports, and analyzes if any vulnerabilities exist. CAT collects cryptographic information from across the enterprise and provides reports to help users better manage the crypto infrastructure and ensure it follows best practices. The use of CAT can help you deal with managing complex cryptography resources across your organization.

z/VM encrypted hypervisor paging (encrypted paging support)

With the PTF for APAR VM65993, z/VM V6.4 provides support for encrypted paging in support of the IBM z16 pervasive encryption philosophy of encrypting all data that is in flight and at rest. Cipherring occurs as data moves between active memory and a paging volume that is owned by z/VM.

Included in this support is the ability to dynamically control whether a running z/VM system is encrypting this data. This support protects guest paging data from administrators or users with access to volumes. Enabled with AES encryption, z/VM Encrypted Paging includes low overhead by using CPACF.

The supported operating systems are listed in Table 7-10 on page 267.

z/TPF transparent database encryption

Shipped in August 2016, z/TPF at-rest Data Encryption provides following features and benefits:

- ▶ Automatic encryption of at-rest data by using AES CBC (128 or 256).
- ▶ No application changes required.
- ▶ Database level encryption by using highly efficient CPACF.
- ▶ Inclusion of data on disk and cached in memory.
- ▶ Ability to include data integrity checking (optionally by using SHA-256) to detect accidental or malicious data corruption.
- ▶ Tools to migrate a database from unencrypted to encrypted state or change the encryption key/algorithm for a specific DB while transactions are flowing (no database downtime).

Pervasive encryption for Linux on IBM Z

Pervasive encryption for Linux on IBM Z combines the full power of Linux with IBM z16 capabilities by using the support of the following features:

- ▶ Kernel Crypto: IBM z16 CPACF
- ▶ LUKS dm-crypt Protected-Key CPACF
- ▶ Libica and openssl: IBM z16 CPACF and acceleration of RSA handshakes by using SIMD
- ▶ Secure Service Container: High security virtual appliance deployment infrastructure

Protection of data at-rest

By using the integration of industry-unique hardware accelerated CPACF encryption into the standard Linux components, users can achieve optimized encryption transparently to prevent raw key material from being visible to operating systems and applications.

Because of the potential costs and overhead, most of the organizations avoid the use of host-based network encryption today. By using enhanced CPACF and SIMD on IBM z16, TLS and IPsec can use hardware performance gains while benefiting from transparent enablement. Reduced cost of encryption enables broad use of network encryption.

IBM Z Security and Compliance Center

The IBM Z Security and Compliance Center is a modern, browser-based application that provides compliance capability mapping, fact collection, and validation. Designed for use with minimal technical skills, this solution can automate evidence collection of compliant-relevant facts from IBM Z platforms, including the new CPACF usage counters that demonstrate crypto algorithm strength and key protection.

The IBM Z Security and Compliance Center enables clients to:

- ▶ Generate detailed reports to enable executives, administrators, and auditors to understand compliance metrics with ease.
- ▶ Track compliance drift over time with dashboard visualizations that include historical compliance information.
- ▶ Use compliance evidence generation facilities from IBM Z software stack (for example, z/OS, z/OS Middleware, z/OS Compliance Integration Manager, Oracle on Linux on IBM Z, and PostgreSQL on Linux on IBM Z).
- ▶ Provide an interactive view of the compliance posture and details around the severity of control deviations from regulations, such as PCI-DSS v3.2.1, NIST SP800-53, and CIS Benchmarks.

z/OS support for compliance

z/OS was enhanced to enable the collection of compliance data from IBM z16 CPACF counters and several z/OS products and components.

A new z/OSMF Compliance fact collection REST API sends an ENF86 signal to all systems. Participating products and components collect and write compliance data to new SMF 1154 records that are associated with its unique subtype. These new SMF 1154 records can be integrated into solutions, such as the IBM z16 IBM Z Security and Compliance Center.

This support requires PTFs for z/OS 2.4 and z/OS 2.5. The PTFs are identified by a fix category that is designated specifically for Compliance data collection support named IBM.Function.Compliance.DataCollection. For more information about how to use this fix category to identify and install the specific PTFs that enable compliance data collection, see “IBM Fix Category Values and Descriptions”.

For more information about z/OS collection sources and enablement, see the following resources:

- ▶ Software Announcement 222-005, IBM Z Security and Compliance Center.
- ▶ Software Announcement 222-092, CICS Transaction Server for z/OS 6.1.
- ▶ Software Announcement 222-003, Db2 13 for z/OS powered by AI innovations provides industry scalability, business resiliency and intelligence.

Linux support for compliance

Linux on IBM Z supports the collection of compliance data from the Linux environment.

The following prerequisite operating system versions are supported for the collection of compliance data:

- ▶ Red Hat Enterprise Linux 8.0 (RHEL) on IBM Z, or later
- ▶ SUSE Linux Enterprise Server (SLES) on IBM Z 15
- ▶ Ubuntu Server LTS for IBM Z 22.04

The following optional software is available for collecting compliance data:

- ▶ Oracle 19c
- ▶ PostgreSQL 13.x, 14.x

7.5 z/OS migration considerations

Except for base processor support, z/OS releases do not require any of the functions that are introduced with the IBM z16. Minimal toleration support that is needed depends on z/OS release.

Although IBM z16 servers do not require any “functional” software, it is recommended to install all IBM z16 service before upgrading to the new server. The support matrix for z/OS releases and the IBM Z servers that support them are listed in Table 7-16, where “X” indicates that the hardware model is supported.

Table 7-16 z/OS support summary

z/OS Release	IBM zEC12 IBM zBC12 WDFM ^a	IBM z13 IBM z13s WDFM ^a	IBM z14 ^a	IBM z15	IBM z16	End of Service	Extended Defect Support ^b
V2R2	X	X	X	X	X	09/2020 ^b	09/2023 ^b
V2R3	X	X	X	X	X	09/2022	09/2025 ^b
V2R4	-	X	X	X	X	09/2024	09/2027 ^b
V2R5	-	-	X	X	X	09/2026	09/2029 ^b

a. Server is withdrawn from marketing.

b. The IBM Software Support Services provides the ability for customers to purchase extended defect support service for z/OS.

7.5.1 General guidelines

The IBM z16 introduces the latest IBM Z technology. Although support is provided by z/OS starting with z/OS V2.R2, the capabilities and use of IBM z16 depends on the z/OS release. Optional web deliverables¹⁴ are needed for some functions on some releases.

New: ICSF support for IBM z16 is provided with PTFs, not Web deliverables

In general, consider the following guidelines:

- ▶ Do not change software releases and hardware at the same time.
- ▶ At a minimum, apply maintenance from the following FIXCAT to all systems that participate in a sysplex with IBM z16, regardless of whether the systems is to be migrated to the current hardware:
IBM.Device.Server.IBM z16-3931.RequiredService
- ▶ Keep members of the sysplex at the same software level, except during brief migration periods.
- ▶ Upgrade Coupling Facility LPARs to current levels (review all structure sizes by using the CFSIZER tool *before* the CF is upgraded).
- ▶ Review any restrictions and migration considerations before creating an upgrade plan.
- ▶ Acknowledge that some hardware features cannot be ordered or carried forward for an upgrade from an earlier server to IBM z16 and plan accordingly.

¹⁴ For example, the use of Crypto Express7S requires the Cryptographic Support for z/OS V2R2 - z/OS V2R3 web deliverable.

- ▶ Determine the changes in IOCP, HCD, and HCM to support defining IBM z16 configuration and the new features and functions it introduces.
- ▶ Ensure that none of the new z/Architecture Machine Instructions (mnemonics) that were introduced with IBM z16 are colliding with the names of Assembler macro instructions you use¹⁵.
- ▶ Check the use of **MACHMIG** statements in **LOADxx** PARMLIB commands.
- ▶ Contact software vendors to inform them of new machine model and request new license keys, if applicable.
- ▶ Review the z/OS Upgrade Workflow for z/OSMF that is provided with APAR OA62703 for z/OS V2R2 and higher. This Workflow also is available in the IBM Documentation library.

7.5.2 Hardware Fix Categories

Base support includes fixes that are required to run z/OS on the IBM z16 server. They are identified by:

```
IBM.Device.Server.IBM z16-3931.RequiredService
```

The use of many functions covers fixes that are required to use the capabilities of the IBM z16 servers. They are identified by:

```
IBM.Device.Server.IBM z16-3931.Exploitation
```

Recommended service is identified by:

```
IBM.Device.Server.IBM z16-3931.RecommendedService
```

General z/OS support documentation provided in the PSP Bucket. For IBM z16 A01: PSP Bucket Upgrade = 3931DEVICE, Subset = 3931/ZOS.

Consider the following other Fix Categories of Interest:

- ▶ Fixes that are required to use the Server Time Protocol function:

```
IBM.Function.ServerTimeProtocol
```

- ▶ Fixes that are required to use the High-Performance FICON function:

```
IBM.Function.zHighPerformanceFICON
```

- ▶ Fixes that are required for IBM Z System Recovery Boost:

```
IBM.Function.SystemRecoveryBoost
```

- ▶ PTFs that allow previous levels of ICSF to coexist with the latest Cryptographic Support for z/OS V2R2 - z/OS V2R4 (HCR77D1) web deliverable:

```
IBM.Coexistence.ICSF.z/OS_V2R2-V2R4-HCR77D1
```

Use the SMP/E **REPORT MISSINGFIX** command to determine whether any FIXCAT APARs exist that are applicable and are not yet installed, and whether any SYSMODs are available to satisfy the missing FIXCAT APARs.

For more information about IBM Fix Category Values and Descriptions, see this [IBM Support web page](#).

¹⁵ For more information, see the [Tool to Compare IBM z16 Instruction Mnemonics with Macro Libraries](#) IBM Technote.

7.5.3 z/OS V2.R5

IBM z/OS, Version 2 Release 5 was announced 27 July 2021. One of the highlights of this release is the support of 16 TB real memory per z/OS image. This support allows new workloads that require more storage than is available.

For more information about this release, see this [announcement letter](#).

7.5.4 z/OS V2.R4

IBM z/OS, Version 2 Release 4, was made generally available on 30 September 2019. This release delivers innovation through an agile, optimized, and resilient platform that helps companies build applications and services that are based on a highly scalable and secure infrastructure. This infrastructure provides the performance and availability for on-premises or provisioned as-a-service workloads.

z/OS V2.R4 delivers many capabilities, including the following examples:

- ▶ IBM z/OS Container Extensions (zCX), which enables the ability to run almost any Linux on IBM Z Docker container in z/OS alongside existing z/OS applications and data without a separate provisioned Linux server.
- ▶ Easier integration of z/OS into private and multi-cloud environments with improvements that deliver a more robust, easy to use, and highly available implementation that uses IBM Cloud Provisioning and Management for z/OS, IBM z/OS Cloud Broker, and IBM Cloud Storage Access for z/OS Data.
- ▶ Enhancements that continue to simplify and modernize the z/OS environment for a better user experience and improved productivity by reducing the level of IBM Z specific skills that are required to maintain z/OS.
- ▶ Ongoing industry-wide simplification improvements to help companies install and configure software by using a common and modern method. These installation improvements range from the packaging of software through the configuration so that faster time to value can be realized throughout the enterprise.
- ▶ IBM Open Data Analytics for z/OS provides enhancements to simplify data analysis by combining open source run times and libraries with analysis of z/OS data at its source,
- ▶ Enhancements to security and data protection on the system with support for new industry cryptography and continued enhancements driving pervasive encryption through the ability to encrypt data without application changes. A new RACF capability improves management of access and privileges.
- ▶ The use of IBM z16 capabilities

System Recovery Boost reduces the time that z/OS is offline when the operating system is offline for any reason. The use of IBM System Recovery Boost expedites planned operating system shutdown processing, operating system Initial Program Load (IPL), middleware and workload restart and recovery, and the client workload execution that follows.

It enables businesses to return their systems to work faster, not just from catastrophes, but after all kinds of disruptions (planned and unplanned). Another aspect of System Recovery Boost is to expedite and streamline the execution of GDPS recovery scripts that perform reconfiguration actions during various planned and unplanned operational scenarios.

7.5.5 z/OS V2.R3

IBM announced z/OS Version 2 Release 3 - Engine for digital transformation through Announcement letter 217-246 on 17 July 2017. Focusing on three critical areas (Security, Simplification, and Cloud), z/OS V2.R3 provides a simple and transparent approach to enable extensive encryption of data and to simplify the overall management of the z/OS system to increase productivity. Focus also is given to providing a simple approach for self-service provisioning and rapid delivery of software as a service, while enabling for the API economy.

Consider the following points before migrating z/OS V2.R3 to IBM z16:

- ▶ IBM z/OS V2.R3 with IBM z16 requires a minimum of 8 GB of memory. When running as a z/VM guest or on an IBM System z® Personal Development Tool, a minimum of 2 GB is required for z/OS V2.R3. If the minimum is not met, a warning WTOR is issued at IPL.

Continuing with less than the minimum memory might affect availability. A migration health check warns if the system is configured with less than 8 GB.

- ▶ Dynamic splitting and merging of Coordinated Timing Network (CTN) is available with IBM z16.
- ▶ RMF support is provided to collect SMC-D related performance measurements in SMF 73 Channel Path Activity and SMF 74 subtype 9 PCIe Activity records. It also provides these measurements in the RMF Postprocessor and Monitor III PCIe and Channel Activity reports.

HyperSwap support is enhanced to allow RESERVE processing. When a system runs a request to swap to secondary devices that are managed by HyperSwap, z/OS detects when RESERVEs are held and ensures that the devices that are swapped also hold the RESERVE. This enhancement is provided with collaboration from z/OS, GDPS HyperSwap, and CSM HyperSwap.

7.5.6 Remote dynamic activation of I/O configurations for stand-alone Coupling Facilities, Linux on Z and z/TPF

The remote activation of dynamic changes avoid the need for disruptive hardware/firmware actions (Power-on Reset or IML) to be taken to instantiate those configuration changes, reducing, or completely eliminating the client workload impact that would otherwise have resulted from taking these disruptive actions.

IBM z16 provide a supported capability to drive these hardware-only I/O configuration changes from a driving z/OS HCD instance to a remote target CPC which is a Coupling facility of hosts IBM Linux on Z and z/TPF.

This new support is applicable only when both the driving CPC and the target CPC are z16s with the required firmware support (Bundle S24 or higher) and when the driving system's z/OS level is 2.3 or higher with APA OA65559.

7.5.7 Coupling links

IBM z16 servers support only active participation in the same Parallel Sysplex with IBM z15 and IBM z14. Configurations with z/OS on one of these servers can add an IBM z16 Server to their Sysplex for a z/OS or a Coupling Facility image.

Configurations with a Coupling Facility on one of these servers can add an IBM z16 Server to their Sysplex for a z/OS or a Coupling Facility image. IBM z16 does not support participating in a Parallel Sysplex with System IBM z13/IBM z13s and earlier systems.

Each system can use, or not use, internal coupling links, CE LR links, or ICA SR coupling links independently of what other systems are using.

Coupling connectivity is available only when other systems also support the same type of coupling. For more information about supported coupling link technologies on IBM z16, see 4.6.4, “Parallel Sysplex connectivity” on page 190, and the [Coupling Facility Configuration Options](#) white paper.

Note: IBM z16 does not support InfiniBand coupling links. More planning might be required to integrate the IBM z16 in a Parallel Sysplex with IBM z14 servers.

7.5.8 z/OS XL C/C++ considerations

IBM z/OS V2.R4 XL C/C++ is an optional feature of z/OS that continues to ship with IBM z16.

The following new functions provide performance improvements for applications by using new IBM z16 instructions:

- ▶ High-performance math libraries
- ▶ MASS
- ▶ Replace Atlas with OpenBLAS
- ▶ Metal C for modernizing HLASM applications and systems programming

To enable the use of new functions, specify **ARCH(14)** and **VECTOR** for compilation. The binaries that are produced by the compiler on IBM z16 can be run only on IBM z16 and above because it uses the vector facility on IBM z16 for new functions. The use of older versions of the compiler on IBM z16 does *not* enable new functions.

z/OS V2R4 can use the latest level (14) of the following C/C++ compiler options:

- ▶ **ARCHITECTURE:** This option selects the minimum level of system architecture on which the program can run. Specific features that are provided by the compiler require a minimum architecture level. **ARCH(14)** uses instructions that are available on the IBM z16.
- ▶ **TUNE:** This option allows optimization of the application for a specific system architecture within the constraints that are imposed by the **ARCHITECTURE** option. The **TUNE** level must not be lower than the setting in the **ARCHITECTURE** option.

Important: Use the previous IBM Z **ARCHITECTURE** or **TUNE** options for C/C++ programs if the same applications run on the previous IBM Z servers. However, if C/C++ applications run on IBM z16 servers only, use the latest **ARCHITECTURE** and **TUNE** options to ensure that the best performance possible is delivered through the latest instruction set additions.

For more information about the **ARCHITECTURE**, **TUNE**, and **VECTOR** compiler options, see [z/OS XL C/C++ User's Guide, SC14-7307-40](#).

z/OS XL C/C++ Web deliverables are available at no charge to z/OS XL C/C++ customers:

- ▶ Based on open-source LLVM infrastructure; supports up to date C++ language standards
- ▶ 64-bit, UNIX System Services only

Statement of Direction: IBM will continue to adopt the LLVM and Clang compiler infrastructure in future C/C++ offerings on IBM Z^a.

- a. Any statements regarding IBM's future direction, intent, or product plans are subject to change or withdrawal without notice.

7.6 IBM z/VM migration considerations

IBM z16 supports z/VM 7.3¹⁶, z/VM 7.2, and z/VM 7.1. z/VM is moving to continuous delivery model. For more information, see [this web page](#).

7.6.1 IBM z/VM 7.3

IBM z/VM 7.3 includes the following features:

- ▶ 8-Member SSI: increases the maximum size of a Single System Image (SSI) cluster from four members to eight, which enables customers to grow their SSI clusters to allow for more workload. It also provides more flexibility to use live guest relocation (LGR) for nondisruptive upgrades and workload balancing.
- ▶ New Architecture Level Set of IBM z14 and IBM z14 ZR1.
- ▶ All new functions are made available in z/VM 7.2 throughout the continuous delivery process.

7.6.2 IBM z/VM 7.2

z/VM 7.2 is available since September, 2020. It includes the following features:

- ▶ Centralized Service Management for non-SSI environments to deploy service to multiple systems, regardless of geographic location, from a centralized primary location.
- ▶ Multiple Subchannel Set (MSS) for Multi-Target Peer-To-Peer Remote Copy (MT-PPRC) z/VM support in the GDPS environment, supports a primary device and up to three secondary devices, each defined in a separate alternative subchannel set (supporting up to three alternative subchannel sets). Also provides the necessary CP updates for VM/HCD support of alternative subchannel sets.
- ▶ New Architecture Level Set of IBM z13, IBM z13s (LinuxONE Emperor or Rockhopper), or newer processor families.
- ▶ z/VM 7.2 includes New Function APARs shipped for z/VM 7.1, such as VSwitch Priority Queuing, EAV Paging, 80 Logical Processors, Dynamic Crypto, and System Recovery Boost support (subcapacity CPs speed boost only).

7.6.3 IBM z/VM 7.1

z/VM 7.1 can be installed directly on IBM z16. z/VM V7R1 and includes the following new features:

- ▶ Single System Image and Live Guest Relocation is included in the base. In z/VM 6.4, this feature was the VMSSI-priced feature.
- ▶ Enhances the dump process to reduce the time that is required to create and process dumps.
- ▶ Upgrades to a new Architecture Level Set. This feature requires an IBM zEnterprise EC12 or BC12, or later.
- ▶ Provides the base for more functions to be delivered as service Small Program Enhancements (SPEs) after general availability.

¹⁶ Preview announcement as of 5 April 2022

7.6.4 Capacity

For the capacity of any z/VM logical partition (LPAR) and any z/VM guest, you might want to adjust the number to accommodate the PU capacity of IBM z16 servers in terms of the number of Integrated Facility for Linux (IFL) processors and central processors (CPs), real or virtual.

7.7 z/VSE migration considerations

As described in 7.2.3, “z/VSE” on page 255, IBM z16 supports z/VSE 6.2.

Consider the following general guidelines when you are migrating z/VSE environment to IBM z16 servers:

- ▶ Collect reference information before migration

This information includes baseline data that reflects the status of, for example, performance data, CPU use of reference workload, I/O activity, and elapsed times.

This information is required to size IBM z16 and is the only way to compare workload characteristics after migration.

For more information, see [z/VSE Release and Hardware Upgrade](#).

- ▶ Apply required maintenance for IBM z16

Review the Preventive Service Planning (PSP) bucket 8561DEVICE for IBM z16 and apply the required PTFs for IBM and independent software vendor (ISV) products.

Note: IBM z16™ supports z/Architecture mode only.

7.8 Software licensing

The IBM z16 software portfolio includes operating system software (that is, z/OS, z/VM, z/VSE, and z/TPF) and middleware that runs on these operating systems. The portfolio also includes middleware for Linux on IBM Z environments.

This section provides an overview of the following IBM Z software licensing options that are available for IBM z16 software, including MLC, zIPLA, subcapacity, sysplex, and Taylor Fit Pricing:

- ▶ Monthly license charge (MLC)

MLC is a recurring charge that is applied monthly. It includes the right to use the product and provides access to IBM product support during the support period. Select an MLC pricing metric that is based on your goals and environment.

The selected metric is used to price MLC products, such as z/OS, z/TPF, z/VSE, middleware, compilers, and selected systems management tools and utilities:

- Key MLC metrics and offerings

MLC metrics include various offerings. The metrics and pricing schemes that are available on IBM z14, IBM z15, and IBM z16 are listed in Table 7-17 on page 328.

Table 7-17 MLC metrics offerings

Key MLC metric	Sub-capacity	Sysplex aggregation	Contract number
Advanced Workload License Charges (AWLC) ^a	Y	Y	Z125-8538
Country Multiplex License Charges (CMLC) ^b	Y	n/a	Z126-6965
Flat Workload License Charges (FWLC) ^{c,a}	see footnotes a,c	see footnotes a,c	see footnotes a,c
IBM Z New Application License Charges (zNALC) ^d	Y	Y	Z125-7454
Parallel Sysplex License Charges (PSLC) ^e	n/a	Y	Z125-5205
Midrange Workload License Charges (MWLC)	Y	n/a	Z125-7452

- a. AWLC and FWLC are available only on IBM z16 A01 and IBM z16 AGZ, z15 T02, or z14 ZR1 when that machine is participating in a qualified Parallel Sysplex environment.
- b. The Country Multiplex offering was withdrawn as of 1 January 2021. For existing CMP customers, machines that are eligible to be included in a multiplex cannot be older than two generations *before* the most recently available server.
- c. Metric available with AWLC or CMLC only.
- d. This metric is eligible for subcapacity charges or for aggregation in a qualified Parallel Sysplex environment.
- e. PSLCs are available only on IBM z16 A02 or IBM z16 AGZ, z15 T02, and z14R1 when that machine is participating in a qualified Parallel Sysplex environment.

► zIPLA licensing

International Program License Agreement (IPLA) programs include a one-time charge (OTC) and an optional annual maintenance charge, called Subscription and Support. This annual charge includes access to IBM technical support and enables you to obtain version upgrades at no charge for products that generally fall under the zIPLA such as application development tools, CICS tools, data management tools, WebSphere for IBM Z products, Linux on IBM Z middleware and z/VM.

The following pricing metrics apply to IBM Z IPLA products:

- Value Unit pricing applies to most IPLA products that run on z/OS. Value Unit pricing is typically based on a number of MSUs and allows for lower cost of incremental growth.
- z/VM V5, V6, V7, and specific z/VM middleware include pricing that is based on the number of engines. Engine-based Value Unit pricing allows for a lower cost of incremental growth with more engine-based licenses that are purchased.
- Most Linux middleware also is priced based on the number of engines. The number of engines is converted into Processor Value Units under the IBM Passport Advantage® terms and conditions.

For more information, see this [web page](#).

► Subcapacity licensing

Subcapacity licensing includes software charges for specific IBM products that are based on the use capacity of the logical partitions (LPARs) on which the product runs.

Subcapacity licensing removes the dependency between the software charges and CPC (hardware) installed capacity.

The subcapacity licensed products are charged monthly based on the highest observed 4-hour rolling average use of the logical partitions in which the product runs.

The 4-hour rolling average use of the logical partition can be limited by a defined capacity value on the image profile of the partition. This value activates the soft capping function of PR/SM, which limits the 4-hour rolling average partition use to the defined capacity value. Soft capping controls the maximum 4-hour rolling average usage (the last 4-hour average value at every 5-minute interval), but does not limit the maximum instantaneous partition use.

You can also use an LPAR group capacity limit, which sets soft capping by PR/SM for a group of logical partitions that are running z/OS. Only the 4-hour rolling average use of the LPAR group is tracked, which allows use peaks above the group capacity value.

- ▶ **Sysplex licensing**

Sysplex licensing allows monthly software licenses to be aggregated across a qualified Parallel Sysplex. To be eligible for Sysplex pricing aggregation, the customer environment must meet hardware, software, operation, and verification criteria to be considered “actively coupled”. For more information about Sysplex licensing, see this [web page](#).

- ▶ **Taylor Fit Software Consumption**

Taylor Fit Software Consumption Solution is a cloud-like, usage-based licensing model. Usage is measured based on MSUs that are used, which removes the need for manual or automated capping. It also allows customers to configure their systems to support optimal response times and service level agreements.

Tailored Fit Pricing (TFP) requires z/OS V2.R2, or later, with the applicable PTFs applied.

The requirements for TFP vary with the solution. The specific requirements for a solution must be met before IBM can accept and process subcapacity reports in which TFP solutions are reported. For more information about TFP, see this [web page](#).

Technology Transition Offerings with IBM z16

Complementing the announcement of the IBM z16 server, IBM introduced the following Technology Transition Offerings (TTOs):

- ▶ **Technology Update Pricing for the IBM z16.**
- ▶ **New and revised Transition Charges for Sysplexes or Multiplexes TTOs for actively coupled Parallel Sysplexes (z/OS), Loosely Coupled Complexes (z/TPF), and Multiplexes (z/OS and z/TPF).**

Technology Update Pricing for the IBM z16 extends the software price and performance that is provided by AWLC for IBM z16 servers. The new and revised Transition Charges for Sysplexes offerings provide a transition to Technology Update Pricing for the IBM z16 for customers who have not fully migrated to IBM z16 servers. This transition ensures that aggregation benefits are maintained and phases in the benefits of Technology Update Pricing for the IBM z16 pricing as customers migrate.

When an IBM z16 server is in an actively coupled Parallel Sysplex or a Loosely Coupled Complex, you might choose aggregated Advanced Workload License Charges (AWLC) pricing or aggregated Parallel Sysplex License Charges (PSLC) pricing (subject to all applicable terms and conditions).

When an IBM z16 server is part of a Multiplex under Country Multiplex Pricing (CMP) terms, Country Multiplex License Charges (CMLC), Multiplex zNALC (MzNALC), and Flat Workload License Charges (FWLC) are the only pricing metrics that are available (subject to all applicable terms and conditions).

When an IBM z16 server is running z/VSE, you can choose Mid-Range Workload License Charges (MWLC), which are subject to all applicable terms and conditions.

For more information about AWLC, CMLC, MzNALC, PSLC, MWLC, or the Technology Update Pricing and Transition Charges for Sysplexes or Multiplexes TTO offerings, see the [IBM Z Software Pricing page](#) of the IBM IT infrastructure website.

7.9 References

For more information about planning, see the home pages for the following operating systems:

- ▶ [z/OS](#)
- ▶ [z/VM](#)
- ▶ [z/VSE](#)
- ▶ [z/TPF](#)
- ▶ [Linux on IBM Z](#)
- ▶ [KVM for IBM Z](#)



System upgrades

This chapter provides an overview of the IBM Z server upgrade process and how, in many cases, customers can manage capacity upgrades by using online tools and automation. The chapter also includes a detailed description of capacity on demand (CoD) offerings available on the IBM z16.

IBM z16 servers support dynamic provisioning features to give clients exceptional flexibility and control over system capacity and costs.

This chapter includes the following topics:

- ▶ 8.1, “Introduction” on page 332
- ▶ 8.2, “Permanent and Temporary Upgrades” on page 332
- ▶ 8.3, “Concurrent upgrades” on page 338
- ▶ 8.4, “Miscellaneous equipment specification upgrades” on page 345
- ▶ 8.5, “Permanent upgrade by using the CIU facility” on page 351
- ▶ 8.6, “On/Off Capacity on Demand” on page 356
- ▶ 8.7, “z/OS Capacity Provisioning” on page 363
- ▶ 8.8, “System Recovery Boost Upgrade” on page 368
- ▶ 8.9, “Capacity for Planned Event” on page 369
- ▶ 8.10, “Capacity Backup” on page 369
- ▶ 8.11, “Flexible Capacity Cyber Resiliency” on page 374
- ▶ 8.12, “Planning for nondisruptive upgrades” on page 376
- ▶ 8.13, “Summary of Capacity on-Demand offerings” on page 382

8.1 Introduction

A key resource for managing client IBM Z servers is the [IBM Resource Link website](#). Once registered, a client can view product information by clicking **Resource Link** → **Client Initiated Upgrade Information**, and selecting **Education**. Select your particular product from the list of available systems.

The scalability of IBM z16 servers includes the following benefits:

- ▶ Enabling new business opportunities
- ▶ Support for dynamic capacity growth and cloud environments
- ▶ Risk management of volatile, high-growth, and high-volume applications
- ▶ Enabling 24 x 7 application availability
- ▶ Enabling capacity growth during lockdown periods
- ▶ Enabling planned downtime without availability effects

8.2 Permanent and Temporary Upgrades

The terminology for CoD and the types of upgrades for an IBM z16 are described in this section.

8.2.1 Overview

Upgrades can be categorized as described in this section.

Permanent versus temporary upgrades

Deciding whether to perform a permanent or temporary upgrade depends on the situation. For example, a growing workload might require more memory, I/O cards, or processor capacity. However, to handle a peak workload or to temporarily replace a system that is down during a disaster or data center maintenance, might require only a temporary upgrade.

IBM z16 servers offer the following solutions:

- ▶ Permanent upgrades
 - Miscellaneous equipment specification (MES)
An MES upgrade might involve adding physical hardware or installing Licensed Internal Code Configuration Control (LICCC). In both cases, the hardware installation is performed by IBM personnel.
 - Customer Initiated Upgrade (CIU)
The use of the CIU facility for a system requires that the online CoD buying feature (FC 9900) is installed on the system and the relevant CIU contract agreements are in place. The CIU facility supports only LICCC upgrades.

For more information, see 8.2.4, “Permanent upgrades” on page 336.

Tip: An MES provides system upgrades that can result in more enabled processors, a different central processor (CP) capacity level, more processor drawers, memory, PCIe+ I/O drawers, and I/O features (physical upgrade). Extra planning tasks are required for nondisruptive logical upgrades. An MES is ordered through your IBM representative and installed by IBM service support representatives (IBM SSRs).

► Temporary upgrades

All temporary upgrades are LICCC-based. The one billable capacity offering is On/Off Capacity on Demand (CoD), which can be used for short-term capacity requirements and are pre-paid or post-paid.

The two replacement capacity offerings available are Capacity Backup (CBU) and Capacity for Planned Event (CPE).

Note: CPE is available only when carried forward to IBM z16.

System Recovery Boost zIIP capacity is a pre-paid offering that is available on IBM z15 T01 and IBM z16 A01. It is intended to provide temporary zIIP capacity to be used to boost CPU performance for boost events. For more information, see *Introducing IBM X System Recovery Boost*, [REDP-5563](#).

Flexible Capacity for Cyber Resiliency is new type of temporary record that is introduced with IBM z16. This record holds the Flexible Capacity Entitlements for IBM z16 machines across two or more sites.

8.2.2 CoD for IBM z16 systems-related terminology

The most frequently used terms that are related to CoD for IBM z16 systems are listed in Table 8-1.

Table 8-1 CoD terminology

Term	Description
Activated capacity	Capacity that is purchased and activated. Purchased capacity can be greater than the activated capacity.
Billable capacity	Capacity that helps handle workload peaks (expected or unexpected). The one billable offering that is available is On/Off CoD.
Capacity	Hardware resources (processor and memory) that can process the workload can be added to the system through various capacity offerings.
Capacity Backup (CBU)	This capacity allows you to place model capacity or specialty engines in a backup system. CBU is used in an unforeseen loss of system capacity because of an emergency or for Disaster Recovery testing.
Capacity for Planned Event (CPE)	Used when temporary replacement capacity is needed for a short-term event. CPE activates processor capacity temporarily to facilitate moving systems between data centers, upgrades, and other routine management tasks. CPE is an offering of CoD.
Capacity levels	Can be full capacity or sub-capacity. For an IBM z16 A01 system, capacity levels for the CP engine are 7, 6, 5, and 4.
Capacity setting	Derived from the capacity level and the number of processors. For the IBM z16 A01 system, the capacity levels are 7nn, 6yy, 5yy, and 4xx, where xx, yy, or nn indicates the number of active CPs. The number of processors can have the following ranges: <ul style="list-style-type: none"> ► 0 - 39 for capacity levels 4xx. An all IFL or an all ICF system has a capacity level of 400. ► 1 - 39 for capacity levels 5yy and 6yy. ► 1 - 99 in decimal and A0 - K0, where A0 represents 100 and K0 represents 200, for capacity level 7nn.

Term	Description
Customer Initiated Upgrade (CIU)	A web-based facility where you can request processor and memory upgrades by using the IBM Resource Link and the system's Remote Support Facility (RSF) connection.
Capacity on Demand (CoD)	The ability of a system to increase or decrease its performance capacity as needed to meet fluctuations in demand.
Capacity Provisioning Manager (CPM)	As a component of z/OS Capacity Provisioning, CPM monitors business-critical workloads that are running z/OS on IBM z16.
Customer profile	This information is on Resource Link and contains client and system information. A customer profile can contain information about systems that are related to their IBM customer numbers.
Flexible Capacity for Cyber Resiliency	Available on IBM z16 A01 servers, the optional Flexible Capacity Record is an orderable feature that entitles a customer to active MIPS flexibility for all engine types between IBM z16 servers across two or more sites. It allows capacity swaps for an extended term.
Full capacity CP feature	For IBM z16 servers, feature (CP7) provides full capacity. Capacity settings 7nn are full capacity settings with the ranges of 1 - 99 in decimal and A0 - K0, where A0 represents 100 and K0 represents 200, for capacity level 7nn.
High-water mark	Capacity that is purchased and owned by the client.
Installed record	The LICCC record is downloaded, staged to the Support Element (SE), and is installed on the central processor complex (CPC). A maximum of eight different records can be concurrently installed.
Model capacity identifier (MCI)	Shows the current active capacity on the system, including all replacement and billable capacity. For IBM z16 A01 servers, the model capacity identifier is in the form of 4xx, 5yy, 6yy, or 7nn, where xx, yy, or nn indicates the number of active CPs: <ul style="list-style-type: none"> ▶ xx can have a range of 00 - 39. An all IFL or an all ICF system has a capacity level of 400. ▶ yy can have a range of 01 - 39. ▶ 1 - 99 in decimal and A0 - K0, where A0 represents 100 and K0 represents 200, for capacity level 7nn.
Model Permanent Capacity Identifier (MPCI)	Keeps information about the capacity settings that are active before any temporary capacity is activated.
Model Temporary Capacity Identifier (MTCI)	Reflects the permanent capacity with billable capacity only, without replacement capacity. If no billable temporary capacity is active, MTCI equals the MPCI.
On/Off Capacity on Demand	Represents a function that allows spare capacity in a CPC to be made available to increase the total capacity of a CPC. For example, On/Off CoD can be used to acquire capacity for handling a workload peak.
Permanent capacity	The capacity that a client purchases and activates. This amount might be less capacity than the total capacity purchased.
Permanent upgrade	LICC that is licensed by IBM to enable the activation of applicable computing resources, such as processors or memory, for a specific CIU-eligible system on a permanent basis.
Purchased capacity	Capacity that is delivered to and owned by the client. It can be higher than the permanent capacity.
Permanent/Temporary entitlement record	The internal representation of a temporary (TER) or permanent (PER) capacity upgrade that is processed by the CIU facility. An <i>entitlement record</i> contains the encrypted representation of the upgrade configuration with the associated time limit conditions.

Term	Description
Replacement capacity	A temporary capacity that is used for situations in which processing capacity in other parts of the enterprise is lost. This loss can be a planned event or an unexpected disaster. The two replacement offerings available are Capacity for Planned Events and Capacity Backup.
Resource Link	The IBM Resource Link website a technical support website that provides a comprehensive set of tools and resources (log in required).
Secondary approval	An option that is selected by the client that requires second approver control for each CoD order. When a secondary approval is required, the request is sent for approval or cancellation to the Resource Link secondary user ID.
Staged record	The point when a record that represents a temporary or permanent capacity upgrade is retrieved and loaded on the SE disk.
Subcapacity	For IBM z16 A01 servers, CP features (CP4, CP5, and CP6) provide reduced capacity relative to the full capacity CP feature (CP7).
System Recovery Boost Upgrade record	Available on IBM z16 A01 servers, the optional System Recovery Boost Upgrade is an orderable feature that provides more capacity for a limited time to enable speeding up shutdown, restart, and catchup processing for a limited event duration.
Temporary capacity	An optional capacity that is added to the current system capacity for a limited amount of time. It can be capacity that is owned or not owned by the client.
Vital product data (VPD)	Information that uniquely defines system, hardware, software, and microcode elements of a processing system.

8.2.3 Concurrent and nondisruptive upgrades

Depending on the effect on the system and application availability, upgrades can be classified in the following manner:

- ▶ Concurrent

In general, *concurrency* addresses the continuity of operations of the *hardware* during an upgrade; for example, whether a system (hardware) must be turned off during the upgrade. For more information, see 8.3, “Concurrent upgrades” on page 338.

- ▶ Nonconcurrent

This type of upgrade requires turning off the hardware that is being upgraded. Examples include memory upgrades to an IBM z16 A01 max 39.

- ▶ Nondisruptive

Nondisruptive upgrades do not require the software or operating system to be restarted for the upgrade to take effect.

- ▶ Disruptive

An upgrade is considered *disruptive* when resources that are modified or added to an operating system image require that the operating system be restarted to configure the newly added resources.

A Concurrent upgrade might be disruptive to operating systems or programs that do not support the upgrades while being nondisruptive to others. For more information, see 8.12, “Planning for nondisruptive upgrades” on page 376.

8.2.4 Permanent upgrades

Permanent upgrades can be obtained by using the following processes:

- ▶ Ordered through an IBM marketing representative
- ▶ Initiated by the client with the CIU on the IBM Resource Link

Tip: The use of the CIU facility for a system requires that the online CoD buying feature (FC 9900) is installed on the system. The CIU facility is enabled through the permanent upgrade authorization feature code (FC 9898).

Permanent upgrades that are ordered through an IBM representative

Through a permanent upgrade, you can accomplish the following tasks:

- ▶ Add:
 - Processor drawers
 - Peripheral Component Interconnect Express (PCIe) drawers and features
 - Model capacity
 - Specialty engines
 - Memory
 - I/O channels
 - Crypto Express cards
- ▶ Activate unassigned model capacity or IFLs, ICFs, or zIIPs
- ▶ Deactivate activated model capacity or IFLs, ICFs, or zIIPs
- ▶ Change specialty engines (recharacterization)

Considerations: Most of the MESs can be concurrently applied without disrupting the workload. For more information, see 8.3, “Concurrent upgrades” on page 338. However, specific MES changes might be disruptive, such as adding PCIe IO drawers.

Memory upgrades that require dual inline memory module (DIMM) changes can be made nondisruptively if multiple CPC drawers are available and the flexible memory option is used.

Permanent upgrades by using CIU on the IBM Resource Link

Ordering the following permanent upgrades by using the CIU application through Resource Link allows you to add capacity to fit within your hardware:

- ▶ Add:
 - Model capacity
 - Specialty engines
 - Memory
- ▶ Activate unassigned model capacity or IFLs, ICFs, or zIIPs
- ▶ Deactivate activated model capacity or IFLs, ICFs, or zIIPs

8.2.5 Temporary upgrades

IBM z16 A01 offers the following types of temporary upgrades:

- ▶ On/Off CoD

This offering allows you to temporarily add capacity or specialty engines to cover seasonal activities, period-end requirements, peaks in workload, or application testing. This temporary upgrade can be ordered by using the CIU application through Resource Link only.

Prepaid On/Off CoD tokens: Beginning with IBM z16, new prepaid On/Off CoD tokens that are purchased do not carry forward to future systems.

- ▶ CBU

This offering allows you to replace model capacity or specialty engines in a backup system that is used in an unforeseen loss of system capacity because of a disaster.

- ▶ CPE¹

This offering allows you to replace model capacity or specialty engines because of a relocation of workload during system migrations or a data center move.

- ▶ System Recovery Boost Upgrade record

This offering allows you to add up to 20 zIIPs for use with the System Recovery Boost facility. System Recovery Boost provides temporary extra capacity for CP workloads to allow rapid shutdown, restart, and recovery of eligible systems. System Recovery Boost records are prepaid, licensed for 1 - 5 years, and can be renewed at any time.

- ▶ Flexible Capacity Record

This offering allows you to move CPU capacity between machines across two or more sites. Capacity can be moved between sites a maximum of 12 times per year for a maximum of 12 months per move.

Consider the following points:

- ▶ CBU, CPE, and System Recovery Boost Records can be ordered by using the CIU application through Resource Link or by contacting your IBM marketing representative.
- ▶ Flexible Capacity can be ordered by contacting your IBM representative.
- ▶ Temporary upgrade capacity changes might be billable or a replacement.

Billable capacity

To handle a peak workload, you can activate up to double the purchased capacity of any processor unit (PU) type temporarily. You are charged daily.

This billable capacity offering is On/Off CoD.

¹ CPE is only available as carry forward on IBM z16

Replacement capacity

When processing capacity is lost in part of an enterprise, replacement capacity can be activated. It allows you to activate any PU type up to your authorized limit.

The following replacement capacity offerings are available:

- ▶ Capacity Backup
- ▶ Capacity for Planned Event
- ▶ Flexible Capacity for Cyber Resiliency

8.3 Concurrent upgrades

Concurrent upgrades on IBM z16 servers can provide more capacity with no system outage. In most cases, a concurrent upgrade can be nondisruptive to the operating system with planning and operating system support.

This capability is based on the flexibility of the design and structure, which allows concurrent hardware installation and Licensed Internal Control Code (LICC) configuration changes.

The sub-capacity models allow more configuration granularity within the family. The added granularity is available for models that are configured with up to 39 CPs, and provides 117 extra capacity settings. Sub-capacity models provide for CP capacity increase in two dimensions that can be used together to deliver configuration granularity. The first dimension is adding CPs to the configuration. The second is changing the capacity setting of the CPs currently installed to a higher model capacity identifier.

IBM z16 allows the concurrent and nondisruptive addition of processors to a running logical partition (LPAR). As a result, you can have a flexible infrastructure to which you can add capacity. This function is supported by z/OS, z/VM, and z/VSE. This addition is made by using one of the following methods:

- ▶ With planning ahead for the future need of extra processors. Reserved processors can be specified in the LPAR's profile. When the extra processors are installed, the number of active processors for that LPAR can be increased without the need for a partition reactivation and initial program load (IPL).
- ▶ Another (easier) way is to enable the dynamic addition of processors through the z/OS LOADxx member. Set the **DYNCPADD** parameter in member LOADxx to ENABLE.

Another function concerns the *system assist processor* (SAP). When more SAPs are concurrently added to the configuration, the SAP-to-channel affinity is dynamically remapped on all SAPs on the system to rebalance the I/O configuration.

8.3.1 PU Capacity feature upgrades

IBM z16 Model A01 has a machine type 3931 and a model capacity identifier.

The 3931 is available in the following CPC drawer configurations:

- ▶ Feature Max39 (one CPC Drawer installed) can have a maximum of 39 PUs for client characterization
- ▶ Feature Max82 (two CPC Drawers) can have a maximum of 82 client PUs
- ▶ Feature Max125 (three CPC Drawers) can have a maximum of 125 client PUs
- ▶ Feature Max168 (four CPC Drawers) can have a maximum of 168 client PUs

- ▶ Feature Max200 (four CPC Drawers) can have a maximum of 200 client PUs
- ▶ Model capacity identifiers 4xx, 5yy, 6yy, or 7nn

The *xx* is a range of 00 - 39², *yy* is a range of 01 - 39, and *nn* is a range of 01 - 99, A0 - K0, where A0 represents the decimal number 100, which combines the character A with decimal 0 and where K0 represents the decimal number 200. It is obtained by continuing the hexadecimal counting to the following values:

- F = 15
- G = 16
- H = 17
- I = 18
- J = 19
- K = 20
- Adding the decimal digit 0 to make 200

An IBM z16 A01 with 200 client usable processors is an IBM z16 7K0. The model capacity identifier describes how many CPs are characterized (*xx*, *yy*, or *nn*) and the capacity setting (4, 5, 6, or 7) of the CPs.

A hardware configuration upgrade always requires more physical hardware (processor drawers, PCIe+ I/O drawers, or both). A system upgrade can change the system model or the MCI.

Consider the following points regarding model upgrades:

- ▶ LICCC upgrade:
 - Can add memory or Virtual Flash Memory (VFM) up to the amount that is physically installed
 - Can change the model capacity identifier, the capacity setting, or both
- ▶ Hardware installation upgrade:
 - Can change the CPC drawer feature by adding one or more drawers
 - Can change the model capacity identifier, the capacity setting, or both
 - Can add physical memory, PCIe+ I/O drawers, and other hardware features

The model capacity identifier can be concurrently changed. Concurrent upgrades can be performed for permanent and temporary upgrades.

Tip: A CPC drawer feature upgrade can be performed concurrently only for a Max39 or a Max82 machine if feature codes 2981 or 2982 were ordered with the base machine.

LICCC upgrades (MES ordered)

The LICCC provides for system upgrades without hardware changes by activating extra (physically installed) unused capacity. Concurrent upgrades through LICCC can be performed for the following resources:

- ▶ Processors, such as CPs, ICFs, z Integrated Information Processors (zIIPs), IFLs, and SAPs, if unused PUs are available on the installed processor drawers, or if the model capacity identifier for the CPs can be increased.
- ▶ Memory, when unused capacity is available on the installed memory cards. The Flexible memory option is available to give you better control over future memory upgrades. For more information, see 2.5.7, “Flexible Memory Option” on page 47.

² The IBM z16 zero CP MCI is 400. This setting applies to an all-IFL or all-ICF system.

Concurrent hardware installation upgrades (MES ordered)

Configuration upgrades can be concurrent when installing the following resources:

- ▶ Processor drawers (which contain processors, memory, and fan-outs). Up to two processor drawers can be added concurrently on an IBM z16 A01 Max39 if feature codes 2981 and 2982 were ordered with the initial configuration.
- ▶ PCIe+ Gen3 fan-outs.
- ▶ I/O cards, when slots are still available on the installed PCIe+ I/O drawers.
- ▶ PCIe+ I/O drawers.

The concurrent I/O upgrade capability can be better used if a future target configuration is considered during the initial configuration.

Concurrent PU conversions (MES ordered)

IBM z16 A01 supports concurrent conversion between all PU types, which includes SAPs, to provide flexibility and meet changing business requirements.

Important: The LICCC-based PU conversions require that at least one PU (CP, ICF, or IFL), remains unchanged. Otherwise, the conversion is disruptive. The PU conversion generates a LICCC that can be installed concurrently in two steps:

1. Remove the assigned PU from the configuration.
2. Activate the newly available PU as the new PU type.

LPARs also might have to free the PUs to be converted. The operating systems must include support to configure processors offline or online so that the PU conversion can be done nondisruptively.

Considerations: Client planning and operator action are required to use concurrent PU conversion. Consider the following points about PU conversion:

- ▶ It is disruptive if *all* current PUs are converted to different types.
- ▶ It might require individual LPAR outages if dedicated PUs are converted.

Unassigned CP capacity is recorded by a model capacity identifier. CP feature conversions change (increase or decrease) the model capacity identifier.

8.3.2 Customer Initiated Upgrade facility

The CIU facility is an IBM online system through which you can order, download, and install permanent and temporary upgrades for IBM Z servers. Access to and use of the CIU facility requires a contract between the client and IBM through for which the terms and conditions for use of the CIU facility are accepted.

The CIU facility is controlled through the permanent upgrade authorization FC 9898. A prerequisite to FC 9898 is the online CoD buying feature code (FC 9900). Although FC 9898 can be installed on your IBM z16 servers at any time, often it is added when ordering an IBM z16.

After you place an order through the CIU facility, you receive a notice that the order is ready for download. You can then download and apply the upgrade by using functions that are available through the Hardware Management Console (HMC), along with the RSF. After all of the prerequisites are met, the entire process (from ordering to activation of the upgrade) is performed by the customer, and does not require any onsite presence of IBM SSRs.

CIU prerequisites

The CIU facility supports LICCC upgrades only. It does not support I/O upgrades. All other capacity that is required for an upgrade must be previously installed. Extra processor drawers or I/O cards cannot be installed as part of an order that is placed through the CIU facility. The sum of CPs, unassigned CPs, ICFs, zIIPs, IFLs, and unassigned IFLs cannot exceed the client PU count of the installed processor drawers. The total number of zIIPs can be twice the number of purchased CPs.

CIU registration and contract for CIU

To use the CIU facility, a customer must be registered and the system must be set up. After you complete the CIU registration, access to the CIU application is available through the [IBM Resource Link website](#).

As part of the setup, provide one resource link ID for configuring and placing CIU orders and, if required, a second ID as an approver. The IDs are then set up for access to the CIU support. The CIU facility allows upgrades to be ordered and delivered much faster than through the regular MES process.

To order and activate the upgrade, log on to the [IBM Resource Link website](#), and start the CIU application to upgrade a system for processors or memory. You can request a client order approval to conform to your operational policies. You also can allow the definition of more IDs to be authorized to access the CIU. More IDs can be authorized to enter or approve CIU orders, or only view orders.

Permanent upgrades

Permanent upgrades can be ordered by using the CIU facility. Through the CIU facility, you can generate online permanent upgrade orders to concurrently add processors (CPs, ICFs, zIIPs, IFLs, and SAPs) and memory, or change the model capacity identifier. You can do so up to the limits of the installed processor drawers on a system.

Temporary upgrades

The IBM z16 A01 base model describes permanent and dormant capacity by using the capacity marker and the number of PU features that are installed on the system. Up to eight temporary offerings can be present. Each offering includes its own policies and controls, and each can be activated or deactivated independently in any sequence and combination. Although multiple offerings can be active at any time, only *one* On/Off CoD offering can be active at any time if enough resources are available to fulfill the offering specifications.

Temporary upgrades are represented in the system by a *record*. All temporary upgrade records are on the SE hard disk drive (HDD). The records can be downloaded from the RSF or installed from portable media. At the time of activation, you can control everything locally.

The provisioning architecture is shown in Figure 8-1.

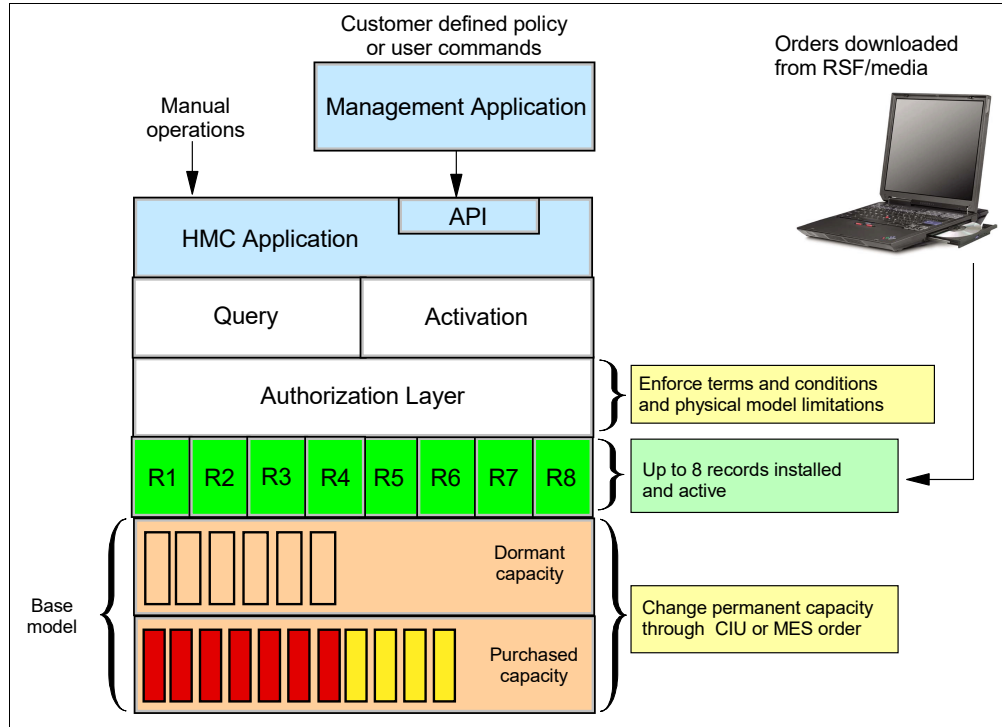


Figure 8-1 Provisioning architecture

The authorization layer enables administrative control over the temporary offerings. The activation and deactivation can be driven manually or under the control of an application through a documented application programming interface (API)³.

By using the API approach, you can customize at activation time the resources that are necessary to respond to the current situation up to the maximum that is specified in the order record. If the situation changes, you can add or remove resources without having to return to the base configuration. This process eliminates the need for temporary upgrade specifications for all possible scenarios.

For a CPE record, only the ordered configuration can be activated.

³ API details can be found in *z/OS MVS Programming: Callable Services for High-Level Languages*, SA23-1377

This approach also enables you to update and replenish temporary upgrades, even in situations where the upgrades are active. Likewise, depending on the configuration, permanent upgrades can be performed while temporary upgrades are active. Examples of the activation sequence of multiple temporary upgrades are shown in Figure 8-2.

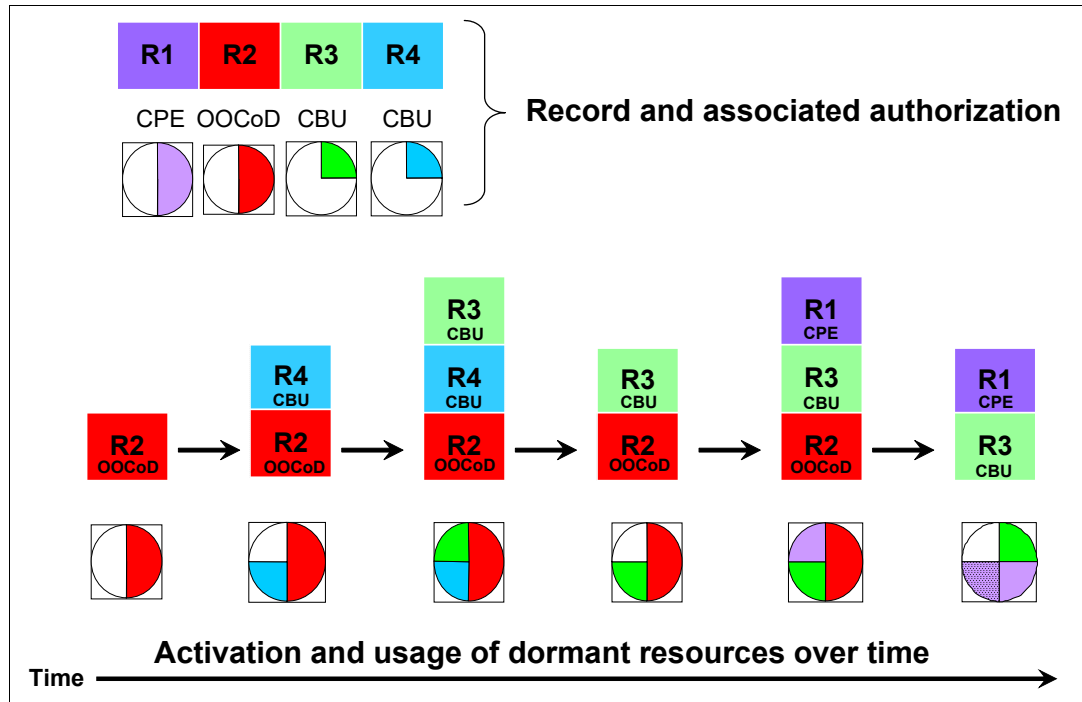


Figure 8-2 Example of temporary upgrade activation sequence

As shown in Figure 8-2, if R2, R3, and R1 are active at the same time, only parts of R1 can be activated because not enough resources are available to fulfill all of R1. When R2 is deactivated, the remaining parts of R1 can be activated as shown.

Temporary capacity can be billable as On/Off CoD, or replacement capacity as CBU, CPE, or System Recovery Boost. Consider the following points:

- ▶ On/Off CoD is a function that enables *concurrent* and *temporary* capacity growth of the system.

On/Off CoD can be used for client peak workload requirements, for any length of time, and includes a daily hardware and maintenance charge. The software charges can vary according to the license agreement for the individual products. For more information, contact your IBM Software Group representative.

On/Off CoD can concurrently add processors (CPs, ICFs, zIIPs, IFLs, and SAPs), increase the model capacity identifier, or both. It can do so up to the limit of the installed processor drawers of a system. It is restricted to twice the installed capacity. On/Off CoD requires a contractual agreement between you and IBM.

You decide whether to pre-pay or post-pay On/Off CoD. Capacity tokens that are inside the records are used to control activation time and resources.
- ▶ CBU is a concurrent and temporary activation of more CPs, ICFs, zIIPs, IFLs, and SAPs; or an increase of the model capacity identifier; or both.

Note: CBU cannot be used for peak workload management in any form.

On/Off CoD is the correct method to use for workload management. A CBU activation can last up to 90 days when a disaster or recovery situation occurs.

CBU features are optional, and require unused capacity to be available on installed processor drawers of the backup system. They can be available as unused PUs, an increase in the model capacity identifier, or both.

A CBU contract must be in place before the special code that enables this capability can be loaded on the system. The standard CBU contract provides for five 10-day tests (the *CBU test activation*) and one 90-day activation over a five-year period. For more information, contact your IBM representative.

You can run production workload on a CBU upgrade during a CBU test. At least an *equivalent* amount of production capacity must be shut down during the CBU test. If you signed CBU contracts, you also must sign an Amendment (US form #Z125-8145) with IBM to allow you to run production workload on a CBU upgrade during your CBU tests. More 10-day tests can be purchased with the CBU record.

- ▶ CPE is a concurrent and temporary activation of extra CPs, ICFs, zIIPs, IFLs, and SAPs; or an increase of the model capacity identifier; or both.

The CPE offering is used to replace temporary lost capacity within a client's enterprise for planned downtime events, such as data center changes.

Notes: Consider the following points:

- ▶ CPE cannot be used for peak load management of client workload or for a disaster situation.
- ▶ CPE is available only as carry forward on IBM z16.

The CPE feature requires unused capacity to be available on installed processor drawers of the backup system. The capacity must be available as unused PUs, as a possibility to increase the model capacity identifier on a sub-capacity system, or as both.

A CPE contract must be in place before the special code that enables this capability can be loaded on the system. The standard CPE contract provides for one 3-day planned activation at a specific date. For more information, contact your IBM representative.

- ▶ The System Recovery Boost Upgrade allows a concurrent activation of extra zIIPs.

The System Recovery Boost Upgrade record offering can be used to provide extra zIIP capacity that can be used by the System Recovery Boost facility. You might want to consider the use of this offering if your server is a full capacity model (7nn) and can benefit from more CP capacity (running on zIIPs) for system shutdown and restart. The capacity is delivered as zIIPs that can perform CP work during the boost periods for an LPAR.

A System Recovery Boost Record contract must be in place before the special code that enables this capability can be loaded on the system. The standard contract provides for one 6-hour activation for the specific purpose of System Recovery Boost only. For more information, contact your IBM representative.

Activation of System Recovery Boost Record does not change the MCI of your system.

8.3.3 Concurrent upgrade functions summary

The possible concurrent upgrades combinations are listed in Table 8-2.

Table 8-2 Concurrent upgrade summary

Type	Name	Upgrade	Process
Permanent	MES	CPs, ICFs, zIIPs, IFLs, SAPs, processor drawer, memory, and I/Os	Installed by IBM SSRs
	Online permanent upgrade	CPs, ICFs, zIIPs, IFLs, SAPs, and memory	Performed through the CIU facility
Temporary	On/Off CoD	CPs, ICFs, zIIPs, IFLs, and SAPs	Performed through the On/Off CoD facility
	CBU	CPs, ICFs, zIIPs, IFLs, and SAPs	Activated through model conversion
	CPE ^a	CPs, ICFs, zIIPs, IFLs, and SAPs	Activated through model conversion
	System Recovery Boost Record	zIIPs	Activated through model conversion
	Flexible Capacity Record	CPs, ICFs, zIIPs, IFLs, and SAPs	Activated through model conversion

a. On IBM z16, only ICFs are supported.

8.4 Miscellaneous equipment specification upgrades

MES upgrades enable concurrent and permanent capacity growth. MES upgrades allow the concurrent adding of processors (CPs, ICFs, zIIPs, IFLs, and SAPs), memory capacity, and I/O ports. For sub-capacity models, MES upgrades allow the concurrent adjustment of the number of processors and the capacity level.

The MES upgrade can be performed by using LICCC only, installing more processor drawers, adding PCIe+ I/O drawers, adding I/O⁴ features, or using the following combinations:

- ▶ MES upgrades for processors are done by any of the following methods:
 - LICCC assigning and activating unassigned PUs up to the limit of the installed processor drawers.
 - LICCC to adjust the number and types of PUs to change the capacity setting, or both.
 - Installing more processor drawers and LICCC assigning and activating unassigned PUs on the installed processor drawers.
- ▶ MES upgrades for memory are done by one of the following methods:
 - By using LICCC to activate more memory capacity up to the limit of the memory cards on the currently installed processor drawers. Flexible memory features enable you to implement better control over future memory upgrades. For more information about the memory features, see 2.5.7, “Flexible Memory Option” on page 47.
 - Installing more processor drawers and the use of LICCC to activate more memory capacity on installed processor drawers.

⁴ Other adapter types, such as zHyperlink, Coupling Express LR, and Remote Direct Memory Access (RDMA) over Converged Ethernet (RoCE), also can be added to the PCIe+ I/O drawers through an MES.

- By using the CPC Enhanced Drawer Availability (EDA), where possible, on multi-drawer systems to add or change the memory cards.
- ▶ MES upgrades for I/O are done by installing I/O features and supporting infrastructure (if required) on PCIe drawers that are installed, or installing PCIe drawers to hold the new cards.

An MES upgrade requires IBM SSRs for the installation. In most cases, the time that is required for installing the LICCC and completing the upgrade is short, depending on how up to date the machine microcode levels are.

To better use the MES upgrade function, carefully plan the initial configuration to allow a concurrent upgrade to a target configuration. The availability of PCIe+ I/O drawers improves the flexibility to perform unplanned I/O configuration changes concurrently.

The Store System Information (STSI) instruction gives more useful and detailed information about the base configuration and temporary upgrades.

The model and model capacity identifiers that are returned by the STSI instruction are updated to coincide with the upgrade. For more information, see “Store System Information instruction” on page 379.

Upgrades: An MES provides the physical upgrade, which results in more enabled processors, different capacity settings for the CPs, and more memory, I/O ports, I/O adapters, and I/O drawers. Extra planning tasks are required for nondisruptive logical upgrades. For more information, see “Guidelines to avoid disruptive upgrades” on page 381.

8.4.1 MES upgrade for processors

An MES upgrade for processors can concurrently add CPs, ICFs, zIIPs, IFLs, and SAPs to an IBM z16 by assigning available PUs on the processor drawers through LICCC. Depending on the quantity of the extra processors in the upgrade, more processor drawers might be required, and can be concurrently installed before the LICCC is enabled if plan-ahead features are available. With the sub-capacity models, capacity can be provided by adding CPs, changing the capacity identifier on the current CPs, or both.

Limits: The sum of CPs, inactive CPs, ICFs, unassigned ICFs, zIIPs, unassigned zIIPs, IFLs, unassigned IFLs, and SAPs cannot exceed the maximum limit of PUs available for client use. The number of zIIPs cannot exceed twice the number of purchased CPs.

An example of an MES upgrade for processors (with two upgrade steps) is shown in Figure 8-3.

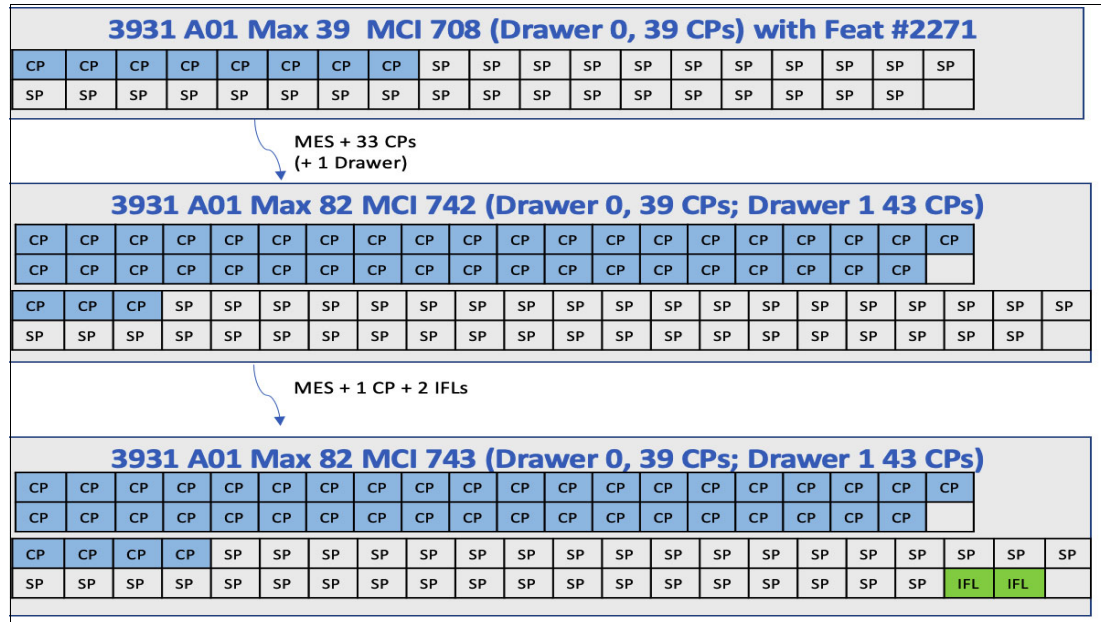


Figure 8-3 MES for processor example

An IBM z16 model A01 Max39 (one processor drawer), model capacity identifier 708 (eight CPs), is concurrently upgraded to a model A01 Max82 (two processor drawers), with MCI 742 (42 CPs). The model upgrade requires adding a processor drawer and assigning and activating 42 PUs as CPs. Then, model Max82, MCI 742, is concurrently upgraded to a capacity identifier 743 (43 CPs) with two IFLs. This process is done by assigning and activating three more unassigned PUs (one as CP and two as IFLs). If needed, LPARs can be created concurrently to use the newly added processors.

The example that is shown in Figure 8-3 shows how the addition of PUs as CPs and IFLs and the addition of a processor drawer works. The addition of a processor drawer to an IBM z16 Max 39 upgrades the machine to Max82.

After the second CPC drawer addition, CPC drawer 0 has 39 configurable PUs and CPC drawer 1 has 43 configurable PUs, which allows 82 PUs to be characterized on the new Max82 configuration.

Consideration: All available processors on a server (including reserved processors) can be defined to an LPAR. However, do not define more processors to an LPAR than the target operating system supports.

The number of processors that are supported by various operating systems releases are listed in Table 8-3.

Table 8-3 Number of processors that are supported by operating system

Operating system	Number of processors that are supported
z/OS V2R3 and later	200 PUs per z/OS LPAR in non-SMT mode and 128 PUs per z/OS LPAR in SMT mode. For both, the PU total is the sum of CPs and zIIPs.
z/VM V7R1 and later	80 (or 40 in SMT mode).
z/VSE	z/VSE Turbo Dispatcher can use up to 4CPs, and tolerates up to 10-way LPARs.
z/TPF	86 CPs.
Linux on IBM z16	The IBM z16 limit is 200 CPs although Linux ^a supports 256 cores without SMT and 128 cores with SMT (256 threads).

a. Supported Linux on IBM Z distributions (for more information, see Chapter 7, “Operating system support” on page 251).

Software charges, which are based on the total capacity of the system on which the software is installed, are adjusted to the new capacity after the MES upgrade.

Software products that use Workload License Charges (WLC) or Taylor Fit Pricing (TFP) might not be affected by the system upgrade. Their charges are based on partition usage, not on the system total capacity. For more information about WLC, see 7.8, “Software licensing” on page 327.

8.4.2 MES upgrades for memory

MES upgrades for memory can concurrently add memory in the following ways:

- ▶ Through LICCC, which enables more capacity up to the limit of the installed DIMM memory cards.
- ▶ Concurrently installing CPC drawers and LICCC-enabling memory capacity on the new CPC drawers.

The Flexible Memory Feature is available to allow better control over future memory upgrades. For more information about flexible memory features, see 2.5.7, “Flexible Memory Option” on page 47.

If the IBM z16 is a multiple processor drawer configuration, you can use the EDA feature to remove a processor drawer and add DIMM memory cards. It also can be used to upgrade the installed memory cards to a larger capacity size. You can then use LICCC to enable the extra memory.

With suitable planning, memory can be added nondisruptively to z/OS partitions and z/VM partitions. If necessary, new LPARs can be created nondisruptively to use the newly added memory.

Concurrency: Upgrades that require DIMM changes can be concurrent by using the EDA feature. Planning is required to see whether this option is a viable for your configuration. The use of the flexible memory option ensures that EDA can work with the least disruption.

The one-processor drawer feature Max39 requires a minimum of 1024 GB addressable memory. The client addressable storage in this case is 512 GB. Memory can be upgraded up to 10 TB of memory (9984 GB client addressable). An upgrade changes the DIMM sizes and adding DIMMs in all available slots in the processor drawer.

You also can add memory by *concurrently* adding a second processor drawer with sufficient memory into the configuration and then, using LICCC to enable that memory. Changing DIMMs in a single CPC drawer system is disruptive.

An LPAR can dynamically take advantage of a memory upgrade if reserved storage is defined to that LPAR. The reserved storage is defined to the LPAR as part of the image profile.

Reserved memory can be configured online to the LPAR by using the LPAR dynamic storage reconfiguration (DSR) function. DSR allows a z/OS operating system image and z/VM partitions to add reserved storage to their configuration if any unused storage exists.

The nondisruptive addition of storage to a z/OS and z/VM partition requires the correct operating system parameters to be set. If reserved storage is not defined to the LPAR, the LPAR must be deactivated, the image profile changed, and the LPAR reactivated. This process allows the extra storage resources to be available to the operating system image.

8.4.3 MES upgrades for I/O

MES upgrades for I/O can concurrently add I/O features by using one of the following methods:

- ▶ Installing I/O features on an installed PCIe+ I/O drawer
- ▶ Adding a PCIe+ I/O drawer to hold the new I/O features

For more information about PCIe+ I/O drawers, see 4.2, “I/O system overview” on page 150.

The number of PCIe+ I/O drawers that can be present in an IBM z16 depends on how many CPC drawers are present and whether the configuration includes the Bulk Power Assembly (BPA) offering. It also depends on whether the CPC drawer reserve features are present.

The number of drawers for a PDU-based IBM z16 configuration options is listed in Table 8-4. Options for a BPA-based IBM z16 are Table 8-5 on page 350. Both tables are based on no CPC drawer reserve options being configured.

Note: The maximum number of I/O drawers in the table is reduced by one for each CPC drawer reserve feature that is present.

Table 8-4 PCIe+ I/O drawer limit for PDU-based IBM z16 systems

Number of frames	Max39	Max82	Max125	Max168/Max200
1	3	2	1	-
2	6	7	6	4
3	-	12	11	9
4	-	-	-	12

Table 8-5 PCIe+ I/O drawer limit for BPA-based IBM z16 systems

Number of frames	Max39	Max82	Max125	Max168/Max200
1	1	0	0	-
2	5	4	4	1
3	6	7	7	5
4	-	10	10	10

Depending on the number of I/O features, the configurator determines the number of PCIe+ I/O drawers that is required.

To better use the MES for I/O capability, carefully plan the initial configuration to allow concurrent upgrades up to the target configuration.

If a PCIe+ I/O drawer is added to an IBM z16 and original features must be physically moved to another PCIe+ I/O drawer, original card moves are disruptive.

z/VSE, z/TPF, and Linux on Z do *not* provide dynamic I/O configuration support. Although installing the new hardware is done concurrently, defining the new hardware to these operating systems requires an IPL.

Tip: IBM z16 A01 features a hardware system area (HSA) of 256 GB (same as IBM z15 T01). IBM z14 M0x servers have a 192 GB HSA. HSA is *not* part of the client-purchased memory.

8.4.4 Feature on Demand

Only one Feature on Demand (FoD) LICCC record is installed or staged at any time in the system. Its contents can be viewed in the Manage window, as shown in Figure 8-4.

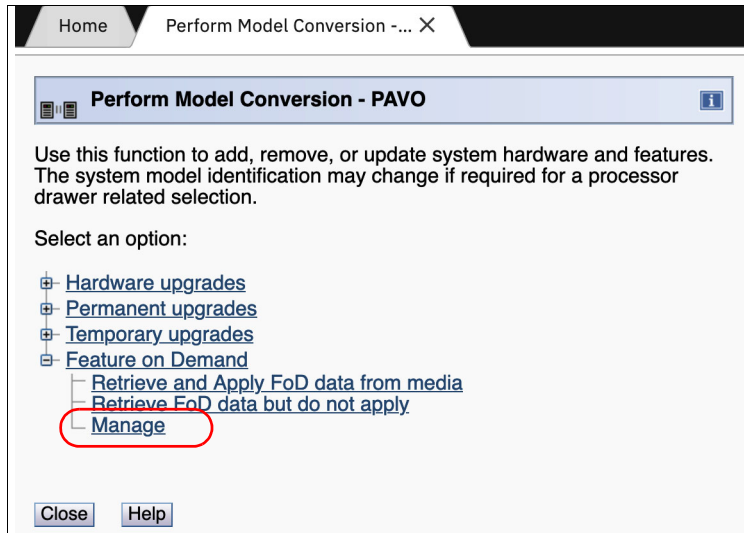


Figure 8-4 Features on-Demand

A staged record can be removed without installing it. A FoD record can be installed only completely; no selective feature or partial record installation is available. The features that are installed are merged with the CPC LICCC after activation.

A FoD record can be installed only once. If it is removed, a new FoD record is needed to reinstall. A remove action cannot be undone.

8.4.5 Summary of plan-ahead feature

The flexible memory plan-ahead feature is available for IBM z16 servers. No feature code is associated with flexible memory. The purpose of flexible memory is to enable enhanced processor drawer availability. If a processor drawer must be serviced, the flexible memory is activated to accommodate storing the CPC drawer that is taken offline. After the repair action, the memory is taken offline again and is made unavailable for use.

Tip: Accurate planning and the definition of the target configuration allows you to maximize the value of these plan-ahead features.

8.5 Permanent upgrade by using the CIU facility

By using the CIU facility (through [the IBM Resource Link](#)), you can start a permanent upgrade for CPs, ICFs, zIIPs, IFLs, SAPs, or memory. When performed through the CIU facility, you add the resources without IBM personnel present at your location. You can also unassign previously purchased CPs and IFL processors through the CIU facility.

Adding permanent upgrades to a system through the CIU facility requires that the permanent upgrade enablement feature (FC 9898) is installed on the system. A permanent upgrade might change the system model capacity identifier (4xx, 5yy, 6yy, or 7nn) if more CPs are requested, or if the capacity identifier is changed as part of the permanent upgrade. If necessary, more LPARs can be created concurrently to use the newly added processors.

Consideration: A permanent upgrade of processors can provide a concurrent upgrade, which results in more enabled processors that are available to a system configuration. More planning and tasks are required for *nondisruptive* logical upgrades. For more information, see “Guidelines to avoid disruptive upgrades” on page 381.

Maintenance charges are automatically adjusted as a result of a permanent upgrade.

Software charges that are based on the total capacity of the system on which the software is installed are adjusted to the new capacity after the permanent upgrade is installed. Software products that use WLC or customers with TFP might not be affected by the system upgrade because their charges are based on LPAR usage rather than system total capacity.

For more information about WLC, see 7.8, “Software licensing” on page 327.

The CIU facility process on IBM Resource Link is shown in Figure 8-5.

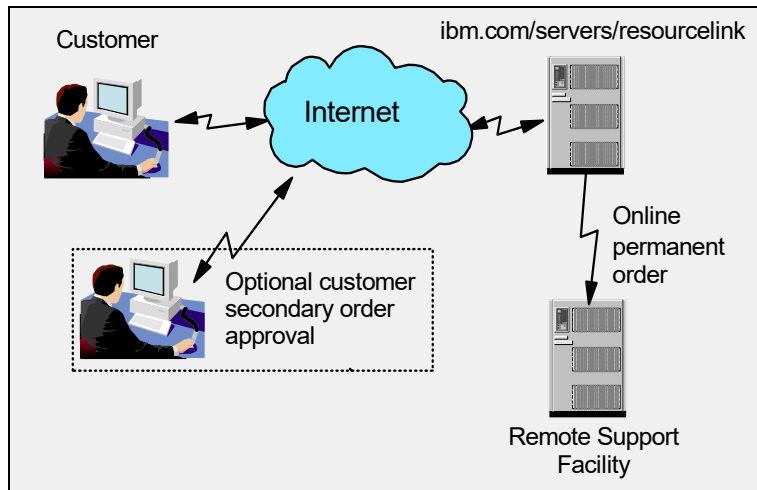


Figure 8-5 Permanent upgrade order example

The following sample sequence shows how to start an order on the IBM Resource Link:

1. Sign on to Resource Link.
2. Select **Customer Initiated Upgrade** from the main Resource Link page. Client and system information that is associated with the user ID are displayed.
3. Select the system to receive the upgrade. The current configuration (PU allocation and memory) is shown for the selected system.
4. Select **Order Permanent Upgrade**. The Resource Link limits the options to those options that are valid or possible for the selected configuration (system).
5. After the target configuration is verified by the system, accept or cancel the order. An order is created and verified against the pre-established agreement.
6. Accept or reject the price that is quoted. A secondary order approval is optional. Upon confirmation, the order is processed. The LICCC for the upgrade is available within hours.

The order activation process for a permanent upgrade is shown in Figure 8-6. When the LICCC is passed to the Remote Support Facility, you are notified through an email that the upgrade is ready to be downloaded.

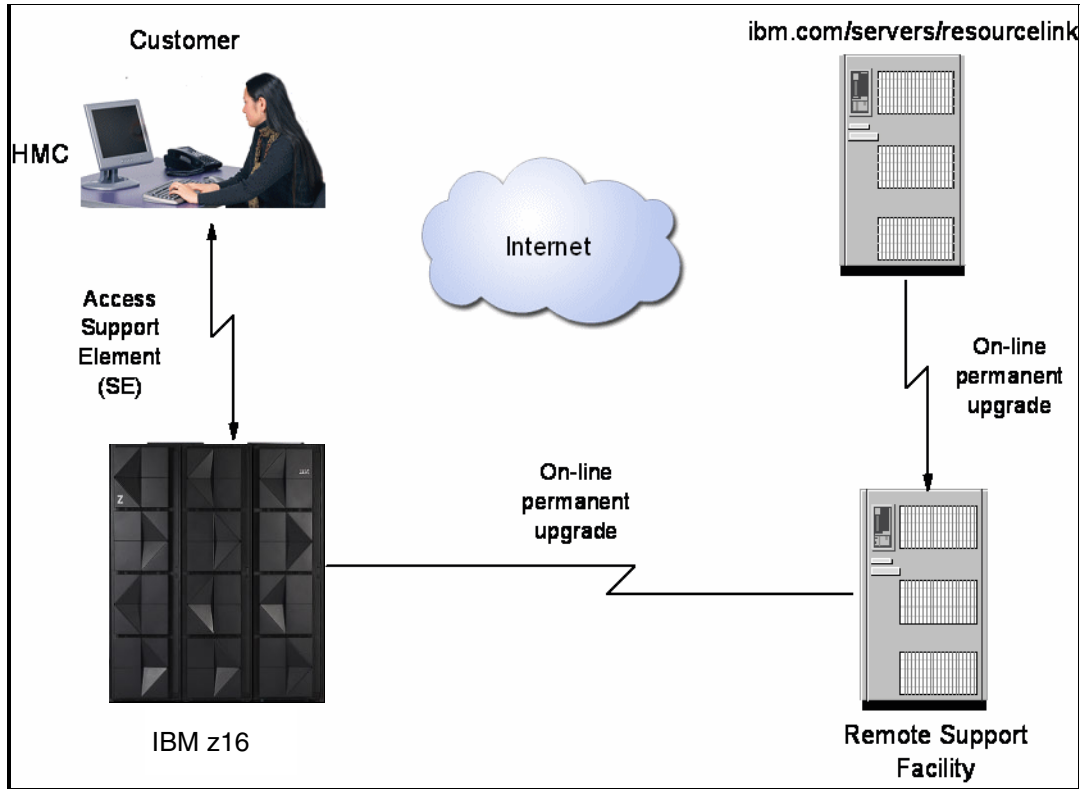


Figure 8-6 CIU-eligible order activation example

8.5.1 Ordering

IBM Resource Link provides the interface that enables you to order a concurrent upgrade for a system. You can create, cancel, or view the order, and view the history of orders that were placed through this interface.

Configuration rules enforce that only valid configurations are generated within the limits of the individual system. Warning messages are issued if you select invalid upgrade options. The process allows only one permanent CIU-eligible order for each system to be placed at a time.

For more information, see the [IBM Resource Link website](#) (log in required).

The initial view of the Machine profile on Resource Link is shown in Figure 8-7.

Current configuration	
Model Capacity:	729 (29 CPs)
ICF:	3
zIIP:	11
IFL:	28
SAP:	8
Memory:	4864
Unassigned IFLs:	0

Current configuration as of 26 Feb 2022 18:49:18

Machine summary	
Type, model, serial:	8561 - T01 - [redacted]
System name:	AFPS06SE

Customer summary	
Company name:	[redacted]
Customer number:	[redacted]
GEO, country:	Americas - zDutchy of Merwyn

About ordering

Authorization to create orders

User ID: brunofarrugia@fr.ibm.com and 3 more

Authorization to approve orders

Ordering options

CIU permanent: Enabled

On/Off CoD: Enabled

To update profile

- Upload VPD
- Upload upgrade billing XML data
- Disable machine profile...

Figure 8-7 Machine profile window

The number of CPs, ICFs, zIIPs, IFLs, SAPs, memory size, and unassigned IFLs on the current configuration are displayed on the left side of the page.

Resource Link retrieves and stores relevant data that is associated with the processor configuration, such as the number of CPs and installed memory cards. It allows you to select only those upgrade options that are deemed valid by the order process. It also allows upgrades only within the bounds of the currently installed hardware.

8.5.2 Retrieval and activation

After an order is placed and processed, the suitable upgrade record is passed to the IBM support system for download.

When the order is available for download, you receive an email that contains an activation number. You can then retrieve the order by using the Perform Model Conversion task from the SE, or through the Single Object Operation to the SE from an HMC.

In the Perform Model Conversion window, select **Permanent upgrades** to start the process, as shown in Figure 8-8.

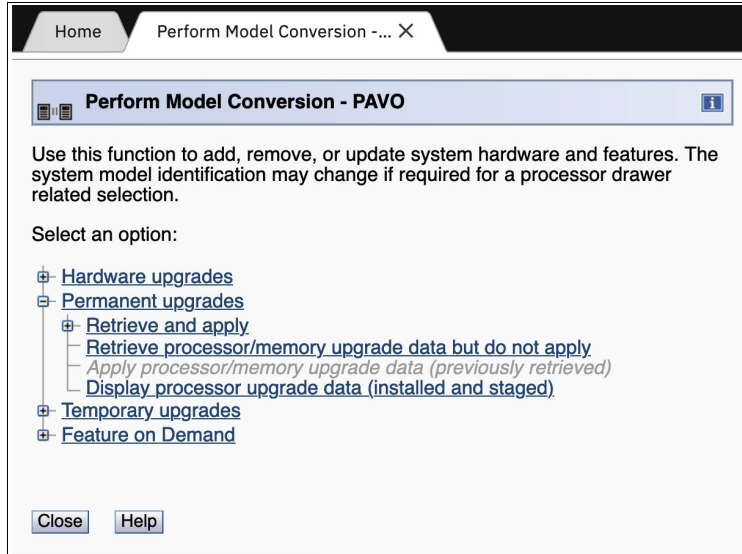


Figure 8-8 IBM z16 Perform Model Conversion window

The window provides several possible options. If you select the **Retrieve and apply** data option, you are prompted to enter the order activation number to start the permanent upgrade, as shown in Figure 8-9.

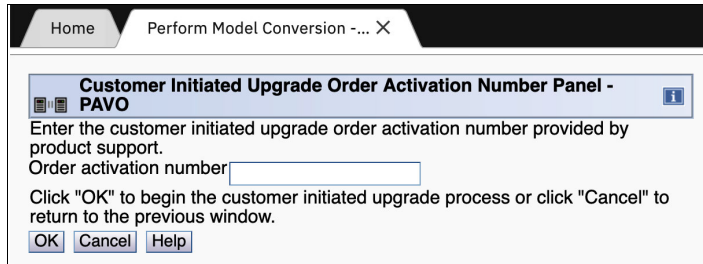


Figure 8-9 Customer Initiated Upgrade Order Activation Number window

8.6 On/Off Capacity on Demand

On/Off CoD allows you to temporarily enable PUs and unassigned IFLs that are available within the current hardware model. You can also use it to change capacity settings for CPs to help meet your peak workload requirements.

8.6.1 Overview

The capacity for CPs is expressed in millions of service units (MSUs). Capacity for specialty engines is expressed in number of specialty engines. Capacity tokens are used to limit the resource consumption for all types of processor capacity.

Capacity tokens were introduced to provide better control over resource consumption when On/Off CoD offerings are activated. Tokens represent the following resource consumptions:

- ▶ For CP capacity, each token represents the amount of CP capacity that results in one MSU of software cost for one day (an *MSU-day token*).
- ▶ For specialty engines, each token is equivalent to one specialty engine capacity for one day (an *engine-day token*).

Each specialty engine type features its own tokens, and each On/Off CoD record includes separate token pools for each capacity type. During the ordering sessions on IBM Resource Link, select how many tokens of each type to create for an offering record. Each engine type must include tokens for that engine type to be activated. Capacity that has no tokens cannot be activated.

When resources from an On/Off CoD offering record that contains capacity tokens are activated, a billing window is started. A billing window is always 24 hours. Billing occurs at the end of each billing window.

The resources that are billed are the highest resource use inside each billing window for each capacity type. An activation period is one or more complete billing windows. The activation period is the time from the first activation of resources in a record until the end of the billing window in which the last resource in a record is deactivated.

At the end of each billing window, the tokens are decremented by the highest usage of each resource during the billing window. If any resource in a record does not have enough tokens to cover usage for the next billing window, the entire record is deactivated.

Note: On/Off CoD requires that the Online CoD Buying feature (FC 9900) is installed on the system that you want to upgrade.

The On/Off CoD to Permanent Upgrade Option gives customers a window of opportunity to assess capacity additions to your permanent configurations by using On/Off CoD. If a purchase is made, the hardware On/Off CoD charges during this window (three days or less) are waived. If no purchase is made, you are charged for the temporary use.

The following resources are eligible for temporary use:

- ▶ CPs
- ▶ ICFs
- ▶ zIIPs
- ▶ IFLs
- ▶ SAPs

The temporary addition of memory and I/O ports or adapters is *not* supported.

Unassigned PUs that are on the installed processor drawers can be temporarily and concurrently activated as CPs, ICFs, zIIPs, IFLs, and SAPs through LICCC. You can assign PUs up to twice the currently installed CP capacity, and up to twice the number of ICFs, zIIPs, or IFLs.

An On/Off CoD upgrade cannot change the system capacity feature. The addition of processor drawers is *not* supported. However, the activation of an On/Off CoD upgrade can increase the model capacity identifier (4xx, 5yy, 6yy, or 7nn).

8.6.2 Capacity Provisioning Manager

The installation of the capacity provision function on z/OS requires the following prerequisites:

- ▶ Setting up and customizing z/OS RMF, including the Distributed Data Server (DDS).
- ▶ Setting up the z/OS CIM Server (included in z/OS base).
- ▶ Performing capacity provisioning customization. For more information, see *z/OS MVS Capacity Provisioning User's Guide*, SC34-2661.

The use of the capacity provisioning function requires the following prerequisites:

- ▶ TCP/IP connectivity to observed systems
- ▶ RMF Distributed Data Server is active
- ▶ CIM server is active
- ▶ Security and CIM are customized
- ▶ Capacity Provisioning Manager is customized

The Capacity Provisioning Manager Console is provided as part of z/OSMF, which provides a browser-based interface for managing z/OS systems.

Customizing the capacity provisioning function is required on the following systems:

- ▶ Observed z/OS systems
These systems are in one or multiple sysplexes that are to be monitored. For more information about the capacity provisioning domain, see 8.12, "Planning for nondisruptive upgrades" on page 376.
- ▶ Runtime systems
These are systems where the Capacity Provisioning Manager is running, or to which the server can fail over after a system failure.

8.6.3 Ordering

Concurrently installing temporary capacity by ordering On/Off CoD is possible in the following manner:

- ▶ CP features equal to the MSU capacity of installed CPs
- ▶ IFL features up to the number of installed IFLs
- ▶ ICF features up to the number of installed ICFs
- ▶ zIIP features up to the number of installed zIIPs
- ▶ SAPs: Up to eight

On/Off CoD can provide CP temporary capacity in two ways:

- ▶ By increasing the number of CPs.
- ▶ For sub-capacity models, capacity can be added by increasing the number of CPs, changing the sub-capacity setting of the CPs, or both. If the On/Off CoD is adding CP resources that have a capacity setting different from the installed CPs, the base capacity settings are changed to match.

On/Off CoD includes the following limits that are associated with its use:

- The number of CPs cannot be reduced.
- The target configuration capacity is limited to these amounts:
 - Twice the currently installed capacity, expressed in MSUs for CPs.
 - Twice the number of installed IFLs, ICFs, and zIIPs. Up to eight SAPs can be activated. For more information, see 8.3.1, “PU Capacity feature upgrades” on page 338.

On/Off CoD can be ordered as prepaid or postpaid. A prepaid On/Off CoD offering record contains resource descriptions, MSUs, specialty engines, and tokens that describe the total capacity that can be used. For CP capacity, the token contains MSU-days. For specialty engines, the token contains specialty engine-days.

When resources on a prepaid offering are activated, they must have enough capacity tokens to allow the activation for an entire billing window, which is 24 hours. The resources remain active until you deactivate them or until one resource uses all of its capacity tokens. Then, all activated resources from the record are deactivated.

A postpaid On/Off CoD offering record contains resource descriptions, MSUs, specialty engines, and can contain capacity tokens that denote MSU-days and specialty engine-days.

When resources in a postpaid offering record *without* capacity tokens are activated, those resources remain active until they are deactivated, or until the offering record expires. The record normally expires 180 days after its installation.

When resources in a postpaid offering record *with* capacity tokens are activated, those resources must include enough capacity tokens to allow the activation for an entire billing window (24 hours). The resources remain active until they are deactivated until all of the resource tokens are used, or until the record expires. The record usually expires 180 days after its installation. If one capacity token type is used, resources from the entire record are deactivated.

For example, for an IBM z16 with capacity identifier 502 (two CPs), a capacity upgrade through On/Off CoD can be delivered in the following ways:

- ▶ Add CPs of the same capacity setting. With this option, the model capacity identifier can be changed to a 503, which adds another CP to make it a three-way CP. It also can be changed to a 504, which adds two CPs and makes it a four-way CP.
- ▶ Change to a different capacity level of the current CPs and change the model capacity identifier to a 602 or 702. The capacity level of the CPs is increased, but no other CPs are added. The 502 also can be temporarily upgraded to a 603, which increases the capacity level and adds a processor. The capacity setting 439 does not have an upgrade path through On/Off CoD because you cannot reduce the number of CPs and a 539 is more than twice the capacity.

Use the Large System Performance Reference (LSPR) information to evaluate the capacity requirements according to your workload type. For more information about LSPR data for current IBM processors, see [this web page](#).

The On/Off CoD hardware capacity is charged on a 24-hour basis. A grace period is granted at the end of the On/Off CoD day. This grace period allows up to an hour after the 24-hour billing period to change the On/Off CoD configuration for the next 24-hour billing period or deactivate the current On/Off CoD configuration. The times when the capacity is activated and deactivated are maintained in the IBM z16 and returned to the IBM support systems.

If On/Off capacity is active, On/Off capacity can be added without having to return the system to its original capacity. If the capacity is increased multiple times within a 24-hour period, the charges apply to the highest amount of capacity active in that period.

If capacity is added from an active record that contains capacity tokens, the system checks whether the resource has enough capacity to be active for an entire billing window (24 hours). If that criteria is not met, no extra resources are activated from the record.

If necessary, more LPARs can be activated concurrently to use the newly added processor resources.

Consideration: On/Off CoD provides a concurrent hardware upgrade that results in more capacity being made available to a system configuration. Extra planning tasks are required for nondisruptive upgrades. For more information, see “Guidelines to avoid disruptive upgrades” on page 381.

To participate in this offering, you must accept contractual terms for purchasing capacity through the Resource Link, establish a profile, and install an On/Off CoD enablement feature on the system. Later, you can concurrently install temporary capacity up to the limits in On/Off CoD and use it for up to 180 days.

Monitoring occurs through the system call-home facility. An invoice is generated if the capacity is enabled during the calendar month. You are billed for the use of temporary capacity until the system is returned to the original configuration. Remove the enablement code if the On/Off CoD support is no longer needed.

On/Off CoD orders can be pre-staged in Resource Link to allow multiple optional configurations. The pricing of the orders is done at the time that you order them, and the pricing can vary from quarter to quarter. Staged orders can have different pricing.

When the order is downloaded and activated, the daily costs are based on the pricing at the time of the order. The staged orders do not have to be installed in the order sequence. If a staged order is installed out of sequence and later a higher-priced order is staged, the daily cost is based on the lower price.

Another possibility is to store multiple On/Off CoD LICCC records on the SE with the same or different capacities, which gives you greater flexibility to enable quickly needed temporary capacity. Each record is easily identified with descriptive names, and you can select from a list of records that can be activated.

Resource Link provides the interface to order a dynamic upgrade for a specific system. You can create, cancel, and view the order. Configuration rules are enforced, and only valid configurations are generated based on the configuration of the individual system. After you complete the prerequisites, orders for the On/Off CoD can be placed. The order process uses the CIU facility on Resource Link.

Memory and channels are not supported on On/Off CoD.

An individual record can be activated only once. Subsequent sessions require a new order to be generated, which produces a new LICCC record for that specific order.

Alternatively, you can use an auto-renewal feature to eliminate the need for a manual replenishment of the On/Off CoD order. This feature is implemented in IBM Resource Link, and you must also select this feature in the machine profile, as shown in Figure 8-10.

IBM Systems > z Systems > Resource Link > Customer Initiated Upgrade > Machine profiles > Machine 2964 - 8DA87 >

Order On/Off CoD record

Step 1 of 2: Configure the record

The On/Off CoD upgrade options on this order form are initialized to the maximum selections for upgrades that have prices set for this machine. Maximizing selections creates an On/Off CoD record that supports the widest possible range of On/Off CoD upgrades for the current machine configuration. Adjust the selections only if you want to change the type or range of On/Off CoD upgrades that can be activated with this record.

(*) indicates setting an expiration date is required to continue. Its initial setting is the maximum date allowed.

Expiration date: 10/11/2015 (mm/dd/yyyy) Renew automatically

Enable upgrades for up to:

Model capacity:	0% 735 (35 CPs)	more model capacity
ICF:	2	more ICF engines
zIIP:	2	more zIIP engines
IFL:	0	more IFL engines
SAP:	0	more SAP engines

Machine summary

Type:	2964 N63
Model:	735
Serial number:	8DA87

Supported upgrades

Model capacity (CPs):	35
ICF:	8
zIIP:	12
IFL:	8
SAP:	12
Available engines:	0

[Show upgrades](#)

[Show upgrade prices](#)

Default is to renew

[Continue](#)

Figure 8-10 Order On/Off CoD record window

8.6.4 On/Off CoD testing

Each On/Off CoD-enabled system is entitled to one no-charge 24-hour test. No IBM charges are assessed for the test, including charges that are associated with temporary hardware capacity, IBM software, and IBM maintenance. The test can be used to validate the processes to download, stage, install, activate, and deactivate On/Off CoD capacity.

This test can have a maximum duration of 24 hours, which commences upon the activation of any capacity resource that is contained in the On/Off CoD record. Activation levels of capacity can change during the 24-hour test period. The On/Off CoD test automatically stops at the end of the 24-hour period.

You also can perform administrative testing. Although capacity is not added to the system, you can test all of the procedures and automation for the management of the On/Off CoD facility.

An example of an On/Off CoD order on the Resource Link web page is shown in Figure 8-11.

IBM Systems > z Systems > Resource Link > Customer Initiated Upgrade > Machine profiles > Machine 2964 - 8DA87 >

Order On/Off CoD record

Step 2 of 2: Review and submit your order

Review the range of upgrades you selected on the previous page. The On/Off CoD record you are about to order will be configured to support activating any configurations within the range.

(*) indicates accepting the [Terms and Conditions of this order](#) is required to submit it. Mark the check box to indicate acceptance.

Expiration date:	Renew automatically:	Machine capacity (CPs):
11 Oct 2015	Yes	35
		ICF: 8
		zIIP: 12
		IFL: 8
		SAP: 12
		Available engines: 0

Model capacity:	Enable upgrades up to	Daily hardware prices	Daily maintenance prices (estimated) ¹
ICF:	0% more model capacity		
zIIP:	2 more ICF engines	\$0.00	\$12.00
IFL:	2 more zIIP engines	\$0.00	\$12.00
SAP:	0 more IFL engines		
	0 more SAP engines		

Description: +0% model capacity, +2 ICF, +2 zIIP, +0 IFL, +0 SAP

Notes:

- Reflects current established prices for the selected machine. Prices are subject to change; the actual prices in effect at the time of use will apply.
- Daily prices for ICF, zIIP, IFL, and SAP upgrades are **per engine**.
- The IFL upgrade daily hardware price includes per IFL for the management enablement level in effect for this machine.

Figure 8-11 On/Off CoD order example

The example order that is shown in Figure 8-11 is an On/Off CoD order for 0% more CP capacity (system is at capacity level 7), and for two more ICFs and two more zIIPs. The maximum number of CPs, ICFs, zIIPs, and IFLs is limited by the current number of available unused PUs of the installed processor drawers. The maximum number of SAPs is determined by the model number and the number of available PUs on the already installed processor drawers.

To finalize the order, you must accept Terms and Conditions for the order, as shown in Figure 8-12.

Terms of Order

You have requested an On/Off Capacity on Demand, or Temporary Capacity upgrade. Your enterprise has previously accepted the Temporary Capacity terms, restated here. In the event there is a conflict between the terms shown on this website and the terms specified in your contract with IBM, the terms of such contract prevail:

1) upon download and installation of this Temporary Capacity Upgrade, IBM grants you only a temporary license to use the LIC enabling such Temporary Capacity Upgrade. You may use such Temporary Capacity Upgrade only on the TC Eligible Machine for which such LIC is provided, and only to the extent of the authorization identified via the CIU Facility.

I accept the Terms and Conditions of this order*

Submit

Figure 8-12 CIU order Terms and Conditions

8.6.5 Activation and deactivation

When a previously ordered On/Off CoD is retrieved from Resource Link, it is downloaded and stored on the SE HDD. You can activate the order manually or through automation when the capacity is needed.

If the On/Off CoD offering record does not contain resource tokens, you must deactivate the temporary capacity manually. Deactivation is done from the SE and is nondisruptive. Depending on how the capacity was added to the LPARs, you might be required to perform tasks at the LPAR level to remove it. For example, you might have to configure offline any CPs that were added to the partition, deactivate LPARs that were created to use the temporary capacity, or both.

On/Off CoD orders can be staged in Resource Link so that multiple orders are available. An order can be downloaded and activated only once. If a different On/Off CoD order is required or a permanent upgrade is needed, it can be downloaded and activated without having to restore the system to its original purchased capacity.

In support of automation, an API is available that allows the activation of the On/Off CoD records. The activation is performed from the HMC and requires specifying the order number. With this API, automation code can be used to send an activation command along with the order number to the HMC to enable the order.

8.6.6 Termination

A customer is contractually obligated to end the On/Off CoD right-to-use feature when a transfer in asset ownership occurs. A customer also can choose to end the On/Off CoD right-to-use feature without transferring ownership.

Removing FC 9898 ends the right to use the On/Off CoD. This feature cannot be ordered if a temporary session is active. Similarly, the CIU enablement feature cannot be removed if a temporary session is active. When the CIU enablement feature is removed, the On/Off CoD right-to-use feature is simultaneously removed. Reactivating the right-to-use feature subjects the client to the terms and fees that apply then.

Upgrade capability during On/Off CoD

Upgrades that involve physical hardware are supported while an On/Off CoD upgrade is active on a specific IBM z16 server. LICCC-only upgrades can be ordered and retrieved from IBM Resource Link, and can be applied while an On/Off CoD upgrade is active. LICCC-only memory upgrades can be retrieved and applied while an On/Off CoD upgrade is active.

Repair capability during On/Off CoD

If the IBM z16 requires service while an On/Off CoD upgrade is active, the repair can occur without affecting the temporary capacity.

Monitoring

When you activate an On/Off CoD upgrade, an indicator is set in vital product data. This indicator is part of the call-home data transmission, which is sent on a scheduled basis. A timestamp is placed into the call-home data when the facility is deactivated. At the end of each calendar month, the data is used to generate an invoice for the On/Off CoD that was used during that month.

Maintenance

The maintenance price is adjusted as a result of an On/Off CoD activation.

Software

Software Parallel Sysplex license charge (PSLC) clients are billed at the MSU level that is represented by the combined permanent and temporary capacity. All PSLC products are billed at the peak MSUs that are enabled during the month, regardless of usage. Customers with WLC licenses are billed by product at the highest four-hour rolling average for the month. In this instance, temporary capacity does not increase the software bill until that capacity is allocated to LPARs and used.

Results from the STSI instruction reflect the current permanent and temporary CPs. For more information, see “Store System Information instruction” on page 379.

8.7 z/OS Capacity Provisioning

This section describes how z/OS Capacity Provisioning can help you manage the addition of capacity to a server to handle workload peaks.

z/OS Capacity Provisioning is delivered as part of the z/OS MVS Base Control Program (BCP).

Capacity Provisioning includes the following components:

- ▶ Capacity Provisioning Manager (Provisioning Manager)
- ▶ Capacity Provisioning Management Console (available in the IBM z/OS Management Facility)
- ▶ Sample data sets and files

The Provisioning Manager monitors the workload on a set of z/OS systems and organizes the provisioning of extra capacity to these systems when required. You define the systems to be observed in a domain configuration file.

The details of extra capacity and the rules for its provisioning are stored in a policy file. These two files are created and maintained through the Capacity Provisioning Management Console (CPMC).

The operational flow of Capacity Provisioning is shown in Figure 8-13 on page 364.

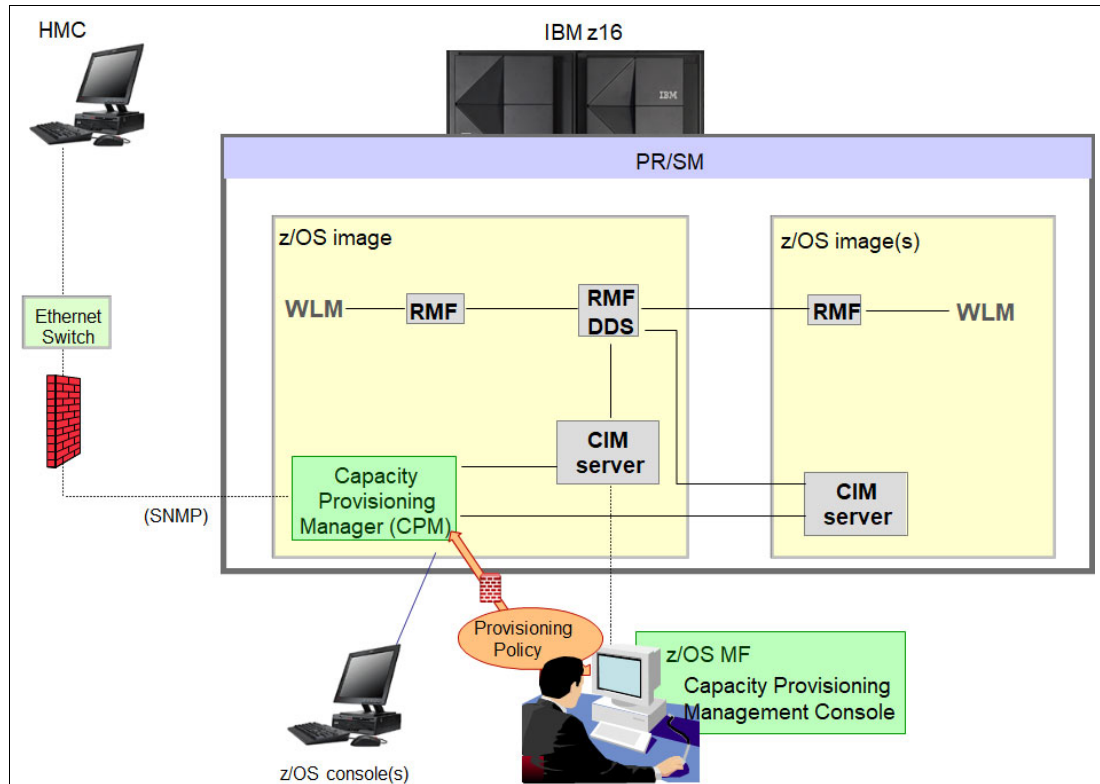


Figure 8-13 The capacity provisioning process and infrastructure

The z/OS WLM manages the workload by goals and business importance on each z/OS system. WLM metrics are available through existing interfaces, and are reported through IBM Resource Measurement Facility (RMF) Monitor III, with one RMF gatherer for each z/OS system.

Sysplex-wide data aggregation and propagation occur in the RMF Distributed Data Server (DDS). The RMF Common Information Model (CIM) providers and associated CIM models publish the RMF Monitor III data.

CPM retrieves critical metrics from one or more z/OS systems' CIM structures and protocols. CPM communicates to local and remote SEs and HMCs by using the Simple Network Management Protocol (SNMP).

CPM can see the resources in the individual offering records and the capacity tokens. When CPM activates resources, a check is run to determine whether enough capacity tokens remain for the specified resource to be activated for at least 24 hours. If insufficient tokens remain, no resource from the On/Off CoD record is activated.

If a capacity token is used during an activation that is driven by the CPM, the corresponding On/Off CoD record is deactivated prematurely by the system. This process occurs even if the CPM activates this record, or parts of it. However, you receive warning messages five days before a capacity token is fully used.

The five days are based on the assumption that the consumption is constant for the five days. You must put operational procedures in place to handle these situations. You can deactivate the record manually, allow it to occur automatically, or replenish the specified capacity token by using the Resource Link application.

The Capacity Provisioning Management Console (CPMC) is a console that administrators use to work with provisioning policies and domain configurations and to monitor the status of a Provisioning Manager. The management console is implemented by the Capacity Provisioning task in the IBM z/OS Management Facility (z/OSMF). z/OSMF provides a framework for managing various aspects of a z/OS system through a web browser interface.

Capacity Provisioning Domain

The provisioning infrastructure is managed by the CPM through the Capacity Provisioning Domain (CPD), which is controlled by the Capacity Provisioning Policy (CPP). The CPD is shown in Figure 8-14.

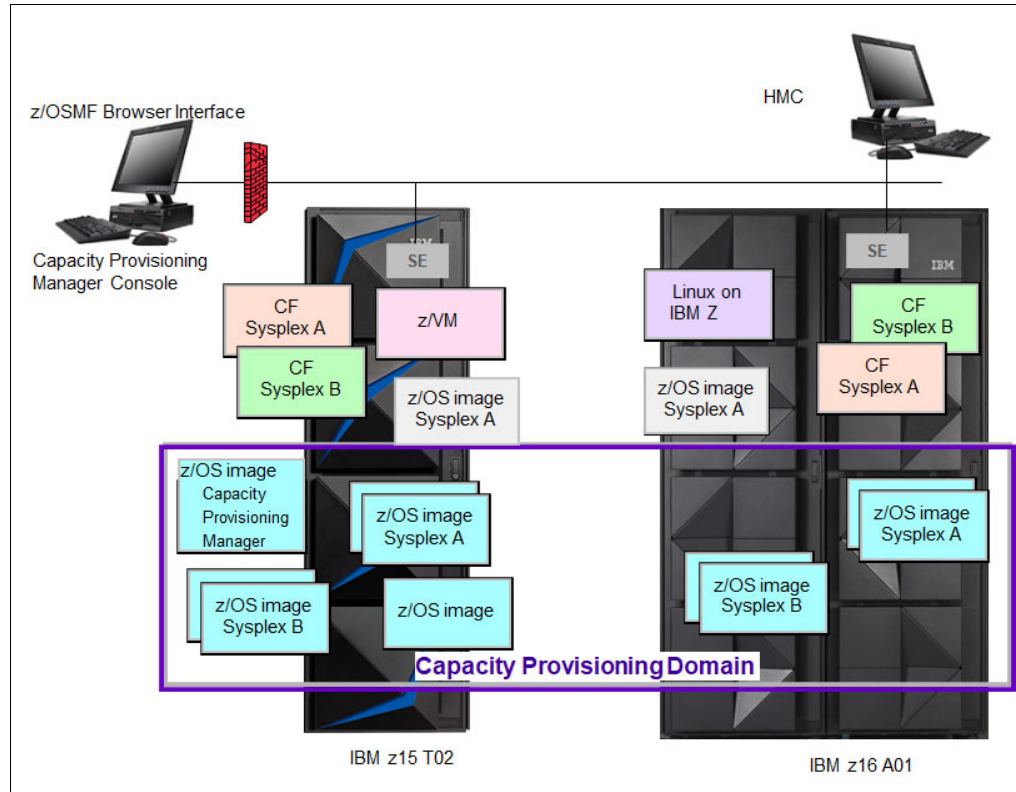


Figure 8-14 Capacity Provisioning Domain

The CPD configuration defines the CPCs and z/OS systems that are controlled by an instance of the CPM. One or more CPCs, sysplexes, and z/OS systems can be defined into a domain. Although sysplexes and CPCs do not have to be contained in a domain, they must not belong to more than one domain.

Each domain has one active capacity provisioning policy.

CPM operates in the following modes, which allows four different levels of automation:

- ▶ Manual
- ▶ Analysis

Use this command-driven mode when no CPM policy is active.

In analysis mode, CPM processes capacity-provisioning policies and informs the operator when a provisioning or deprovisioning action is required according to policy criteria.

Also, the operator determines whether to ignore the information or to manually upgrade or downgrade the system by using the HMC, SE, or available CPM commands.

► Confirmation

In this mode, CPM processes capacity provisioning policies and interrogates the installed temporary offering records. Every action that is proposed by the CPM must be confirmed by the operator.

► Autonomic

This mode is similar to the confirmation mode, but no operator confirmation is required.

Several reports are available in all modes that contain information about the workload, provisioning status, and the rationale for provisioning guidelines. User interfaces are provided through the z/OS console and the CPMC application.

The provisioning policy defines the circumstances under which more capacity can be provisioned (when, which, and how). The criteria features the following elements:

- A time condition is when provisioning is allowed:
 - Start time indicates when provisioning can begin.
 - Deadline indicates that provisioning of more capacity is no longer allowed.
 - End time indicates that deactivation of capacity must begin.
- A workload condition is which work qualifies for provisioning. It can have the following parameters:
 - The z/OS systems that can run eligible work.
 - The importance filter indicates eligible service class periods, which are identified by WLM importance.
 - Performance Index (PI) criteria:
 - Activation threshold: PI of service class periods must exceed the activation threshold for a specified duration before the work is considered to be suffering.
 - Deactivation threshold: PI of service class periods must fall below the deactivation threshold for a specified duration before the work is considered to no longer be suffering.
 - Included service classes are eligible service class periods.
 - Excluded service classes are service class periods that must not be considered.

Tip: If no workload condition is specified, the full capacity that is described in the policy is activated and deactivated at the start and end times that are specified in the policy.

- Provisioning scope is how much more capacity can be activated and is expressed in MSUs.

The number of zIIPs must be one specification per CPC that is part of the CPD and are specified in MSUs.

The maximum provisioning scope is the maximum extra capacity that can be activated for all the rules in the CPD.

In the specified time interval, the provisioning rule is that up to the defined extra capacity can be activated if the specified workload is behind its objective.

The rules and conditions are named and stored in the Capacity Provisioning Policy.

For more information about z/OS Capacity Provisioning functions, see *z/OS MVS Capacity Provisioning User's Guide*, SC34-2661.

Planning considerations for using automatic provisioning

Although only one On/Off CoD offering can be active at any one time, several On/Off CoD offerings can be present on the system. Changing from one offering to another requires stopping the active offering before the inactive one can be activated. This operation decreases the current capacity during the change.

The provisioning management routines can interrogate the installed offerings, their content, and the status of the content of the offering. To avoid the decrease in capacity, create only one On/Off CoD offering on the system by specifying the maximum allowable capacity. Then, when an activation is needed, the CPM can activate a subset of the contents of the offering sufficient to satisfy the demand. If more capacity is needed later, the Provisioning Manager can activate more capacity up to the maximum allowed increase.

Multiple offering records can be pre-staged on the SE HDD. Changing the content of the offerings (if necessary) also is possible.

Remember: CPM controls capacity tokens for the On/Off CoD records. In a situation where a capacity token is used, the system deactivates the corresponding offering record. Therefore, you must prepare routines for catching the warning messages about capacity tokens being used, and have administrative procedures in place for such a situation.

The messages from the system begin five days before a capacity token is fully used. To avoid capacity records being deactivated in this situation, replenish the necessary capacity tokens before they are used.

The CPM operates based on Workload Manager (WLM) indications, and the construct that is used is the Performance Index (PI) of a service class period. It is important to select service class periods that are suitable for the business application that needs more capacity.

For example, the application in question might be running through several service class periods, where the first period is the important one. The application might be defined as importance level 2 or 3, but might depend on other work that is running with importance level 1. Therefore, it is important to consider which workloads to control and which service class periods to specify.

8.8 System Recovery Boost Upgrade

Important: The base System Recovery Boost capability is built into IBM z16 firmware and does not require ordering more features. System Recovery Boost Upgrade (consisting of FC 9930 and FC 6802) is an optional, orderable feature that provides more temporary zIIP capacity for use during boost periods. Consider the following points:

- ▶ FC 9930 is *not* required to use the base System Recovery Boost capability.
- ▶ FC 9930 is *only* needed if more zIIP temporary capacity is required.

The System Recovery Boost Upgrade optional feature is offered with IBM z16 A01 to provide more capacity for System Recovery Boost processing. For example, if a z/OS operating system change requires a sequence of system shutdowns and restarts, and these procedures can benefit from extra CPU capacity, the System Recovery Boost record can be used to activate more zIIPs on the server at the commencement of the change window. These zIIPs are used by the z/OS systems to run general CP work during the boost periods.

The System Recovery Boost Upgrade requires the following feature codes:

- ▶ FC 6802: System Recovery Boost Record

This feature code provides extra zIIP capacity (20 zIIP records for 1 - 5 years, orderable by FC 6799, and must be renewed if expired) for use in System Recovery Boost events (shutdown, restart/IPL, and stand-alone memory dumps).

Note: At least one permanent zIIP record must be present for ordering System Recovery Boost Upgrade (FC 6802).

- ▶ FC 9930: Boost Authorization contract

This code enables the ordering of On/Off CoD for System Recovery Boost through Resource Link.

Important: The System Recovery Boost Upgrade record is for System Recovery Boost capacity only. It cannot be used for peak workload management. The customer must deactivate the boost capacity at the end of the system boost procedure. The zIIP capacity that is provided in the SRB Record is for LPAR shutdown and startup (IPL and Catchup) and is not available for process boost events.

The zIIP processors that can be activated by System Recovery Boost record come from the “dark core” capacity on the server. They can be added to an IBM z16 nondisruptively.

The base system configuration must have sufficient memory and channels to accommodate the potential requirements of the larger capacity system.

Note: The System Recovery Boost configuration is activated temporarily and provides up to a maximum of 20 extra zIIPs to the system’s original, permanent configuration and can violate the 2:1 zIIP rule. The number of zIIPs that can be activated is limited by the unused capacity that is available on the system.

When activating the System Recovery Boost record, the extra zIIPs are added to the zIIP pool when they are activated. Review the LPAR zIIP assignments and weights in the image profiles to ensure that the LPAR can use the extra capacity when it becomes available.

Configure a quantity for the initial and reserved zIIPs in the image profile so that extra zIIPs can be brought online dynamically when the boost record is activated. Also, consider adjusting the LPAR zIIP weight.

This feature can be ordered in the range of 1 - 5 years. Only one record can be installed on a system and it must be replenished before it can be used again (if expired).

A System Recovery Boost Upgrade contract (through FC 9930) must be in place before the special code that enables this capability can be installed on the system.

8.9 Capacity for Planned Event

The Capacity Planned Event feature (6833) can no longer be ordered for a new IBM z16; however, if installed on the base system, the record is brought forward during an upgrade into IBM z16 (by way of the support element Save/Restore process). Also, the CPE record cannot be replenished through e-configuration or IBM Resource Link.

Flexible Capacity for Cyber Resiliency is a new CoD offering that is available on IBM z16 machines. This offering allows processing capacity flexibility between an organization's primary site and alternative data centers.

Flexible Capacity for Cyber Resiliency is designed to provide increased flexibility and control to organizations that want to shift production capacity between participating IBM z16 servers at different sites. The capacity of any engine type can be shifted up to 12 times annually and stay at the target machine for up to 12 months after the flexible capacity record activation on the target machine. Capacity shifts can be done under full customer control without IBM intervention and can be fully automated by using IBM GDPS automation tools.

Flexible Capacity for Cyber Resiliency supports a broad set of scenarios and can be combined with other IBM On-Demand offerings.

For more information, see "IBM Z Flexible Capacity for Cyber Resiliency" on page 524.

8.10 Capacity Backup

CBU provides reserved emergency backup processor capacity for unplanned situations in which capacity is lost in another part of your enterprise. It allows you to recover by adding the reserved capacity on a designated IBM z16 server.

CBU is the quick, temporary activation of PUs:

- ▶ For up to 90 contiguous days, for a loss of processing capacity as a result of an emergency or disaster recovery situation.
- ▶ For 10 days, for testing your disaster recovery procedures or running the production workload. This option requires that IBM Z workload capacity that is equivalent to the CBU upgrade capacity is shut down or otherwise made unusable during the CBU test.⁵

Important: CBU is for disaster and recovery purposes only. It *cannot* be used for peak workload management or for a planned event.

⁵ All new CBU contract documents contain new CBU test terms to allow execution of production workload during CBU test. CBU clients must sign the IBM client Agreement Amendment for IBM Z Capacity Backup Upgrade Tests (US form #Z125-8145).

8.10.1 Ordering

The CBU process allows for CBU to activate CPs, ICFs, zIIPs, IFLs, and SAPs. To use the CBU process, a CBU enablement feature (FC 9910) must be ordered and installed. You must order the quantity and type of PU that you require by using the following feature codes:

- ▶ FC 6805: More CBU test activations
- ▶ FC 6817: Total CBU years ordered
- ▶ FC 6818: CBU records that are ordered
- ▶ FC 6820: Single CBU CP-year
- ▶ FC 6821: 25 CBU CP-year
- ▶ FC 6822: Single CBU IFL-year
- ▶ FC 6823: 25 CBU IFL-year
- ▶ FC 6824: Single CBU ICF-year
- ▶ FC 6825: 25 CBU ICF-year
- ▶ FC 6828: Single CBU zIIP-year
- ▶ FC 6829: 25 CBU zIIP-year
- ▶ FC 6830: Single CBU SAP-year
- ▶ FC 6831: 25 CBU SAP-year
- ▶ FC 6832: CBU replenishment

The CBU entitlement record (FC 6818) contains an expiration date that is established at the time of the order. This date depends on the quantity of CBU years (FC 6817). You can extend your CBU entitlements through the purchase of more CBU years.

The number of FC 6817 per instance of FC 6818 remains limited to five. Fractional years are rounded up to the nearest whole integer when calculating this limit.

If two years and eight months exist before the expiration date at the time of the order, the expiration date can be extended by no more than two years. One test activation is provided for each CBU year that is added to the CBU entitlement record.

FC 6805 allows for ordering more tests in increments of one. The maximum number of tests that is allowed is 15 for each FC 6818.

The processors that can be activated by CBU come from the available unassigned PUs on any installed processor drawer. A maximum of 200 CBU features that can be ordered. The number of features that can be *activated* is limited by the number of unused PUs on the system; for example:

- ▶ An IBM z16 Max 39 with Capacity Model Identifier 401 can activate up to 39 CBU features. These CBU features can be used to change the capacity setting of the CPs, and to activate unused PUs.
- ▶ An IBM z16 Max 82 CMI 715 with 15 CPs, 4 IFLs, and 1 ICF has 62 unused PUs available. It can *activate* up to 62 CBU features.

The ordering system allows for over-configuration in the order. You can order up to 200 CBU features, regardless of the current configuration. However, at activation, only the capacity that is installed can be activated. At activation, you can decide to activate only a subset of the CBU features that are ordered for the system.

Sub-capacity makes a difference in the way that the CBU features are completed. On the full-capacity models, the CBU features indicate the amount of extra capacity that is needed. If the amount of necessary CBU capacity is equal to four CPs, the CBU configuration is four CBU CPs.

The sub-capacity models feature multiple capacity settings of 4xx, 5yy, or 6yy. The standard models use the capacity setting 7nn. To change the capacity setting, the number of CBU CPs must be equal to or greater than the number of CPs in the base configuration.

For example, if the base configuration is a two-way 402, two CBU feature codes are required to provide a CBU configuration of a four-way of the same capacity setting. If the required CBU capacity changes the capacity setting of the CPs, going from model capacity identifier 402 to a CBU configuration of a four-way 504 requires four CBU feature codes with a capacity setting of 5yy.

If the capacity setting of the CPs is changed, more CBU features are required, not more physical PUs. Therefore, your CBU contract requires more CBU features when the capacity setting of the CPs is changed.

CBU can add CPs through LICCC only, and the IBM z16 A01 must have the correct number of installed processor drawers to allow the required upgrade. CBU can change the model capacity identifier to a *higher* value than the base setting (4xx, 5yy, or 6yy), but the CBU feature cannot *decrease* the capacity setting.

A CBU contract must be in place before the special code that enables this capability can be installed on the system. CBU features can be added to an IBM z16 nondisruptively. For each system enabled for CBU, the authorization to use CBU is available for 1 - 5 years.

The alternative configuration is activated *temporarily*, and provides more capacity than the system's original, *permanent* configuration. At activation time, determine the capacity that you require for that situation. You can decide to activate only a subset of the capacity that is specified in the CBU contract.

The base system configuration must have sufficient memory and channels to accommodate the potential requirements of the large CBU target system. Ensure that all required functions and resources are available on the backup systems. These functions include CF LEVELs for coupling facility partitions, memory, and cryptographic functions, and connectivity capabilities.

When the emergency is over (or the CBU test is complete), the system must be returned to its original configuration. The CBU features can be deactivated at any time before the expiration date. Failure to deactivate the CBU feature before the expiration date can cause the system to downgrade resources gracefully to the original configuration. The system does not deactivate dedicated engines, or the last of in-use shared engines.

Planning: CBU for processors provides a concurrent upgrade. This upgrade can result in more enabled processors, changed capacity settings that are available to a system configuration, or both. You can activate a subset of the CBU features that are ordered for the system. Therefore, more planning and tasks are required for *nondisruptive* logical upgrades. For more information, see "Guidelines to avoid disruptive upgrades" on page 381.

For more information, see the *Capacity on Demand User's Guide*, SC28-6846.

8.10.2 CBU activation and deactivation

The activation and deactivation of the CBU function is your responsibility and does not require the onsite presence of IBM SSRs. The CBU function is activated or deactivated concurrently from the HMC by using the API. On the SE, CBU is activated by using the Perform Model Conversion task or through the API. The API enables task automation.

CBU activation

CBU is activated from:

- ▶ The SE by using the HMC and SSO to the SE
- ▶ By using the Perform Model Conversion task
- ▶ Through automation by using the API on the SE or the HMC

During a real disaster, use the Activate CBU option to activate the 90-day period.

Image upgrades

After CBU activation, the IBM z16 can have more capacity, more active PUs, or both. The extra resources go into the resource pools and are available to the LPARs. If the LPARs must increase their share of the resources, the LPAR weight can be changed or the number of logical processors can be concurrently increased by configuring reserved processors online. The operating system must concurrently configure more processors online. If necessary, more LPARs can be created to use the newly added capacity.

CBU deactivation

To deactivate the CBU, the extra resources must be released from the LPARs by the operating systems. In some cases, this process involves varying the resources offline. In other cases, it can mean shutting down operating systems or deactivating LPARs. After the resources are released, the same facility on the HMC/SE is used to turn off CBU. To deactivate CBU, select the **Undo temporary upgrade** option from the Perform Model Conversion task on the SE.

CBU testing

Test CBUs are provided as part of the CBU contract. CBU is activated from the SE by using the Perform Model Conversion task. Select the test option to start a 10-day test period. A standard contract allows one test per CBU year. However, you can order more tests in increments of one up to a maximum of 15 for each CBU order.

Tip: The CBU test activation is done the same way as the real activation; that is, by using the same SE Perform a Model Conversion window and selecting the **Temporary upgrades** option. The HMC windows were changed to avoid accidental real CBU activations by setting the test activation as the default option.

The test CBU must be deactivated in the same way as the regular CBU. Failure to deactivate the CBU feature before the expiration date can cause the system to degrade gracefully back to its original configuration. The system does not deactivate dedicated engines or the last in-use shared engine.

CBU example

An example of a CBU operation is shown in Figure 8-15. The permanent configuration is a 504, and a record contains seven CP CBU features. During an activation, multiple target configurations are available. With 7 CP CBU features, you can add up to 7CPs within the same MCI, which allows the activation of a 506, 507, through to a 511 (the blue path).

Alternatively, 4 CP CBU features can be used to change the MCI (in the example from a 504 to a 704) and then add the remaining 3 CP CBU features to upgrade to a 707 (the red path).

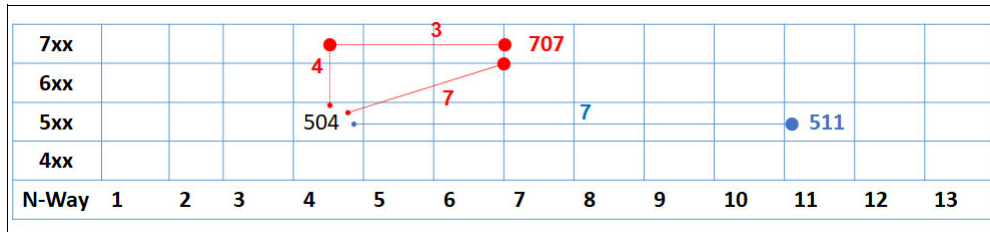


Figure 8-15 CBU example

Note: System Recovery Boost record does *not* affect model capacity identifier.

8.10.3 Automatic CBU enablement for GDPS

The IBM Geographically Dispersed Parallel Sysplex (GDPS) enables automatic management of the PUs that are provided by the CBU feature during a system or site failure. Upon detection of a site failure or planned disaster test, GDPS concurrently adds CPs to the systems in the take-over site to restore processing power for mission-critical production workloads. GDPS automation runs the following tasks:

- ▶ The analysis that is required to determine the scope of the failure. This process minimizes operator intervention and the potential for errors.
- ▶ Automates authentication and activation of the reserved CPs.
- ▶ Automatically restarts the critical applications after reserved CP activation.
- ▶ Reduces the outage time to restart critical workloads from several hours to minutes.

The GDPS service is for z/OS only, or for z/OS in combination with Linux on Z.

8.11 Flexible Capacity Cyber Resiliency

Flexible Capacity for Cyber Resiliency is a new CoD offering that is available on IBM z16 machines. It allows processing capacity flexibility between an organization's primary site and alternative data centers. This section summarizes the main features of Flexible Capacity for Cyber Resiliency.

For more information, see Appendix D, "Tailored Fit Pricing and IBM Z Flexible Capacity for Cyber Resiliency" on page 517.

Flexible Capacity for Cyber Resiliency can be ordered by contacting your IBM hardware sales representative. The offering requires that an order is placed against each serial number (SN) that is involved in capacity transfer with one record per SN.

The following feature codes were introduced:

- ▶ Flexible Capacity Authorization (#9933)
- ▶ Flexible Capacity Record (#0376)
- ▶ Billing feature codes (FC 0317 - 0322, and FC 0378 - 0386)

Installation and setup: The new Flexible Capacity Record is installed and set up on each participating IBM z16 system. Consider the following points:

- ▶ On the IBM z16 source system, the permanent capacity is unassigned to the base level.
- ▶ The new Flexible Capacity Record is installed and activated on the IBM z16 source system to restore capacity back to the purchased level.
- ▶ On the IBM z16 target systems, the new Flexible Capacity Record enables clients to bring the capacity up to the level of the production system when activated. The Flexible Capacity Record remains inactive until capacity is shifted from the base system to the target systems.
- ▶ After deactivating the Flexible Capacity Record on the base system, the capacity active through Flexible Capacity Transfer records on the target systems must not exceed the capacity active on the base system before the swap.
- ▶ If GDPS is used to automate the shift, it must be set up with the correct LIC records to add capacity in the target systems and remove capacity in the base systems site.

Site swap example

Figure 8-16 on page 375 - Figure 8-18 on page 376 show a sequence of events to move capacity from one site to another by using the Flexible Capacity features of the IBM z16.

A Flexible Capacity record is installed on the machines at each site. The machine at Site A has the base capacity that is configured at the same level as the high water mark of the Site B machine and has flex capacity that is activated to its HWM.

The flex capacity is then added to the machine at Site B, which brings it up to the Site A HWM and workload is transferred.

After all workload is transferred (within 24 hours), the capacity of the Site A machine is reduced to the base level. Workload can continue to run at Site B for up to a year.

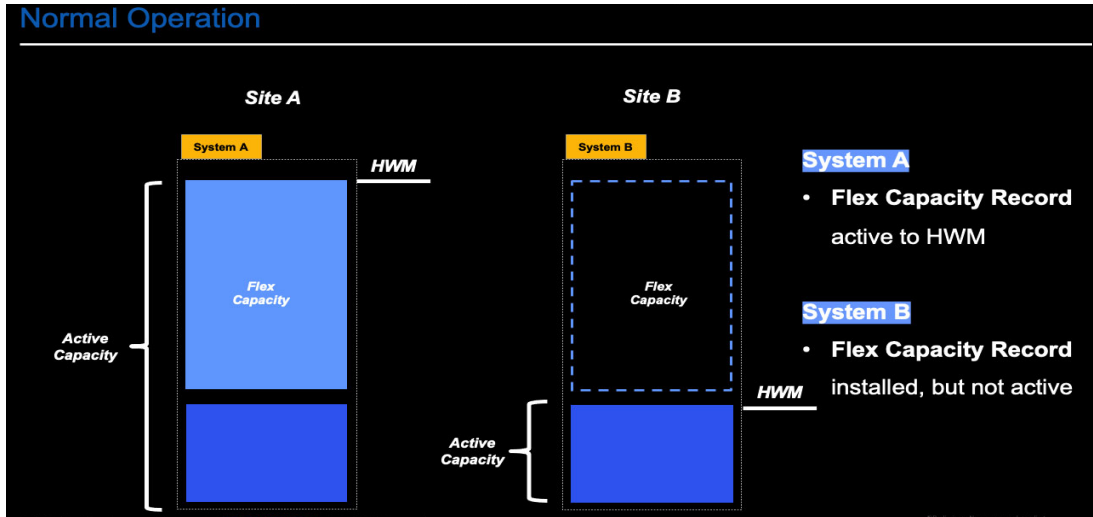


Figure 8-16 Flexible Capacity Normal Operation

Capacity transfer is shown in Figure 8-17. Flexible Capacity Record is ACTIVE in both sites for up to 24 hours.

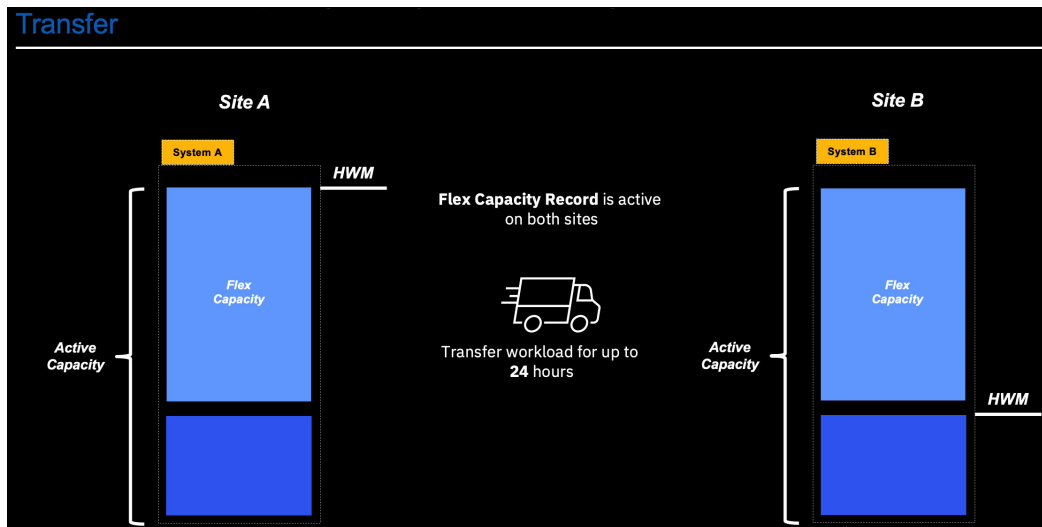


Figure 8-17 Flexible Capacity record at Site B is activated and workload transferred

After the site swap (capacity active in both sites for up to 24 hours), workload can stay in Site B for up to one year (see Figure 8-18 on page 376).

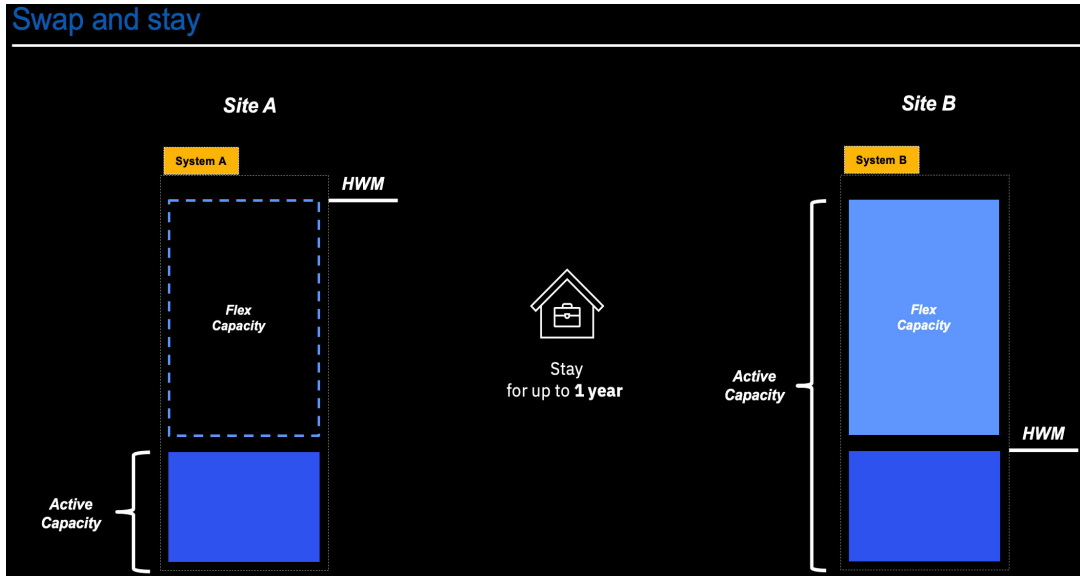


Figure 8-18 Stay at Site B for up to 1 year

8.12 Planning for nondisruptive upgrades

Continuous availability is an important requirement for customers, and planned outages are no longer acceptable. Although Parallel Sysplex clustering technology is the best continuous availability solution for z/OS environments, nondisruptive upgrades within a single system can avoid system outages and cover non-z/OS operating systems.

IBM z16 allows *concurrent* upgrades, which means that dynamically adding capacity to the system is possible. If the operating system images that run on the upgraded system do not require disruptive tasks to use the new capacity, the upgrade is also *nondisruptive*. This process avoids power-on resets (POR), LPAR deactivation, and IPLs.

If the concurrent upgrade is intended to satisfy an *image* upgrade to an LPAR, the operating system that is running in this partition must concurrently configure more capacity online. z/OS operating systems include this capability. z/VM can concurrently configure new processors and I/O devices online, and memory can be dynamically added to z/VM partitions.

If the concurrent upgrade is intended to satisfy the need for more operating system images, more LPARs can be created *concurrently* on the IBM z16 system. These LPARs include all resources that are needed. These extra LPARs can be activated concurrently.

These enhanced configuration options are available through the HSA, which is an IBM reserved area in system memory.

In general, Linux operating systems cannot add more resources concurrently. However, Linux and other types of virtual machines that run under z/VM can benefit from the z/VM capability to nondisruptively configure more resources online (processors and I/O).

With z/VM, Linux guests can manipulate their logical processors by using the Linux CPU hotplug daemon. The daemon can start and stop logical processors that are based on the Linux *load average* value. The daemon is available in Linux SLES 10 SP2 and later, and in Red Hat Enterprise Linux (RHEL) V5R4 and up.

8.12.1 Components

The following components can be added, depending on the considerations as described in this section:

- ▶ PUs
- ▶ Memory
- ▶ I/O
- ▶ Cryptographic adapters
- ▶ Special features

PUs

CPs, ICFs, zIIPs, IFLs, and SAPs can be added concurrently to an IBM z16 if unassigned PUs are available on any installed processor drawer. The number of zIIPs cannot exceed twice the number of CPs. The IBM z16 allows the concurrent addition of a second and third processor drawer if the CPC reserve features are installed.

If necessary, more LPARs can be created concurrently to use the newly added processors.

The Coupling Facility Control Code (CFCC) also can configure more processors online to coupling facility LPARs by using the CFCC image operations window.

Memory

Memory can be added concurrently up to the physical installed memory limit. More processor drawers can be installed concurrently, which allows further memory upgrades by LICCC, and enables memory capacity on the new processor drawers.

By using the previously defined reserved memory, z/OS operating system images, and z/VM partitions, you can dynamically configure more memory online. This process allows nondisruptive memory upgrades. Linux on Z supports Dynamic Storage Reconfiguration.

I/O

I/O features can be added concurrently if all the required infrastructure (I/O slots and PCIe Fan-outs) is present in the configuration. PCIe+ I/O drawers can be added concurrently without planning if free space is available in one of the frames and the configuration permits.

Dynamic I/O configuration changes are supported by specific operating systems (z/OS and z/VM), which allows for nondisruptive I/O upgrades. Dynamic I/O reconfiguration on a stand-alone coupling facility system also is possible by using the Dynamic I/O activation for stand-alone CF CPCs features.

Cryptographic adapters

Crypto Express8S features can be added concurrently if all the required infrastructure is in the configuration.

Special features

Special features, such as zHyperlink, Coupling Express2 LR, and RoCE features can be added concurrently if all infrastructure is available in the configuration.

8.12.2 Concurrent upgrade considerations

By using an MES upgrade, On/Off CoD, CBU, or CPE, an IBM Z server can be upgraded concurrently from one model to another (temporarily or permanently).

Enabling and using the extra processor capacity is not apparent to most applications. However, specific programs depend on processor model-related information, such as ISV products. Consider the effect on the software that is running on an IBM z16 when you perform any of these configuration upgrades.

Processor identification

The following instructions are used to obtain processor information:

- ▶ Store System Information (STSI) instruction

The STSI instruction can be used to obtain information about the current execution environment and any processing level that is below the current environment. It can be used to obtain processor model and model capacity identifier information from the basic machine configuration form of the system information block (SYSIB). It supports concurrent upgrades and is the recommended way to request processor information.

- ▶ Store CPU ID (STIDP) instruction

STIDP returns information that identifies the execution environment, system serial number, and machine type.

Note: To ensure unique identification of the configuration of the issuing CPU, use the STSI instruction specifying basic machine configuration (SYSIB 1.1.1).

Store System Information instruction

The format of the basic machine configuration SYSIB that is returned by the STSI instruction is shown in Figure 8-19. The STSI instruction returns the model capacity identifier for the permanent configuration and the model capacity identifier for any temporary capacity. This data is key to the functioning of CoD offerings.

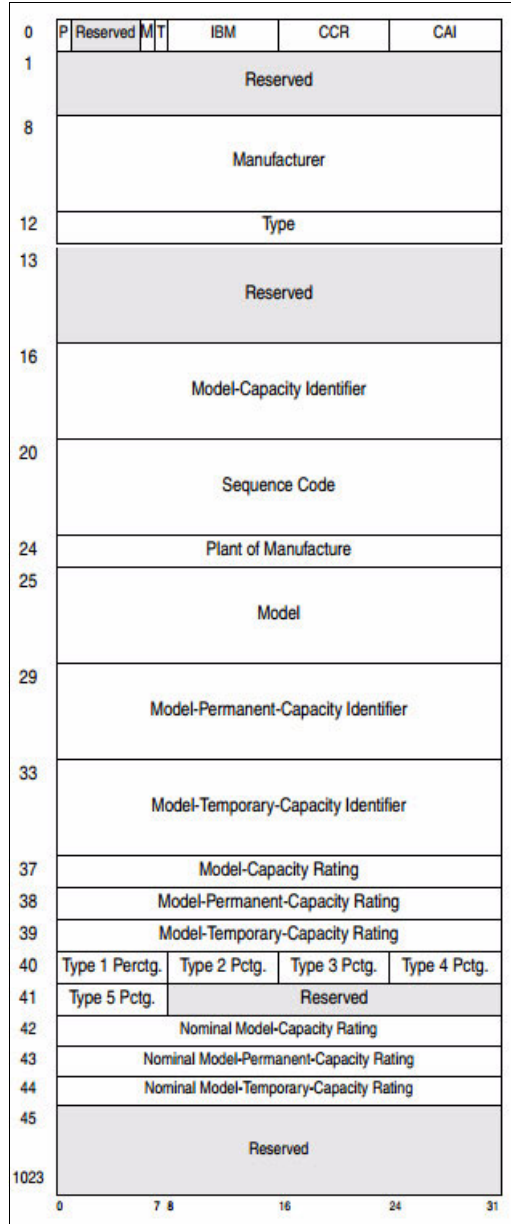


Figure 8-19 Format of system-information block (SYSIB)

The model capacity identifier contains the base capacity, On/Off CoD, and CBU. The Model Permanent Capacity Identifier and the Model Permanent Capacity Rating contain the base capacity of the system. The Model Temporary Capacity Identifier and Model Temporary Capacity Rating contain the base capacity and On/Off CoD.

For more information about the STSI instruction, see *z/Architecture Principles of Operation*, SA22-7832.

Store CPU ID instruction

The Store CPU ID (STIDP) instruction returns information about the processor type, serial number, and LPAR identifier, as shown in Figure 8-20.

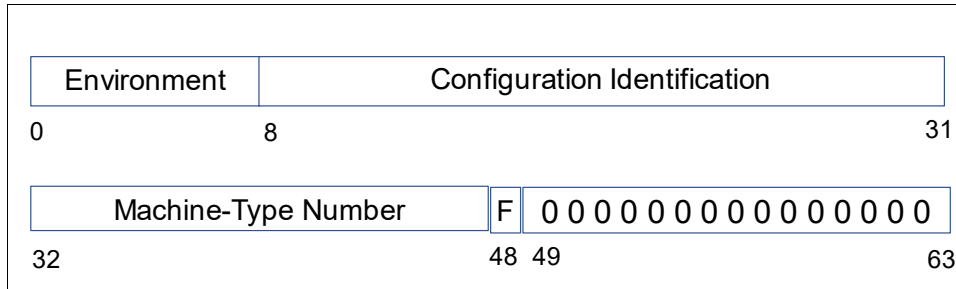


Figure 8-20 STIDP Information

Consider the following points:

- ▶ Bits 0 - 7:
 - For a program that is run by an IBM machine in a level-1 configuration (basic machine mode), or for a program being run by a level-2 configuration (in a logical partition), the environment field contains 00 hex.
 - For a program that is run natively by the System z Personal-Development Tool, the environment field contains C1 hex or D3 hex.
 - For a program that is run by a level-3 configuration (a virtual machine, such as a z/VM guest), the environment field contains FF hex.
- ▶ Bit positions 8 - 31
Contains six hexadecimal digits. The right-most of these digits can represent the machine's serial number.
- ▶ Bit positions 32 - 47
Contains an unsigned packed-decimal number that identifies the machine type of the CPU.
- ▶ Bit position 48
Specifies the format of the first two hexadecimal digits of the configuration-identification field.
- ▶ Bit positions 49 - 63 are reserved and stored as zeros.

For more information about the STIDP instruction, see *z/Architecture Principles of Operation*, SA22-7832.

Planning for nondisruptive upgrades

Online permanent upgrades, On/Off CoD, CBU, and CPE can be used to upgrade an IBM Z server concurrently. However, specific situations require a disruptive task to enable capacity that was recently added to the system. Some of these situations can be avoided if planning is done. Planning is a key factor for nondisruptive upgrades.

In a multi-site high-availability configuration, another option is the use of Flexible Capacity for Cyber Resilience to move workload to another site while hardware maintenance is performed.

Disruptive upgrades are performed for the following reasons:

- ▶ LPAR memory upgrades when reserved storage was not previously defined are disruptive to image upgrades. z/OS and z/VM support this function.
- ▶ An I/O upgrade when the operating system cannot use the dynamic I/O configuration function is disruptive to that partition. Linux, z/VSE, and z/TPF do not support dynamic I/O configuration.

You can minimize the need for these outages by carefully planning and reviewing “Guidelines to avoid disruptive upgrades” on page 381.

Guidelines to avoid disruptive upgrades

Based on the reasons for disruptive upgrades (see “Planning for nondisruptive upgrades” on page 380), you can use the following guidelines to avoid or at least minimize these situations, which increases the chances for nondisruptive upgrades:

- ▶ By using an SE function that is called Logical Processor add, which is under Operational Customization tasks, CPs and zIIPs can be added concurrently to a running partition. The CP and zIIP and initial or reserved number of processors can be changed dynamically.
- ▶ The operating system that runs in the targeted LPAR must support the dynamic addition of resources and to configure processors online. The total number of defined and reserved CPs cannot exceed the number of CPs that are supported by the operating system.

z/OS V2.R5, V2.R4, and V2.R3 support 200 PUs per z/OS LPAR in non-SMT mode and 128 PUs per z/OS LPAR in SMT mode. For both, the PU total is the sum of CPs and zIIPs. z/VM supports up to 64 processors.

- ▶ Configure reserved storage to LPARs.

Configuring reserved storage for all LPARs before their activation enables them to be nondisruptively upgraded. The operating system that is running in the LPAR must configure memory online. The amount of reserved storage can be greater than the CPC drawer threshold limit, even if no other CPC drawer is installed.

With IBM z16 servers, the current partition storage limit is 4 TB for z/OS V2.R3 and V2.R4, and 16 TB for z/OS V2.R5 and later. z/VM V7.R1 supports 2 TB and z/VM V7.R2 supports 4 TB memory partitions.

- ▶ Consider the flexible memory options.

Use a convenient entry point for memory capacity, and select memory options that allow future upgrades within the memory cards that are installed on the CPC drawers.

For more information about the offerings, see 2.5.7, “Flexible Memory Option” on page 47.

Considerations when installing CPC drawers

During an upgrade, a second and third processor drawer can be installed concurrently if they are planned. Depending on the number of processor drawers in the upgrade and your I/O configuration, a fan-out rebalancing might be needed for availability reasons.

A fourth or fifth processor drawer can be installed at the IBM Manufacturing plant only.

8.13 Summary of Capacity on-Demand offerings

The CoD infrastructure and its offerings are based on client requirements for more flexibility, granularity, and better business control over the IBM Z infrastructure, operationally, and financially.

One major client requirement was to eliminate the need for a client authorization connection to the IBM Resource Link system when activating an offering. This requirement is met by the IBM z14, IBM z15, and IBM z16 servers.

After the offerings are installed on the IBM z16 SE, they can be activated at any time at the customer's discretion. No intervention by IBM or IBM personnel is necessary. In addition, the activation of CBU does not require a password.

The IBM z16 A01 can have up to eight offerings that are installed at the same time, with the limitation that only *one* of them can be an On/Off CoD offering, and only one can be an SRB Upgrade record. The others can be any combination.

The installed offerings can be activated fully or partially, and in any sequence and any combination. The offerings can be controlled manually through command interfaces on the HMC, or programmatically through a number of APIs. IBM applications, ISV programs, and client-written applications can control the use of the offerings.

Resource usage (and therefore, financial exposure) can be controlled by using capacity tokens in the On/Off CoD offering records.

The CPM is an example of an application that uses the CoD APIs to provision On/Off CoD capacity that is based on the requirements of the workload. The CPM cannot control other offerings.

For more information about any of the topics in this chapter, see *Capacity on Demand User's Guide*, SC28-6943.



Reliability, availability, and serviceability

From the quality perspective, the IBM z16 reliability, availability, and serviceability (RAS) design is driven by a set of high-level program RAS objectives. The IBM Z platform continues to drive toward Continuous Reliable Operation (CRO) at the single footprint level.

Note: Throughout this chapter, IBM z16 refers to IBM z16 Model A01 (Machine Type 3931).

The key objectives, in order of priority, are to ensure data integrity, computational integrity, reduce or eliminate unscheduled outages, reduce scheduled outages, reduce planned outages, and reduce the number of Repair Actions.

RAS can be accomplished with improved concurrent replace, repair, and upgrade functions for processors, memory, drawers, and I/O. RAS also extends to the nondisruptive capability for installing Licensed Internal Code (LIC) updates. In most cases, a capacity upgrade can be concurrent without a system outage. As an extension to the RAS capabilities, environmental controls are implemented in the system to help reduce power consumption and meet cooling requirements.

This chapter includes the following topics:

- ▶ “RAS strategy” on page 384
- ▶ “Technology” on page 384
- ▶ “Structure” on page 389
- ▶ “Reducing complexity” on page 390
- ▶ “Reducing touches” on page 390
- ▶ “IBM z16 availability characteristics” on page 391
- ▶ “IBM z16 RAS functions” on page 394
- ▶ “Enhanced drawer availability” on page 398
- ▶ “Concurrent Drawer Maintenance” on page 406
- ▶ “RAS capability for the HMA and SE” on page 408

9.1 RAS strategy

The RAS strategy is to manage change by learning from previous generations and investing in new RAS function to eliminate or minimize all sources of outages. Enhancements that were introduced with IBM z15 RAS designs are implemented on the IBM z16 design through the introduction of new technology, structure, and requirements. Continuous improvements in RAS are associated with new features and functions to ensure that IBM Z servers deliver exceptional value to clients.

The following overriding RAS requirements are principles as shown in Figure 9-1:

- ▶ Include existing (or equivalent) RAS characteristics from previous generations.
- ▶ Learn from current field issues and addressing the deficiencies.
- ▶ Understand the trend in technology reliability (hard and soft) and ensure that the RAS design points are sufficiently robust.
- ▶ Invest in RAS design enhancements (hardware and firmware) that provide IBM Z and Customer valued differentiation.

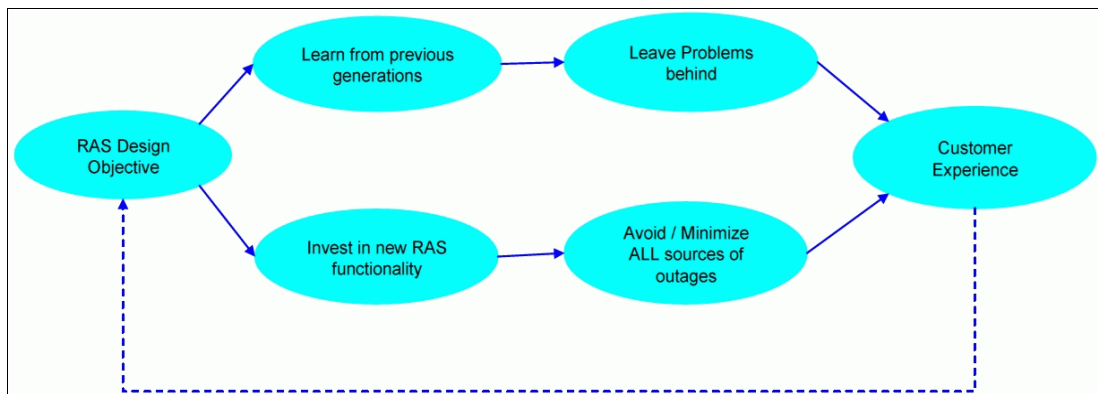


Figure 9-1 Overriding RAS requirements

9.2 Technology

This section introduces some of the RAS features that are incorporated in the IBM z16 design.

9.2.1 Processor Unit chip

IBM z16 uses the Processor Unit (PU) chip with the following technical changes:

- ▶ A PU chip is implemented by using EUV process with 7 nm FinFET lithography, and has eight cores (PUs) per chip (design) that are running at 5.2 GHz.
- ▶ Each core has private L1 (instruction and data) caches and a semi-private L2 cache, which are 32 MB. The eight cores and L2 caches on the chip communicate through bidirectional high-speed on-chip ring and with all SMP, I/O, and memory interfaces (see Figure 9-2 on page 385).

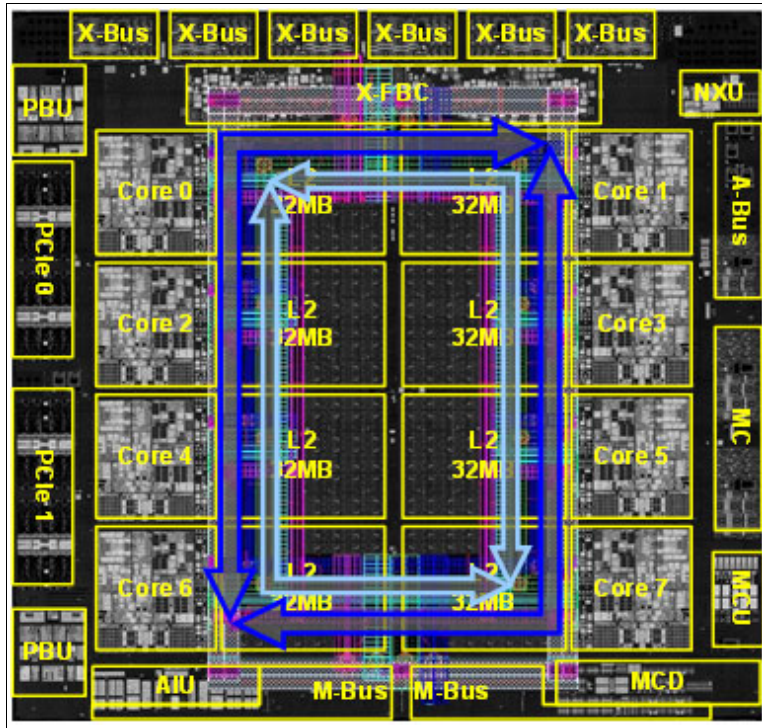


Figure 9-2 PU chip structure (with bidirectional ring shown)

- ▶ Two PU chips are packaged on a dual chip module (DCM), as shown in Figure 9-3. PU chip to PU chip communication is performed through the M-Bus, which is a high-speed bus that acts as ring-to-ring extension communication at 160 Gbps data rate, with the following RAS characteristics:
 - ECC on data path and snoop bus
 - Parity on miscellaneous control lines
 - One spare per ~50 data bit bus

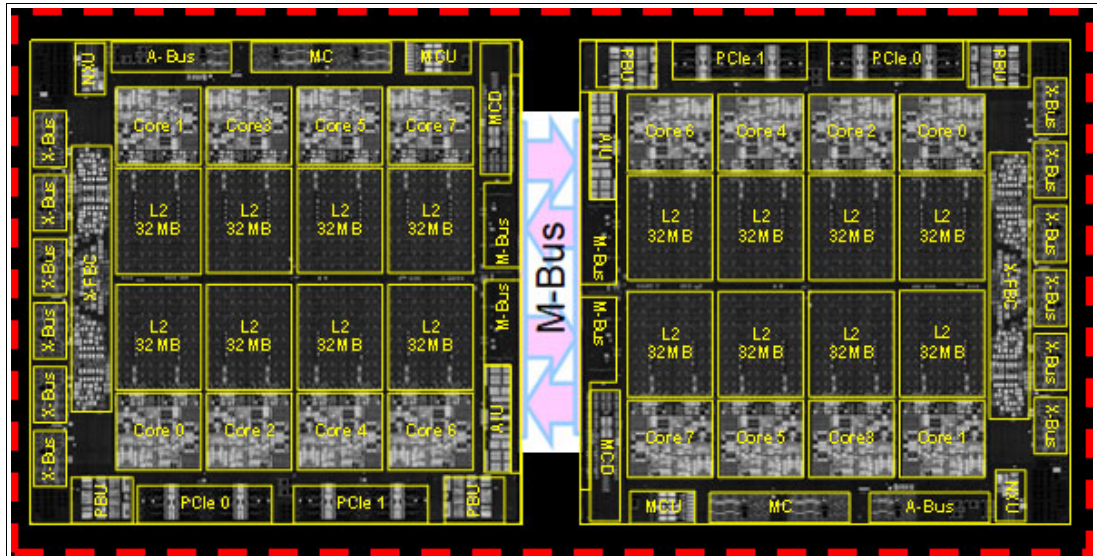


Figure 9-3 IBM z16 Dual Chip Module (M-Bus connects the two chips)

- ▶ The processor recovery logic is on the DCM and includes the following RAS characteristics:
 - PU refresh for soft errors
 - Hardened RU (recovery unit) with wordline failure detection
 - Improved latch interleaving (spacing) for soft error resistance
 - Core sparing for hard errors: All servers ship with two spare cores
 - Improved long-term thresholding
 - Redesigned nest
 - Concurrent repair by way of concurrent drawer repair (CDR)
 - Concurrent upgrade by way of LICCC and enhanced drawer availability (EDA)
- ▶ L1 and L1 shadow: L1 shadow is new on IBM z16 and includes the following characteristics:
 - Behaves like the L1 (for repairs)
 - Contains changed data
 - All unrecoverable error (UE) checkstop core: UEs are refetched before acting
 - UE impact depends on system state:
 - Before end OP, IPD without storage validity
 - Before SIE sync, System Damage
- ▶ IBM Z Integrated Accelerator for AI (AIU)

AIU is an on-chip AI Accelerator, which is new on IBM z16. AIU behaves like a co-processor to process the synchronous instructions, but AIU is in nest. The core control the AIU by issuing instruction (NNPA):

 - The array macro has row and column repair (MD and ABIST)
 - 1 MB cache with single error correction double error detection (SECDEC) ECC
- ▶ On-chip L2, caches are implemented in dense SRAM. The IBM z16 removed the physical L3 (on-chip for IBM z15) and L4 (on extra storage controller single chip module - SC SCM) and implemented clustered cache algorithms that provide virtualized L3 (shared victim) and virtual L4 (shared victim) caches (see Figure 9-4).

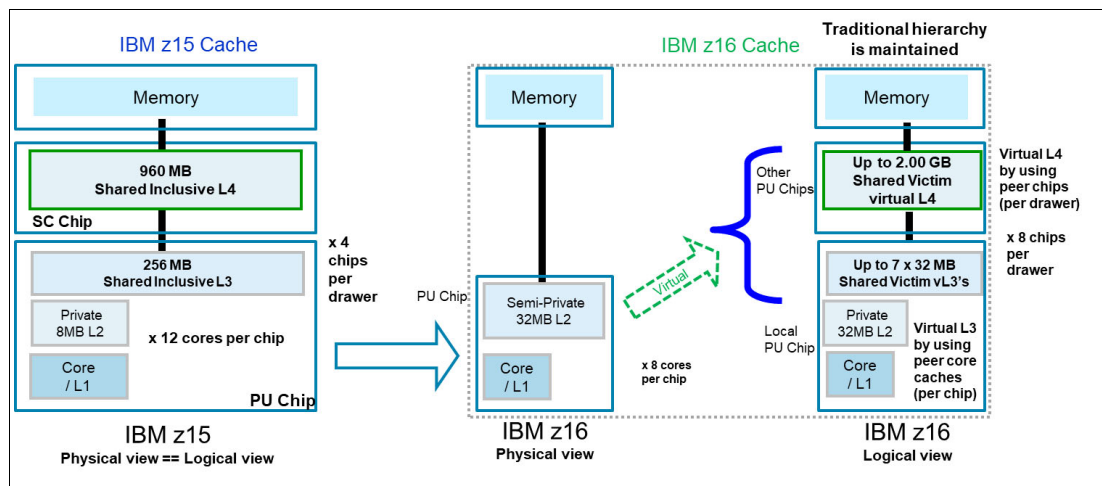


Figure 9-4 IBM z15 versus IBM z16 cache hierarchy

- ▶ The dedicated L2 cache (dense SRAM) is semi-private to the core; that is, each core features an associated 32-MB slice of the L2 cache (semi-private):
 - Virtual L3 on PU Chip (shared victim 256 MB)
 - Virtual L4 on drawer up to 2 GB
- ▶ L2 cache and L2 cache recovery:
 - The L2 cache includes expected inline Symbol ECC (RAID4) recovery:
 - 64:1 interleaving (4:1 physical, 16:1 logical)
 - L2 symbol ECC is inherited by virtual L3 and virtual L4
 - The array macro includes row and column repair (module manufacturing and ABIST)
 - Ring can be fenced from L2 for yield and fences core (module manufacturing):
 - If the core checkstops, all 32 MB can be used by the system
 - L2 dedicated and shared split are managed in the LRU logic
 - Dynamic macro sparing: Four spare macros, one spare for each quarter slice
 - L2 1/8 portion is taken offline when a spare is needed, and none is available (named 7/8 recovery): The core must be spared
 - L2 directory is SECEDED ECC protected

IBM z16 processor memory and cache structure are shown in Figure 9-5. The physical L3 cache (on chip) and System Controller (SC) SCM (physical L4 cache for IBM z15), which was implemented in EDRAM, were removed and replaced on IBM z16 virtual L3 and L4 cache structure.

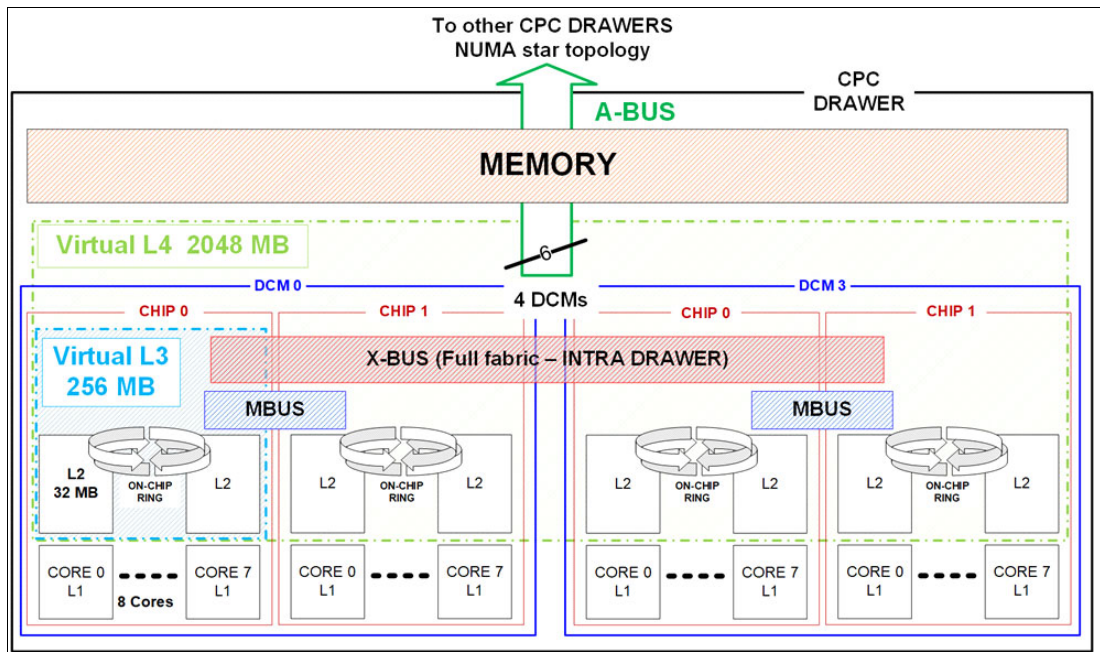


Figure 9-5 IBM z16 CPC Drawer Cache structure

9.2.2 Main memory

IBM z16 memory consists of the following features:

- ▶ Up to 48 DIMM are used per drawer in two rows (40 TB system maximum):
 - Organized in 8-channel Reed-Solomon RAIM groups
 - 50% reduced RAIM overhead (compared to IBM z15)
 - RAIM protection (similar to IBM z15)
 - Up to three chip marks and one channel mark
 - DDR4 DRAM with on chip power regulation: N+1 voltage regulators
 - Standard Open Memory Interface (OMI); up to six OMI per drawer:
 - CRC/Retry for soft errors
 - Degrade bus lanes from four lanes to two lanes on hard error
 - No waiting for all eight RAIM channels, use first seven to respond:
 - RAIM recovery is used to enhance performance without affecting RAS
 - Processor uses data from the first seven channels to respond
 - Refetch data by using all eight RAIM channels if an error occurs
- ▶ Flexible memory:
 - Provides more physical memory DIMMs that are needed to support activation of all customer-purchased memory and HSA on a multiple drawer zNext with one drawer down for:
 - Scheduled concurrent drawer upgrade (for example, memory add)
 - Scheduled concurrent drawer maintenance (N+1 repair)
 - Concurrent repair of an out-of-service CPC drawer “fenced” during Activation (POR)

Note: All of these features are available without Flexible Memory, but all customer purchased memory is not available for use in most cases. Some work might need to be shut down or not restarted.

- Offered on Max82, Max125, Max168, and Max200:
 - Flex Memory doubles the installed (configurable) memory for a two-CPC drawer system
 - Flex memory adds 1/2, 1/3, or 1/4 capacity to the ordered memory for a 2-, 3-, or 4-CPC drawer system
- Virtual Flash Memory considerations:
 - Each VFM Feature (FC 0644) takes 512 GB of memory. Up to 12 VFM features can be ordered.
 - If VFM is present, it is included in the Flexible memory calculations.
- ▶ Concurrent service and upgrade by way of Concurrent Drawer Repair (CDR)

9.2.3 I/O and service

I/O and service consist of the following features:

- ▶ New I/O features on IBM z16:
 - FICON Express 32S
 - Coupling Express2 LR
 - OSA Express7 1.2

- Crypto Express 8S
- RoCE Express3
- ▶ The number of PSP, support partitions, for managing native PCIe I/O:
 - Four partitions
 - Reduced effect on MCL updates
 - Better availability
- ▶ Faster Dynamic Memory Relocation engine:
 - Enables faster reallocation of memory that is used for LPAR activations, CDR, and concurrent upgrade
 - Enables also LPAR Optimizations with Dynamic Storage Reconfiguration (DSR)
 - Provides faster, more robust service actions
- ▶ IBM z16 has same Fill and Drain tool as IBM z15.

9.3 Structure

The IBM z16 was designed in a 19-inch frames format. The IBM z16 A01 can be delivered only as an air-cooled system and fulfills the requirements for ASHRAE A3 class environment.

The IBM z16 A01 can have up to 10 PCIe+ I/O drawers when delivered with Bulk Power Assembly (BPA) and 12 PCIe+ I/O drawers when delivered with Power Distribution Unit (PDU). The structure of the IBM z16 is designed with the following goals:

- ▶ Enhanced system modularity
- ▶ Standardization to enable rapid integration
- ▶ Platform simplification

Cables are keyed to ensure that correct lengths are plugged. Plug detection ensures correct location, and custom latches ensure retention. Further improvements to the fabric bus include symmetric multiprocessing (SMP) cables that connect the drawers.

To improve field-replaceable unit (FRU) isolation, advanced continuity checking techniques are applied to the SMP cables (Concurrent Cable Repair), with the new SMP cable plugging and unplugging tool.

The thermal RAS design also was improved for the field-replaceable water manifold for PU cooling.

The IBM z16 includes the following characteristics:

- ▶ Processing infrastructure is designed by using drawer technology.
- ▶ Keyed cables and plugging detection.
- ▶ SMP cables that are used for fabric bus connections.
- ▶ Master-master redundant oscillator design in the main memory.
- ▶ Point of load cards are separate FRUs.
- ▶ Improved serviceability for the water manifold
- ▶ Improved redundant oscillator design
- ▶ Redundant combined Base Management Card (BMC) and Oscillator Cards (OSC) are provided per CPU drawer.
- ▶ Redundant N+1 Power Supply Units (PSU) to CPC drawer and PCIe+ I/O drawer.

9.4 Reducing complexity

IBM z16 servers continue the IBM z15 enhancements that reduced system RAS complexity.

Independent channel recovery with replay buffers on all interfaces allows recovery of a single DIMM channel, while other channels remain active. Further redundancies are incorporated in I/O pins for clock lines to main memory, which eliminates the loss of memory clocks because of connector (pin) failure. The following RAS enhancements reduce service complexity:

- ▶ Continued use of RAIM ECC
- ▶ RAIM logic was moved on DIMM
- ▶ N+1 on-DIMM voltage regulation
- ▶ Replay buffer for hardware retry on soft errors on the main memory interface
- ▶ Redundant I/O pins for clock lines to main memory
- ▶ Staggered refresh for performance enhancement
- ▶ The new RAIM scheme achieves a higher ratio of data to ECC symbols, while also providing another chip mark

9.5 Reducing touches

IBM Z RAS efforts focus on the reduction of unscheduled, scheduled, planned, and unplanned outages. IBM Z technology has a long history of demonstrated RAS improvements. This effort continues with changes that reduce service *touches* on the system.

Firmware was updated to improve filtering and resolution of errors that do not require action. Enhanced integrated sparing in processor cores, cache relocates, N+1 SEEPROM and Point of load (POL) N+2 redundancies, and DRAM marking also are incorporated to reduce touches.

The following RAS enhancements reduce service touches:

- ▶ Improved error resolution to enable filtering
- ▶ Enhanced integrated sparing in processor cores
- ▶ Cache relocates
- ▶ N+1 SEEPROM
- ▶ N+2 POL
- ▶ DRAM marking
- ▶ (Dynamic) Spare BUS lanes for PU-PU, PU-MEM, MEM-MEM fabric
- ▶ N+1 Support Element (SE) with N+1 SE power supplies
- ▶ Redundant temperature sensor (one SEEPROM and one temperature sensor per I2C bus)
- ▶ FICON forward error correction
- ▶ A-Bus Lane Sparing
- ▶ OMI Bus Lane Sparing
- ▶ PU Core Sparing

9.6 IBM z16 availability characteristics

The following functions include availability characteristics on IBM z16:

- ▶ Enhanced drawer availability (EDA)

EDA is a *procedure* under which a CPC drawer in a multi-drawer system can be removed and reinstalled during an upgrade or repair action with no effect on the workload.

- ▶ Concurrent memory upgrade or replacement

Memory can be upgraded concurrently by using Licensed Internal Code Configuration Control (LICCC) if physical memory is available on the drawers.

The EDA function can be useful if the physical memory cards must be changed in a multi-drawer configuration (requiring the drawer to be removed).

It requires the availability of more memory resources on other drawers or reducing the need for memory resources during this action. Select the flexible memory option to help ensure that the suitable level of memory is available in a multiple-drawer configuration. This option provides more resources to use EDA when repairing a drawer or memory on a drawer. They also are available when upgrading memory when larger memory cards might be required.

- ▶ Concurrent Driver Maintenance (CDM)

One of the greatest contributors to downtime during planned outages is LIC driver updates that are performed in support of new features and functions. IBM z16 supports the concurrent activation of a selected new driver level.

- ▶ Plan Ahead for Balanced Power (FC 3003)

This feature allows you to order the maximum number of bulk power regulators (BPRs) on any server configuration. This feature helps to ensure that your configuration is in a balanced power environment if you intend to add CPC drawers and I/O drawers to your server in the future. The feature is available with Bulk Power Adapters (BPA) only.

- ▶ Concurrent fan-out addition or replacement

A PCIe+ fan-out card provides the path for data between memory and I/O through PCIe cables. With IBM z16, a hot-pluggable and concurrently upgradeable fan-out card is available. Up to 12 PCIe fan-out cards per CPC drawer are available for IBM z16 servers. An IBM z16 Model A01 feature Max168 and Max200 hold four CPC drawers and can have 48 PCIe fan out slots.

Internal I/O paths from the CPC drawer fan-out ports to a PCIe drawer or an I/O drawer are spread across multiple CPC drawers (for feature Max71, Max108, Max145, and Max190) and across different nodes within a single CPC drawer Feature Max34. During an outage, a fan-out card that is used for I/O can be repaired concurrently while redundant I/O interconnect ensures that no I/O connectivity is lost.

- ▶ Redundant I/O interconnect

Redundant I/O interconnect helps maintain critical connections to devices. IBM z16 A01 allows a single drawer in a multi-drawer system to be removed and reinstalled concurrently during an upgrade or repair. Connectivity to the system I/O resources is maintained through a second path from a different drawer.

- ▶ Base Management Card (BMC)/Oscillator Cards (OSC)

IBM z16 A01 features two combined BMC and OSC per CPU draw. The strategy of redundant clock and switchover stays the same. One primary and one backup is available. If the primary OSC fails, the backup detects the failure, takes over transparently, and continues to provide the clock signal to the CPC.

▶ Processor unit (PU) sparing

IBM z16 A01 has two spare PUs per system to maintain performance levels if an active PU, Internal Coupling Facility (ICF), Integrated Facility for Linux (IFL), IBM Z Integrated Information Processor (zIIP), integrated firmware processor (IFP), or system assist processor (SAP) fails. Transparent sparing for failed processors is supported and sparing is supported across the drawers.

▶ Application preservation

This function is used when a PU fails and no spares are available. The state of the failing PU is passed to another active PU, where the operating system uses it to successfully resume the task (in most cases, without customer intervention).

▶ Cooling change

The IBM z16 air-cooled configuration includes a front-to-rear radiator cooling system. The radiator pumps, blowers, controls, and sensors are N+1 redundant. In normal operation, one active pump supports the system. A second pump is turned on and the original pump is turned off periodically, which improves reliability of the pumps. The replacement of pumps or blowers is concurrent with no effect on performance.

Note: Customer chilled water (WCU) is not offered on IBM z16.

▶ FICON Express 32S with Forward Error Correction (FEC)

FICON Express32S features continue to provide a new standard for transmitting data over 32 Gbps links by using 64b/66b encoding. The new standard that is defined by T11.org FC-FS-3 is more efficient than the current 8b/10b encoding.

FICON Express32S channels that are running at 32 Gbps can take advantage of FEC capabilities when connected to devices that support FEC.

FEC allows FICON Express32S channels to operate at higher speeds, over longer distances, with reduced power and higher throughput. They also retain the same reliability and robustness for which FICON channels are traditionally known.

FEC is a technique that is used for controlling errors in data transmission over unreliable or noisy communication channels. When running at 32 Gbps link speeds, customers often see fewer I/O errors, which reduces the potential effect to production workloads from those I/O errors.

Read Diagnostic Parameters (RDP) improve Fault Isolation. After a link error is detected (for example, IFCC, CC3, reset event, or a link incident report), link data that is returned from Read Diagnostic Parameters is used to differentiate between errors that result from failures in the optics versus failures because of dirty or faulty links.

Key metrics can be displayed on the operator console. The results of a display matrix command with the LINKINFO=FIRST parameter, which collects information from each device in the path from the channel to the I/O device (see Figure 9-6 on page 393):

- Transmit (Tx) and Receive (Rx) optic power levels from the PCHID, Switch Input and Output, and I/O device
- Capable and Operating speed between the devices
- Error counts
- Operating System requires new function APAR OA49089

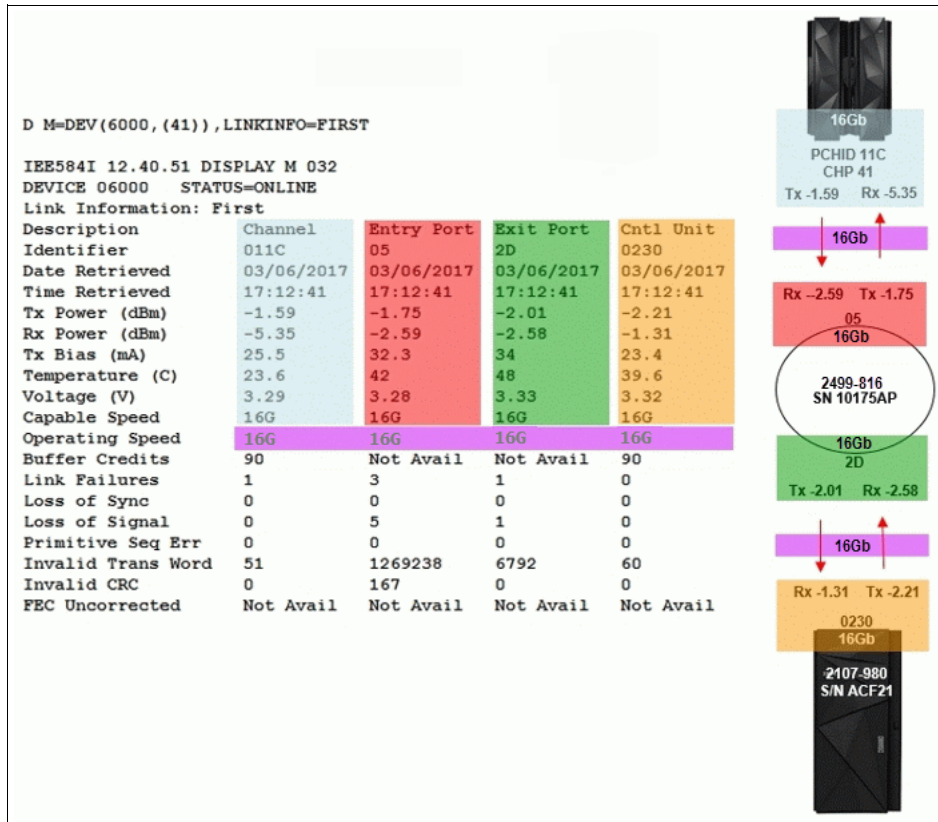


Figure 9-6 Read Diagnostic Parameters function

The new IBM Z Channel Subsystem Function performs periodic polling from the channel to the end points for the logical paths that are established and reduces the number of useless Repair Actions (RAs).

The RDP data history is used to validate Predictive Failure Algorithms and identify Fibre Channel Links with degrading signal strength before errors start to occur. The new Fibre Channel Extended Link Service (ELS) retrieves signal strength.

► FICON Dynamic Routing

FICON Dynamic Routing (FIDR) enables the use of storage area network (SAN) dynamic routing policies in the fabric. With the IBM z16, FICON channels are no longer restricted to the use of static routing policies for inter-switch links (ISLs) for cascaded FICON directors.

FICON Dynamic Routing dynamically changes the routing between the channel and control unit that is based on the Fibre Channel Exchange ID. Each I/O operation has a unique exchange ID. FIDR supports static SAN routing policies and dynamic routing policies.

FICON Dynamic Routing can help clients reduce costs by providing the following features:

- Share SANs between their FICON and FCP traffic.
- Improve performance because of SAN dynamic routing policies that better use all of the available ISL bandwidth through higher use of the ISLs,
- Simplify management of their SAN fabrics by using static routing policies that assign different ISL routes with each power-on-reset (POR), which makes the SAN fabric performance difficult to predict.

Customers must ensure that all devices in their FICON SAN support FICON Dynamic Routing before they implement this feature.

9.7 IBM z16 RAS functions

Hardware RAS function improvements focus on addressing all sources of outages. Sources of outages feature the following classifications:

- ▶ **Unscheduled**

This outage occurs because of an unrecoverable malfunction in a hardware component of the system.

- ▶ **Scheduled**

This outage is caused by changes or updates that must be done to the system in a timely fashion. A scheduled outage can be caused by a disruptive patch that must be installed, or other changes that must be made to the system.

- ▶ **Planned**

This outage is caused by changes or updates that must be done to the system. A planned outage can be caused by a capacity upgrade or a driver upgrade. A planned outage usually is requested by the customer, and often requires planning. The IBM z16 design phase focuses on enhancing planning to simplify or eliminate planned outages.

The difference between scheduled outages and planned outages might not be obvious. The general consensus is that scheduled outages occur sometime soon. The timeframe is approximately two weeks.

Planned outages are outages that are planned well in advance and go beyond this approximate two-week timeframe. This chapter does not distinguish between scheduled and planned outages.

Preventing unscheduled, scheduled, and planned outages was addressed by the IBM Z system design for many years.

IBM z16 A01 has a fixed size HSA of 256 GB. This size helps eliminate planning requirements for HSA and provides the flexibility to update dynamically the configuration. You can perform the following tasks dynamically:¹

- ▶ **Add:**

- Logical partition (LPAR)
- Logical channel subsystem (LCSS)
- Subchannel set
- Logical PU to an LPAR
- Cryptographic coprocessor
- Memory
- Physical processor

- ▶ Remove a cryptographic coprocessor
- ▶ Enable I/O connections
- ▶ Swap processor types

By addressing the elimination of planned outages, the following tasks also are possible:

- ▶ Concurrent driver upgrades
- ▶ Concurrent and flexible customer-initiated upgrades

For more information about the flexible upgrades that are started by customers, see 8.3.2, “Customer Initiated Upgrade facility” on page 340.

¹ Some planning considerations might exist. For more information, see Chapter 8, “System upgrades” on page 331.

- ▶ STP management of concurrent CTN Split and Merge
- ▶ Dynamic I/O for stand-alone CF, Linux on Z and z/TPF running on IBM z16

Dynamic I/O configuration changes can be made to a stand-alone CF, Linux on Z and z/TPF without requiring a disruptive power on reset. A firmware LPAR with a firmware-based appliance version of an HCD instance is used to apply the new I/O configuration changes. The firmware-based LPAR is driven by updates from an HCD instance that is running in a z/OS LPAR on a different IBM z16 CPC that is connected to the same IBM z16 HMA.
- ▶ System Recovery Boost Stage 3

System Recovery Boost enhancements for IBM z16 introduce the possibility of significantly reducing the effect of these disruptions by boosting a set of recovery processes that create significant pain points for users.

These recovery processes include the following examples:

 - IBM SAN Volume Controller memory dump boost
 - Middleware restart or recycle boost
 - HyperSwap configuration load boost

For more information about System Recovery Boost, see *Introducing IBM Z System Recovery Boost*, [REDP-5563](#).

9.7.1 Scheduled outages

Concurrent hardware upgrades, parts replacement, driver upgrades, and firmware fixes that are available with IBM z16 all address the elimination of scheduled outages. Also, the following indicators and functions that address scheduled outages are included:

- ▶ Memory data bus lane sparing.

This feature reduces the number of repair actions for memory.
- ▶ Dual tabbed Memory Clock signals.
- ▶ Triple DRAM chipkill tolerance.
- ▶ Processor drawer power distribution $N+2$ design.

The CPC drawer uses POL cards in a highly redundant $N+2$ configuration. POL regulators are daughter cards that contain the voltage regulators for the principle logic voltage boundaries in the IBM z16 CPC drawer. They plug into the CPC drawer system board and are nonconcurrent FRUs for the affected drawer (similar to the memory DIMMs). If you can use EDA, the replacement of POL cards is concurrent for the entire IBM Z server.
- ▶ Redundant ($N+1$) Ethernet switches.
- ▶ Redundant ($N+2$) ambient temperature sensors.
- ▶ Dual inline memory module (DIMM) field-replaceable unit (FRU) indicators.

These indicators imply that a memory module is not error-free and might fail eventually. This indicator gives IBM a warning and provides time to concurrently repair the storage module if the IBM z16 is a multi-drawer system.

The process to repair the storage module is to isolate or “fence off” the drawer, remove the drawer, replace the failing storage module and then, add the drawer. The flexible memory option might be necessary to maintain sufficient capacity while repairing the storage module.
- ▶ Single processor core checkstop and sparing.

This indicator shows that a processor core malfunctioned and is *spared*. IBM determines what to do based on the system and the history of that system.

- ▶ Point-to-point fabric for symmetric multiprocessing (SMP) RAS design
 - The A-bus is the logical bus and it is split over 2 SMP9 cables:
 - 11 bits per A-Bus
 - One SMP9 cable has six bits and the other has five bits.
 - CRC detection and replay
 - RAS lane Degrade and Call Home Strategy design
 - Concurrent repair of the SMP9 cable.

Having fewer components that can fail is an advantage. In a multi-drawer system, all of the drawers are connected by point-to-point connections. A drawer can always be added concurrently.

- ▶ Air-cooled system: radiator with redundant ($N+1$) pumps.

IBM z16 implements true $N+1$ redundancy on pumps and blowers for the radiator.

One radiator unit in Frame A and one radiator unit in frame B, which is configuration-dependent. The radiator cooling system can support up to three CPC drawers simultaneously with a redundant design that consists of two pumps and two blowers.

The replacement of a pump or blower causes no performance effect.

- ▶ The PCIe+ I/O drawer is available for IBM z16. It and all of the PCIe+ I/O drawer-supported features can be installed concurrently.
- ▶ Memory interface logic to maintain channel synchronization when one channel goes into replay. IBM z16 can isolate recovery to only the failing channel.
- ▶ Out-of-band access to DIMM (for background maintenance functions).

Out-of-band access (by using an I2C interface) allows maintenance (such as logging) without disrupting customer memory accesses.
- ▶ OMI Memory Bus lane sparing.
- ▶ Improved DIMM exerciser for testing memory during IML.
- ▶ PCIe redrive hub cards plug straight in (no blind mating of connector). Simplified plugging that is more reliable is included.
- ▶ ICA SR (short distance) coupling cards plug straight in (no blind mating of the connector). Simplified plugging that is more reliable is included.
- ▶ Coupling Express2 LR (CE2 LR) coupling cards plug into the PCIe+ I/O drawer, which allows more connections with a faster bandwidth.

9.7.2 Unscheduled outages

An *unscheduled outage* occurs because of an unrecoverable malfunction in a hardware component of the system.

The following improvements can minimize unscheduled outages:

- ▶ Continued focus on firmware quality

For LIC and hardware design, failures are eliminated through rigorous design rules; design walk-through; peer reviews; element, subsystem, and system simulation; and extensive engineering and manufacturing testing.

► Memory subsystem

Redundant Array of Independent Memory (RAIM) on IBM Z servers is a concept that is similar to the concept of Redundant Array of Independent Disks (RAID). The RAIM design detects and recovers from dynamic random access memory (DRAM), socket, memory channel, or DIMM failures. Memory size now includes RAIM protection and recovery.

Memory channels are organized in 8-card RAIM groups that provide 50% reduced RAIM overhead (compared to IBM z15).

RAIM protection is similar to IBM z15:

- Up to three chip marks and one channel mark
- DDR4 DRAM with on chip power regulation
- N+1 voltage regulators

Memory is implemented by using Standard Open Memory Interface (OMI) with up to six OMIs per drawer, has CRC/Retry for soft errors, degrade bus lanes 4->2 on hard error, and no waiting for all eight cards (use first seven to respond).

A precise marking of faulty chips helps ensure timely DIMM replacements. The design of the IBM z16 further improved this chip marking technology. Graduated DRAM marking is available, and channel marking and scrubbing calls for replacement on the third DRAM failure is available.

For more information about the memory system on IBM z16 A01, see 2.5, “Memory” on page 38.

► Soft-switch firmware

IBM z16 is equipped with the capabilities of soft-switching firmware. Enhanced logic in this function ensures that every affected circuit is powered off during the soft-switching of firmware components. For example, when you are upgrading the microcode of a FICON feature, enhancements are implemented to avoid any unwanted side effects that were detected on previous systems.

► Server Time Protocol (STP) recovery enhancement. IBM z16 updated the clocking structure:

- System uses a mesosynchronous clocking structure (similar to IBM z15)
- Two redundant oscillator cards in each drawer with dynamic oscillator switchover
- STP now has external clock reference support, separate Ethernet ports for ETS
- PTP and NTP (Ethernet cabling) are now directly connected to the CPC (no SE ETS connection needed)
- Oscillator card shares FRU package with drawer’ Base Control Card (BMC)
- Concurrent repair of oscillator or control card

A new signal was implemented in IBM z16 hardware for helping with STP recovery. This signal is called *N-Mode power signal*. In a CTN with PTS and BTS being IBM z16 servers, CTN recovery can be started by the new signal. Systems must have dual power with at least one side of the power capable of holding the power (UPS or similar) for five minutes if a utility power failure occurs.

When PCIe-based integrated communication adapter (ICA) Short Reach (SR) links are used, an unambiguous “going away signal” is sent when the server on which the coupling link is running is about to enter a failed (check stopped) state.

When the “going away signal” that is sent by the Current Time Server (CTS) in an STP-only Coordinated Timing Network (CTN) is received by the Backup Time Server (BTS), the BTS can safely take over as the CTS without relying on the previous Offline Signal (OLS) in a two-server CTN, or as the Arbiter in a CTN with three or more servers.

Enhanced Console Assisted Recovery (ECAR) contains recovery algorithms during a failing Primary Time Server (PTS) and uses communication over the HMA/SE network to assist with BTS takeover.

For more information, see Chapter 10, “Hardware Management Console and Support Element” on page 411.

Coupling Express2 LR does not support the “going away signal”; however, ECAR can be used to assist with recovery in the following configurations:

- ▶ Design of pervasive infrastructure controls in processor chips in memory ASICs.
- ▶ Improved error checking in the processor recovery unit (RU) to better protect against word line failures in the RU arrays.

9.8 Enhanced drawer availability

EDA is a procedure in which a drawer in a multi-drawer system can be removed and reinstalled during an upgrade or repair action. This procedure has no effect on the running workload with suitable planning and depending on your system configuration. A single CPC drawer IBM z16 A01 does *not* support EDA.

The EDA procedure and careful planning help ensure that all the resources are still available to run critical applications in an $(n-1)$ drawer configuration. This process allows you to avoid planned outages. Consider the flexible memory option to provide more memory resources when you are replacing a drawer.

For more information about flexible memory, see 2.5.7, “Flexible Memory Option” on page 47.

To minimize the effect on current workloads, ensure that sufficient inactive physical resources exist on the remaining drawers to complete a drawer removal. Also, consider deactivating noncritical system images, such as test or development LPARs. After you stop these noncritical LPARs and free their resources, you might find sufficient inactive resources to contain critical workloads while completing a drawer replacement.

9.8.1 EDA planning considerations

To use the EDA function, configure enough physical memory and engines so that the loss of a single drawer does not result in any degradation to critical workloads during the following occurrences:

- ▶ A degraded restart in the rare event of a drawer failure
- ▶ A drawer replacement for repair or a physical memory upgrade

The following configurations especially enable the use of the EDA function. These IBM z16 features need enough spare capacity so that they can cover the resources of a fenced or isolated drawer. This configuration imposes limits on the following number of the client-owned PUs that can be activated when one drawer within a model is fenced:

- ▶ A maximum of:
 - 39 PUs are configured on the Max39
 - 82 PUs are configured on the Max82
 - 125 PUs are configured on the Max125
 - 168 PUs are configured on the Max168
 - 200 PUs are configured on the Max200

- ▶ No special feature codes are required for PU and model configuration.
- ▶ Feature Max39 to Max168 each have 5 SAPs in each drawer. Max200 has in total 24 standard SAPs.
- ▶ The flexible memory option delivers physical memory so that 100% of the purchased memory increment can be activated even when one drawer is fenced.

The system configuration must have sufficient dormant resources on the remaining drawers in the system for the *evacuation* of the drawer that is to be replaced or upgraded. Dormant resources include the following possibilities:

- ▶ Unused PUs or memory that is not enabled by LICCC
- ▶ Inactive resources that are enabled by LICCC (memory that is not being used by any activated LPARs)
- ▶ Memory that is purchased with the flexible memory option
- ▶ Extra drawers

The I/O connectivity also must support drawer removal. Most of the paths to the I/O feature redundant I/O interconnect support in the I/O infrastructure (drawers) that enable connections through multiple fan-out cards.

If sufficient resources are not present on the remaining drawers, specific noncritical LPARs might need to be deactivated. One or more PUs or storage might need to be configured offline to reach the required level of available resources. Plan to address these possibilities to help reduce operational errors.

Exception: Single-drawer systems cannot use the EDA procedure.

Include the planning process as part of the initial installation and any follow-on upgrade that modifies the operating environment. A customer can use the IBM Resource Link machine information report to determine the number of drawers, active PUs, memory configuration, and channel layout.

If the IBM z16 is installed, click **Prepare for Enhanced Drawer Availability** in the Perform Model Conversion window of the EDA process on the Hardware Management Appliance (HMA). This task helps you determine the resources that are required to support the removal of a drawer with acceptable degradation to the operating system images.

The EDA process determines which resources (including memory, PUs, and I/O paths) are free to allow for the removal of a drawer. You can run this preparation on each drawer to determine which resource changes are necessary. Use the results as input in the planning stage to help identify critical resources.

With this planning information, you can examine the LPAR configuration and workload priorities to determine how resources might be reduced and still allow the drawer to be concurrently removed.

Include the following tasks in the planning process:

- ▶ Review of the IBM z16 configuration to determine the following values:
 - Number of drawers that are installed and the number of PUs enabled. Consider the following points:
 - Use the Resource Link machine information or the HMA to determine the model, number, and types of PUs (CPs, IFLs, ICFs, and zIIPs).
 - Determine the amount of memory (physically installed and LICCC-enabled).
 - Work with your IBM Service Support Representative (IBM SSR) to determine the memory card size in each drawer. The memory card sizes and the number of cards that are installed for each drawer can be viewed from the SE under the CPC configuration task list. Use the View Hardware Configuration option.
 - ICA SR fan-out layouts and ICA to ICA connections.

Use the Resource Link machine information to review the channel configuration. This process is a normal part of the I/O connectivity planning. The alternative paths must be separated as far into the system as possible.
- ▶ Review the system image configurations to determine the resources for each image.
- ▶ Determine the importance and relative priority of each LPAR.
- ▶ Identify the LPAR or workloads and the actions to be taken:
 - Deactivate the entire LPAR.
 - Configure PUs.
 - Reconfigure memory, which might require the use of reconfigurable storage unit (RSU) values.
 - Vary off the channels.
- ▶ Review the channel layout and determine whether any changes are necessary to address single paths.
- ▶ Develop a plan to address the requirements.

When you perform the review, document the resources that can be made available if the EDA is used. The resources on the drawers are allocated during a POR of the system and can change after that process.

Perform a review when changes are made to your IBM z16, such as adding drawers, PUs, memory, or channels. Also, perform a review when workloads are added or removed, or if the HiperDispatch feature was enabled and disabled since the last time you performed a POR.

9.8.2 Enhanced drawer availability processing

To use the EDA, first ensure that the following conditions are met:

- ▶ The used processors (PUs) on the drawer that is removed are freed.
- ▶ The used memory on the drawer is freed.
- ▶ For all I/O domains that are connected to the drawer, ensure that alternative paths exist. Otherwise, place the I/O paths offline.

For the EDA process, this phase is the preparation phase. It is started from the SE, directly or on the HMA, by using the Single object operation option on the Perform Model Conversion window from the CPC configuration task list, as shown in Figure 9-7.

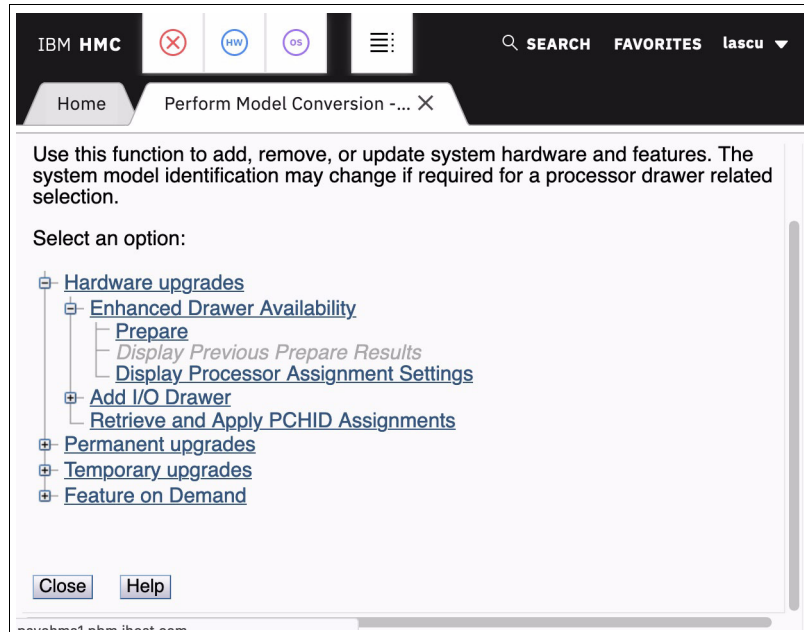


Figure 9-7 Clicking Prepare for Enhanced Drawer Availability option

Processor availability

Processor resource availability for reallocation or deactivation is affected by the type and quantity of the resources in use, such as the following examples:

- ▶ Total number of PUs that are enabled through LICCC
- ▶ PU definitions in the profiles that can be dedicated and dedicated reserved or shared
- ▶ Active LPARs with dedicated resources at the time of the drawer repair or replacement

To maximize the PU availability option, ensure that sufficient inactive physical resources are on the remaining drawers to complete a drawer removal.

Memory availability

Memory resource availability for reallocation or deactivation depends on the following factors:

- ▶ Physically installed memory
- ▶ Image profile memory allocations
- ▶ Amount of memory that is enabled through LICCC
- ▶ Flexible memory option
- ▶ Virtual Flash Memory if enabled and configured

For more information, see 2.7.2, “Enhanced drawer availability” on page 55.

Fan out card to I/O connectivity requirements

The optimum approach is to maintain maximum I/O connectivity during drawer removal. The redundant I/O interconnect (RII) function provides for redundant connectivity to all installed I/O domains in the PCIe+ I/O drawers.

Preparing for enhanced drawer availability

The Prepare Concurrent Drawer replacement option validates that enough dormant resources are available for this operation. If enough resources are not available on the remaining drawers to complete the EDA process, the process identifies those resources. It then guides you through a series of steps to select and free up those resources. The preparation process does not complete until all processors, memory, and I/O conditions are successfully resolved.

Preparation: The preparation step does not reallocate any resources. It is used only to record customer choices and produce a configuration file on the SE that is used to run the concurrent drawer replacement operation.

The preparation step can be done in advance. However, if any changes to the configuration occur between the preparation and the physical removal of the drawer, you must rerun the preparation phase.

The process can be run multiple times because it does not move any resources. To view the results of the last preparation operation, click **Display Previous Prepare Enhanced Drawer Availability Results** from the Perform Model Conversion window in the SE.

The preparation step can be run without performing a drawer replacement. You can use it to dynamically adjust the operational configuration for drawer repair or replacement before IBM SSR activity. The Perform Model Conversion window in you click **Prepare for Enhanced Drawer Availability** is shown in Figure 9-7 on page 401.

After you click **Prepare for Enhanced Drawer Availability**, the Enhanced Drawer Availability window opens. Select the drawer that is to be repaired or upgraded; then, select **OK**, as shown in Figure 9-8. Only one target drawer can be selected at a time.

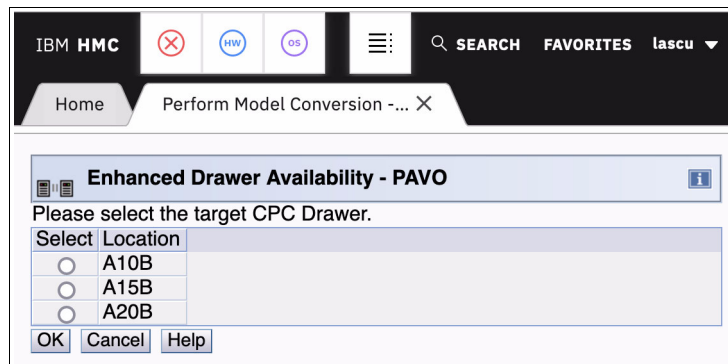


Figure 9-8 Selecting the target drawer

The system verifies the resources that are required for the removal, determines the required actions, and presents the results for review. Depending on the configuration, the task can take from a few seconds to several minutes.

The preparation step determines the readiness of the system for the removal of the targeted drawer. The configured processors and the memory in the selected drawer are evaluated against unused resources that are available across the remaining drawers. The system also analyzes I/O connections that are associated with the removal of the targeted drawer for any single path I/O connectivity.

If insufficient resources are available, the system identifies the conflicts so that you can free other resources.

The following states can result from the preparation step:

- ▶ The system is ready to run the EDA for the targeted drawer with the original configuration.
- ▶ The system is not ready to run the EDA because of conditions that are indicated by the preparation step.
- ▶ The system is ready to run the EDA for the targeted drawer. However, to continue with the process, processors are reassigned from the original configuration.

Review the results of this reassignment relative to your operation and business requirements. The reassignments can be changed on the final window that is presented. However, before making any changes or approving reassignments, ensure that the changes are reviewed and approved by the correct level of support based on your organization's business requirements.

Preparation tabs

The results of the preparation are presented for review in a tabbed format. Each tab indicates conditions that prevent the EDA option from being run. The following tab selections are available:

- ▶ Processors
- ▶ Memory
- ▶ Single I/O
- ▶ Single Domain I/O
- ▶ Single Alternative Path I/O

Only the tabs that feature conditions that prevent the drawer from being removed are displayed. Each tab indicates the specific conditions and possible options to correct them.

For example, the preparation identifies single I/O paths that are associated with the removal of the selected drawer. These paths must be varied offline to perform the drawer removal. After you address the condition, rerun the preparation step to ensure that all the required conditions are met.

Preparing the system to perform enhanced drawer availability

During the preparation, the system determines the PU configuration that is required to remove the drawer. The results and the option to change the assignment on nondedicated processors are shown in Figure 9-9.

The screenshot shows a software window titled 'Processor Assignments - PAVO'. It has a tabbed interface with 'Drawer_A10B' selected. Below the tabs is a table with the following data:

Processor Type	Dedicated Count	Non-Dedicated Count	Processor Totals	LICCC Count
CPU	0	21	21	24
ICF	0	1	1	2
IFL	0	21	21	24
zIIP	0	14	14	16
SAP	14	0	14	16
Available to use		0	0	
Remaining processor drawer Totals	14	58	72	

At the bottom of the window, there are 'Cancel' and 'Help' buttons.

Figure 9-9 Reassign Non-Dedicated Processors results

Important: Consider the results of these changes relative to the operational environment. Understand the potential effect of making such operational changes. Changes to the PU assignment, although technically correct, can result in constraints for critical system images. In specific cases, the solution might be to defer the reassignments to another time that has less effect on the production system images.

After you review the reassignment results and make any necessary adjustments, click **OK** (see Figure 9-10).

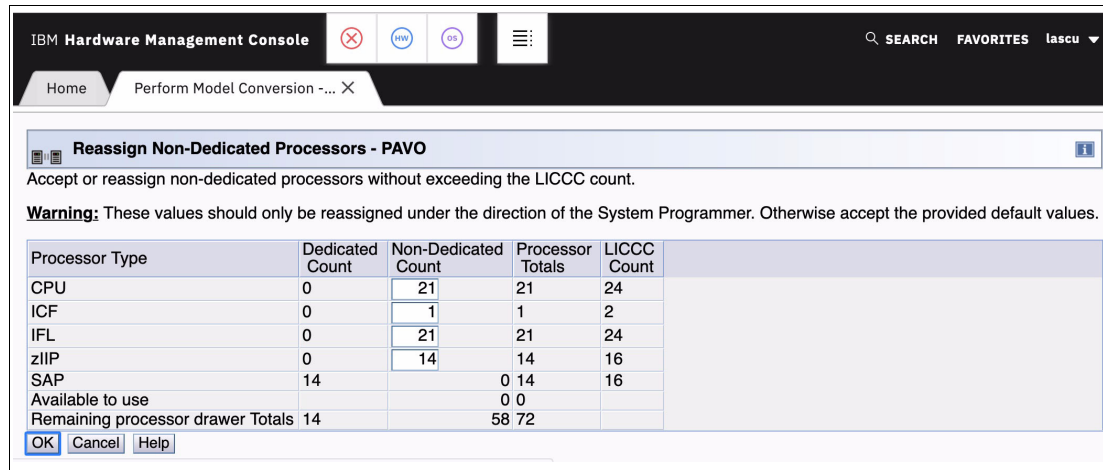


Figure 9-10 Reassign Non-Dedicated Processors, message ACT37294

Summary of the drawer removal process steps

To remove a drawer, the following resources must be moved to the remaining active drawers:

- ▶ PUs: Enough PUs must be available on the remaining active drawers, including all types of PUs that can be characterized (CPs, IFLs, ICFs, zIIPs, SAPs, and IFP).
- ▶ Memory: Enough installed memory must be available on the remaining active drawers.
- ▶ I/O connectivity: Alternative paths to other drawers must be available on the remaining active drawers, or the I/O path must be taken offline.

By understanding the system configuration and the LPAR allocation for memory, PUs, and I/O, you can make the best decision about how to free the necessary resources to allow for drawer removal.

Complete the following steps to concurrently replace a drawer:

1. Run the preparation task to determine the necessary resources.
2. Review the results.
3. Determine the actions to perform to meet the required conditions for EDA.
4. When you are ready to remove the drawer, free the resources that are indicated in the preparation steps.
5. Repeat the step that is shown in Figure 9-7 on page 401 to ensure that the required conditions are all satisfied.

Upon successful completion, the system is ready for the removal of the drawer.

The preparation process can be run multiple times to ensure that all conditions are met. It does not reallocate any resources; instead, it produces only a report. The resources are not reallocated until the Perform Drawer Removal process is started.

Rules during EDA

During EDA, the following rules are enforced:

▶ Processor rules

All processors in any remaining drawers are available to be used during EDA. This requirement includes the two spare PUs or any available PU that is non-LICCC.

The EDA process also allows conversion of one PU type to another PU type. One example is converting a zIIP to a CP during the EDA function. The preparation for the concurrent drawer replacement task indicates whether any SAPs must be moved to the remaining drawers.

▶ Memory rules

All physical memory that is installed in the system, including flexible memory, is available during the EDA function. Any physical installed memory, whether purchased or not, is available to be used by the EDA function.

▶ Single I/O rules

Alternative paths to other drawers must be available, or the I/O path must be taken offline.

Review the results. The result of the preparation task is a list of resources that must be made available before the drawer replacement can occur.

Freeing any resources

At this stage, create a plan to free these resources. The following resources and actions are necessary to free them:

▶ Freeing any PUs:

- Vary off the PUs by using the Perform a Model Conversion window, which reduces the number of PUs in the shared PU pool.
- Deactivate the LPARs.

▶ Freeing memory:

- Deactivate an LPAR.
- Vary offline a portion of the reserved (online) memory. For example, in z/OS, run the following command:

```
CONFIG_STOR(E=1),<OFFLINE/ONLINE>
```

This command enables a storage element to be taken offline. The size of the storage element depends on the RSU value. In z/OS, the following command configures offline smaller amounts of storage than the amount that was set for the storage element:

```
CONFIG_STOR(nnM),<OFFLINE/ONLINE>
```

- A combination of both LPAR deactivation and varying memory offline.

Reserved storage: If you plan to use the EDA function with z/OS LPARs, set up reserved storage and an RSU value. Use the RSU value to specify the number of storage units that are to be kept free of long-term fixed storage allocations. This configuration allows for storage elements to be varied offline.

9.9 Concurrent Driver Maintenance

CDM is one more step toward reducing the necessity for and the duration of a scheduled outage. One of the components to planned outages is LIC Driver updates that are run in support of new features and functions.

When correctly configured, IBM z16 supports concurrently activating a selected new LIC Driver level. Concurrent activation of the selected new LIC Driver level is supported only at specific released sync points. Concurrently activating a selected new LIC Driver level anywhere in the maintenance stream is not possible. Specific LIC updates do not allow a concurrent update or upgrade.

Consider the following key points about CDM:

- ▶ The HMA can query whether a system is ready for a concurrent driver upgrade.
- ▶ Previous firmware updates, which require an initial machine load (IML) of the IBM z16 system to be activated, can block the ability to run a concurrent driver upgrade.
- ▶ A function on the SE allows you or your IBM SSR to define the concurrent driver upgrade sync point to be used for a CDM.
- ▶ The ability to concurrently install and activate a driver can eliminate or reduce a planned outage.
- ▶ IBM z16 introduces Concurrent Driver Upgrade (CDU) cloning support to other CPCs for CDU preinstallation and activation.
- ▶ Concurrent crossover from Driver level N to Driver level $N+1$, then to Driver level $N+2$, must be done serially. No composite moves are allowed.
- ▶ Disruptive upgrades are permitted at any time, and allow for a composite upgrade (Driver N to Driver $N+2$).
- ▶ Concurrently backing up to the previous driver level is not possible. The driver level must move forward to driver level $N+1$ after CDM is started. Unrecoverable errors during an update might require a scheduled outage to recover.

The CDM function does not eliminate the need for planned outages for driver-level upgrades. Upgrades might require a system level or a functional element scheduled outage to activate the new LIC. The following circumstances require a scheduled outage:

- ▶ Specific complex code changes might dictate a disruptive driver upgrade. You are alerted in advance so that you can plan for the following changes:
 - Design data or hardware initialization data fixes
 - CFCC release level change
- ▶ OSA CHPID code changes might require PCHID Vary OFF/ON to activate new code.
- ▶ Crypto code changes might require PCHID Vary OFF/ON to activate new code.

Note: zUDX clients should contact their User Defined Extensions (UDX) provider before installing Microcode Change Levels (MCLs). Any changes to Segments 2 and 3 from a previous MCL level might require a change to the customer's UDX. Attempting to install an incompatible UDX at this level results in a Crypto checkstop.

9.9.1 Resource Group and native PCIe features MCLs

Microcode fixes, referred to as *individual MCLs* or *packaged in bundles*, might be required to update the Resource Group code and the native PCIe features. Although the goal is to minimize changes or make the update process concurrent, the maintenance updates at times can require the Resource Group or the affected native PCIe to be **toggle**d offline and online to implement the updates.

The native PCIe features (managed by Resource Group code) are listed Table 9-1.

Table 9-1 Native PCIe cards for IBM z16

Native PCIe adapter type	Feature code	Resource required to be offline
25 GbE RoCE Express3 SR	0452	FIDs/PCHID
25 GbE RoCE Express3 LR	0453	FIDs/PCHID
25 GbE RoCE Express2.1	0450	FIDs/PCHID
25 GbE RoCE Express2	0430	FIDs/PCHID
10 GbE RoCE Express3 SR	0440	FIDs/PCHID
10 GbE RoCE Express3 LR	0441	FIDs/PCHID
10 GbE RoCE Express2.1	0432	FIDs/PCHID
10 GbE RoCE Express2	0412	FIDs/PCHID
zHyperLink Express1.1	0451	FIDs/PCHID
zHyperLink Express	0431	FIDs/PCHID
Coupling Express2 LR	0434	CHPIDs/PCHID

Consider the following points for managing native PCIe adapters microcode levels:

- ▶ Updates to the Resource Group require all native PCIe adapters that are installed in that RG to be offline.
- ▶ Updates to the native PCIe adapter require the adapter to be offline. If the adapter is not defined, the MCL session automatically installs the maintenance that is related to the adapter.

The PCIe native adapters are configured with Function IDs (FIDs) and might need to be configured offline when changes to code are needed. To help alleviate the number of adapters (and FIDs) that are affected by the Resource Group code update, IBM z16 have four Resource Groups per system (CPC).

Note: Other adapter types, such as FICON Express, OSA Express, and Crypto Express that are installed in the PCIe+ I/O drawer are not affected because they are not managed by the Resource Groups.

The front, rear, and top view of the PCIe+ I/O drawer and the Resource Group assignment by card slot are shown in Figure 9-11. All PCIe+ I/O drawers that are installed in the system feature the same Resource Group assignment.

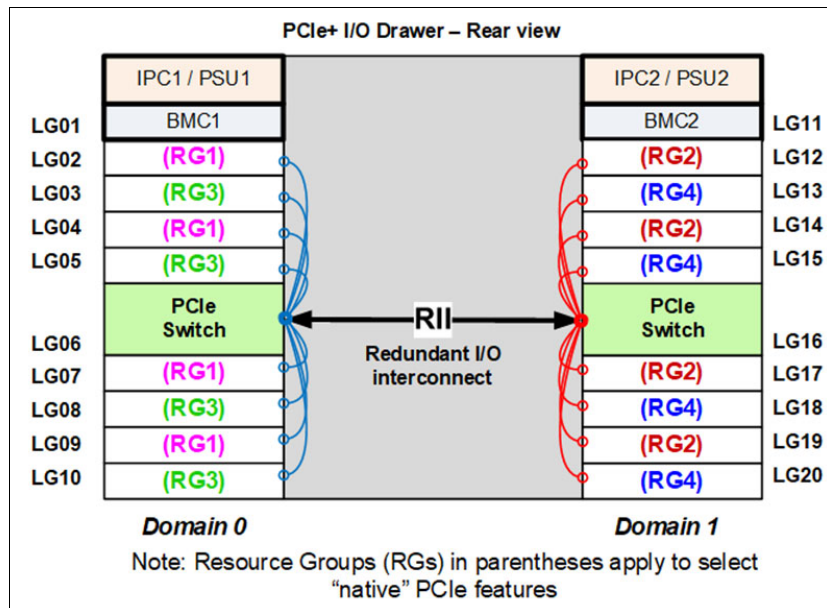


Figure 9-11 Resource Group slot assignment

9.10 RAS capability for the HMA and SE

The HMA and the SE include the following RAS capabilities:

- ▶ Back up from HMA and SE

For the customers who do not have an FTP server that is defined for backups, the HMA can be configured as an FTP server.

On a scheduled basis, the HMA hard disk drive (HDD) is backed up to the USB flash memory drive (UFD), a defined FTP server, or both.

SE HDDs are backed up on to the primary SE HDD and an alternative SE HDD. In addition, you can save the backup to a defined FTP server.

For more information, see 10.2, "HMC and SE changes and new features" on page 413.

- ▶ Remote Support Facility (RSF)

The HMA RSF provides the important communication to a centralized IBM support network for hardware problem reporting and service.

For more information, see 10.4, "Remote Support Facility" on page 434.

- ▶ Microcode Change Level (MCL)

Regular installation of MCLs is key for RAS, optimal performance, and new functions. Generally, plan to install MCLs quarterly at a minimum. Review hiper MCLs continuously. You must decide whether to wait for the next scheduled apply session, or schedule one earlier if your risk assessment of the new hiper MCLs warrants.

For more information, see 10.5.5, "HMC and SE microcode" on page 441.

► SE

IBM z16 servers are provided with two 1U trusted servers inside the IBM Z server A frame: One is always the primary SE and the other is the alternative SE². The primary SE is the active SE. The alternative acts as the backup. Information is mirrored once per day. The SE servers include N+1 redundant power supplies.

For more information, see 10.2.4, “HMC and SE server” on page 424.

² If HMA feature is installed on the system, special upgrade procedure must be followed to ensure nondisruptive SE upgrade.



Hardware Management Console and Support Element

The Hardware Management Console (HMC) supports the functions and tasks that are required to manage the IBM Z. When tasks are performed on the HMC, the commands are sent to the Primary Support Element (SE) of the targeted system, which then issues commands to their respective central processor complex (CPC).

This chapter describes the newest elements for the HMC and SE.

Tip: The Help function is a good starting point to get more information about all of the functions that can be used by the HMC and SE. The Help feature is available by clicking **Help** from the drop-down menu that appears when you click your user ID.

For more information, see the [IBM Resource Link](#), select **Library**, the applicable server and then, select **Hardware Management Console Operations Guide** or **Support Element Operations Guide**.

This chapter includes the following topics:

- ▶ 10.1, “Introduction” on page 412
- ▶ 10.2, “HMC and SE changes and new features” on page 413
- ▶ 10.3, “HMC and SE connectivity” on page 427
- ▶ 10.4, “Remote Support Facility” on page 434
- ▶ 10.5, “HMC and SE capabilities” on page 435

10.1 Introduction

The HMC is a closed system (appliance), which means that no other applications can be installed on it.

The HMC runs a set of management applications. On IBM z16, two HMCs are delivered with the Hardware Management Appliance (HMA) feature FC 0129. The HMC code runs on the two integrated 1U rack-mounted servers on the top of the IBM z16 A frame. Stand-alone outside the IBM z16 HMCs (Tower or Rack Mount) no longer can be ordered.

The following HMC feature codes can be carried forward from previous orders:

- ▶ FC 0062
- ▶ FC 0063
- ▶ FC 0082
- ▶ FC 0083

On the carry forward HMC features, Driver 51/Version 2.16.0 must be installed to support IBM z16. Also, Driver 51/Version 2.16.0 can be installed on the SE/HMC hardware that is provided with the HMA feature FC 0100 on IBM z15.

You can use the IBM z16 with carry forward HMCs and no initial order of FC 0129 (HMA for IBM z16). Order of the HMA FC 0129 is possible later as MES.

With IBM z16, the HMA feature shares the integrated 1U server hardware (installed on top of rack A with) the SE code. The SE code runs virtualized under the HMC on each of the two integrated 1U rack-mounted servers. One SE is the Primary SE (active) and the other is the Alternative SE (backup). As with the HMCs, the SEs are closed systems (appliances), and no other applications can be installed on the same hardware.

The HMC is used to set up, manage, monitor, and operate one or more IBM Z CPCs. It manages IBM Z hardware and its logical partitions (LPARs), and provides support applications. At least one HMC is required to operate an IBM Z. An HMC can manage multiple IBM Z CPCs.

When tasks are performed at the HMC, the commands are routed to the Primary SE of the IBM z16. The SE then issues those commands to their CPC.

Note: The new Driver level for HMC and SE for IBM z16 is Driver 51. Driver 51 is equivalent to Version 2.16.0.

With HMC and SE Driver 41/Version 2.15.0, several “traditional” SE-only functions were moved to HMC tasks. On HMC and SE Driver 41/Version 2.15.0 and Driver 51/Version 2.16.0, these functions appear as native HMC tasks, but run on the SE. These HMC functions run in parallel with Single Object Operations (SOOs), which simplifies and streamlines system management.

For more information about SOOs, see “Single Object Operations” on page 439.

For more information about the HMC, see the [IBM Z Hardware Management Console Videos](#).

Note: HMC 2.16.0 supports managing IBM z14, IBM z15, and IBM z15 IBM Z server generations (N-2),

10.2 HMC and SE changes and new features

The initial release that is included with IBM z16 is HMC and SE Driver 51/Version 2.16.0. Check the “What’s new” widget (which is available in the HMC interface) to examine the new features that are available.

For more information about HMC and SE functions, use the HMC and SE console help system or see [IBM Resource Link](#) (login required), select **Library**, the applicable server and then, select **Hardware Management Console Operations Guide** or **Support Element Operations Guide**.

10.2.1 Driver 51/Version 2.16.0 HMC and SE new features

The following support was added with Driver 51/Version 2.16.0:

► Enhanced Multi-Factor Authentication (MFA) functions

With Driver 41/Version 2.15.0, MFA by way of Time-based One-time Password (TOTP) or IBM Z MFA (z/OS) and RSA Secure ID is supported on the HMC.

New with Driver 51/Version 2.16.0, the following MFA possibilities are supported:

- Certificates:
 - Personal Identity Verification (PIV)
 - Common Access Card (CAC)
 - Certificates on USB keys
- Generic remote authentication dial-in user service (RADIUS) supports all various RADIUS factor types and requires a customer-provided RADIUS server.

New is the support of IBM Z MFA for Red Hat Enterprise Linux Server or SUSE Linux Enterprise Server that is running on z/VM or native in an LPAR.

For more information see the following resources:

- This [IBM Documentation web page](#)
- 10.3.8, “HMC multi-factor authentication” on page 433.

► Log in changes to support PCI-DSS

To support Payment Card Industry-Data Security Standard (PCI-DSS), a single GUI login window now is used for user ID, password, and the authentication code if MFA is used. Previously, the entry for the authentication code was on a separate window.

For greater security, the details about the login failure can be reviewed only in the Audit and Security Log (which needs specific access level). For the GUI and Web Services APIs, the HMC returns a message that indicates that the login failed. No other information is provided.

► HMC/SE TLS 1.3 support

The HMC and SE support TLS 1.3. Before setting the TLS level to 1.3, you must ensure that all services and servers that are connecting by way of TLS to the HMC and SE support TLS 1.3 as well (for example, the remote browser, LDAP Authentication Servers, Web Services API connections, Fibre Channel End Point Security, and FTPS, Single Object Operations).

TLS 1.0 and 1.1 are not supported by Driver 51/Version 2.16.0.

If minimum TLS version is set to 1.2, TLS 1.3 is attempted first and then, falls back to TLS 1.2 if required.

Figure 10-1 shows the HMC window that allows the selection of the wanted TLS version.

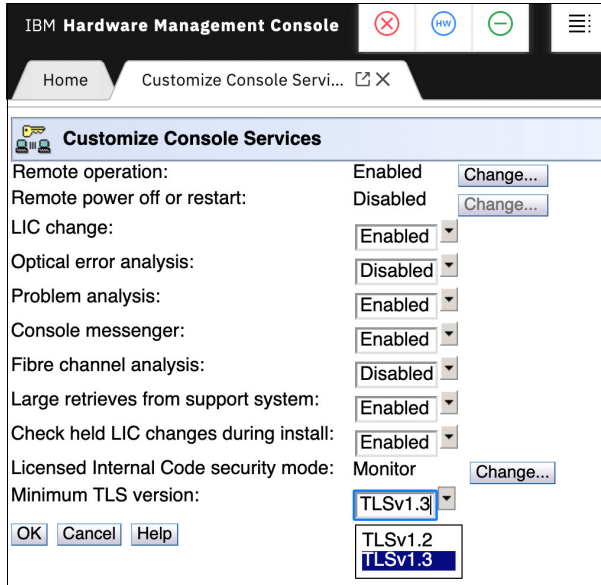


Figure 10-1 Minimum TLS version selection on HMC

► HMC/SE certification expiration updates

The new default for HMC and SE certificate expiration is 398 days and it can be modified. This expiration period is driven by an industry shorter certificate lifespan that is used by the Apple Safari browser and iOS.

A hardware message is posted for every expiration event 90, 30, and 7 days and 1 day before the expiry date is reached. If the expiration occurs, a hardware message is posted daily.

A Call Home to IBM also is placed 7 days and 1 day before the certificate expiration and daily afterward. These events also are recorded in the Audit Log and Resource Link.

It is the customer's responsibility to manage all certificates.

Figure 10-2 shows an example to change the number of days until the expiration occurs while a certificate is created.

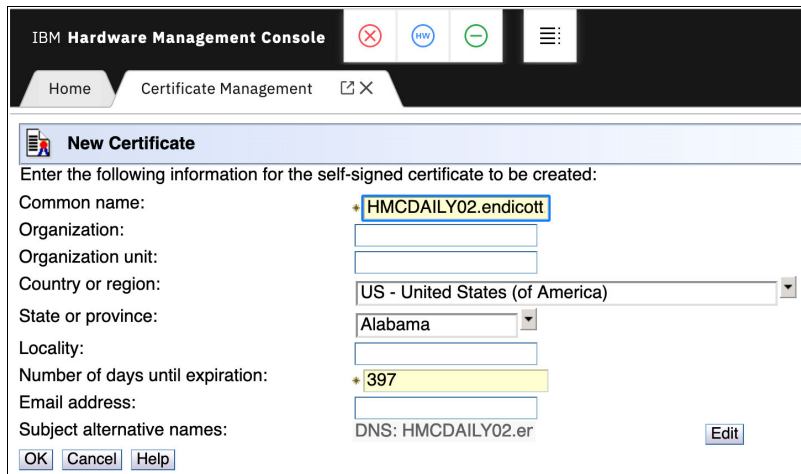


Figure 10-2 Certificate Management on the HMC

To change the expiration days for a certificate, click **Certificate Management** → and select **Valid Until** → **Selected** → **Modify**.

► **Task Display Alter**

The tasks Display or Alter on the SE are possible for an ACSADMIN role only. The roles for SYSPROG and SERVICE no longer include this task by default.

► **View only HMC tasks**

The following tasks can be assigned as View only for a specific role with Driver 51/Version 2.16.0:

- Hardware Messages
- Operating System Messages
- Manage Coupling Facility Port Enablement
- OSA Advanced Facilities
- Cryptographic Configuration
- Cryptographic Management
- Change LPAR Controls
- Change LPAR Group Controls
- Configure Channel Path On/Off
- Advanced Facilities
- Configure On/Off
- Manage System Time
- View Activation Profiles

Figure 10-3 shows how you can change the permission from Edit to View only for a task in User Management.

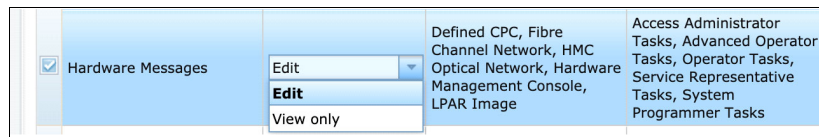


Figure 10-3 Selection of View only for a task

► **New HMC Dashboard**

A new dashboard is available in the Home tab. It is the first page that appears when you log in to the HMC. It replaces the Welcome window that was used in previous HMC drivers and versions. Initially, the following widgets are available:

- What's new: Displays information about the latest console feature
- Systems health: Summarizes that status of systems that are managed by the HMC
- Hardware messages: Manages hardware messages for all managed systems
- Frequently used tasks: Displays your most frequently used tasks

Under the Helpful links section, links to Resource Link, videos, and so on, are available. Under the About this HMC section, more information is available, such as the installed bundle level.

An example of the new Dashboard is shown in Figure 10-4.

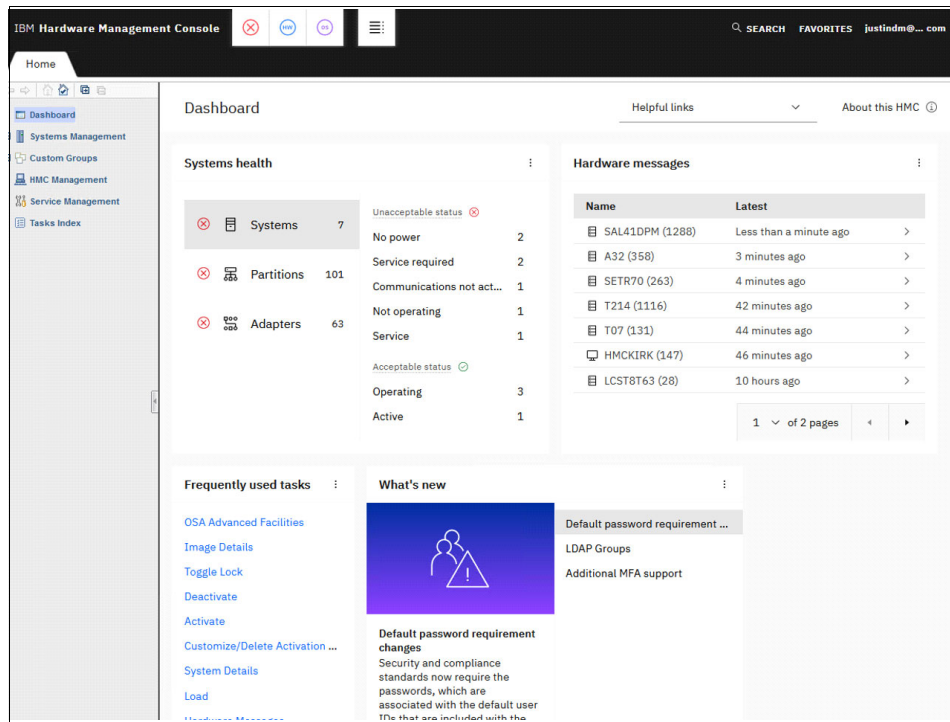


Figure 10-4 The new Dashboard on the HMC

► N-mode Power STP Imminent disruption Signal option

With IBM z16, a new recovery signal was implemented (N-mode power) for STP recovery. A CTN with IBM z16 for the Primary Time Server and the Backup Time server can be enabled (configured) to recover from a PTS or CTS failure by using the N-mode power (imminent power failure on the CTS [IBM z16 hardware] that is configured with dual utility power).

For more information, see the *IBM Z Server Time Protocol Guide*, [SG24-8480](#).

► BCPii enhancements for SE restarts

With IBM z16, the SE and the BCPii for GDPS and System Automation (SA) features an improved communication to not disturb important tasks on each side. For example, if you want to restart an SE and GDPS or SA is performing an important task, the restart window prompts you to confirm that you want to force the restart, as shown in Figure 10-5 on page 417.

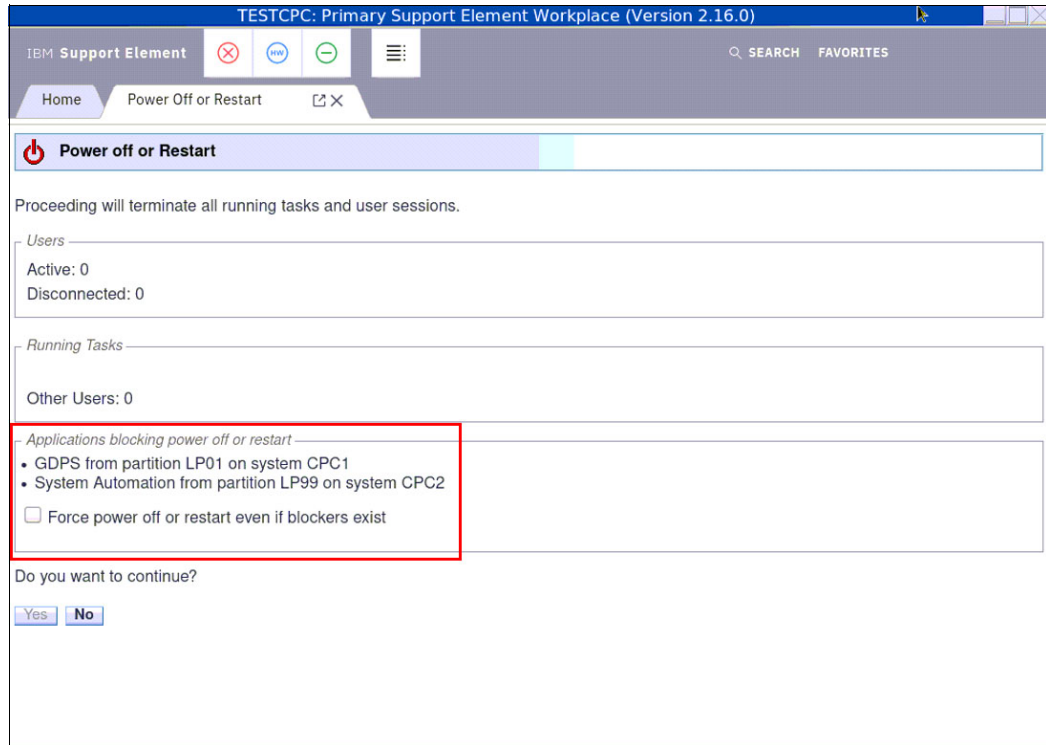


Figure 10-5 New information/question for SE power off or restart regarding GDPS or SA

► **Manage System Time Enhancements**

Starting with IBM z14, a major change was made to how STP management is handled on the HMC and SE. All STP management is now done by way of the Manage System Time option on the HMC.

With IBM z16, further improvements were made in the wizards to guide you through the different configuration possibilities. Most of the changes are visual to provide clearer guidance.

► **System Availability Data changes**

Transmit System Availability Data (TSAD) contains important data for the client and IBM. For example, this task sends data to IBM Resource Link to have MCL and configuration information available. Also, Capacity on Demand (CoD) information is exchanged. IBM proactively monitors Reliability, Availability, and Serviceability (RAS) data for potential actions or improvements for the system.

Users sometimes wanted to modify the execution time of this TSAD and accidentally deleted this TSAD Scheduled Operation.

With previous IBM Z generations, TSAD was scheduled in the Customize Scheduled Operation task for the HMC and the SE/CPC.

With IBM z16, this TSAD function moved to the Customize Console Services task, as shown in Figure 10-6.

The screenshot shows a dialog box titled "Customize Console Services". It contains several settings, each with a "Change..." button. The settings are: Remote operation: Enabled; Remote power off or restart: Restart console; LIC change: Enabled; Optical error analysis: Disabled; Problem analysis: Enabled; Console messenger: Enabled; Fibre channel analysis: Disabled; Large retrieves from support system: Enabled; Check held LIC changes during install: Enabled; Licensed Internal Code security mode: Monitor; Minimum TLS version: TLSv1.2; and Transmit system availability data: Enabled. The "Transmit system availability data" row is highlighted with a red border. At the bottom are "OK", "Cancel", and "Help" buttons.

Figure 10-6 New option in Customize Console Services

A weekly schedule for health and diagnostic data (which is also sent to IBM Resource Link) is available in a new window (see Figure 10-7). The active health checking feeds data daily to IBM for an automatic analysis of your IBM Z for potential problems.

The screenshot shows a window titled "Manage system availability collection". It has a sub-header "Manage system availability collection" and a description "Enable sending system availability data to support teams for analysis." Below this is a checkbox "Enable system availability analysis" which is checked. There are two main sections: "Health and diagnostic data" and "Active health checking". The "Health and diagnostic data" section has a description "Choose the date and time each week to send health and diagnostic data. Send now to immediately send data for analysis when requested by support." and a "Set weekly schedule" section with dropdowns for "Monday", "01:30", "AM", and "GMT-1". Below this is a "Send data now" button. The "Active health checking" section has a description "Choose the time each day to send active health checking data. Send now to immediately send data for analysis when requested by support." and a "Set daily schedule" section with dropdowns for "15:30", "AM", and "GMT-1". Below this is a "Send data now" button. On the right side, there are two "GUIDANCE" sections. The first one says "This data is collected weekly which you can examine within Resource Link." The second one says "This data is collected daily and automatically analyzed for potential problems."

Figure 10-7 Window for Manage system availability collections

We highly recommend enabling the System availability collection on your IBM Z to get the full RAS support.

► HMC Monitor Systems Events email Domain Setting enhancement

Thus far, the email for HMC System Events was sent from `CONSOLENAME_EventMonitor@CONSOLENAME.DOMAINNAME`. With IBM z16, you can change the sender name (see Figure 10-8).

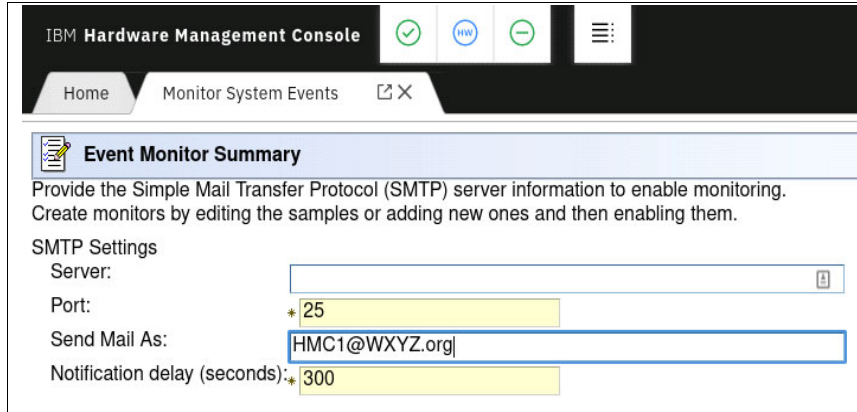


Figure 10-8 New sender option for HMC Event email notifications

► HMC Data Replication enhancements

By using the Configure Data Replication task, configuration data can be exchanged between linked HMCs; for example, the User Profile Data can be replicated.

An HMC can feature the following replication roles:

– Primary

An HMC in the role of primary is a Data Replication source to other HMCs that are in the role of replica. A primary HMC can be only a source for Data Replication; it cannot receive replicated data from other HMCs.

– Peer

An HMC in the role of peer is Data Replication source to other HMCs that are in the role of peer or replica. An HMC in this role receives replicated data from other HMCs that are in the role of peer or primary.

– Replica

An HMC in the role of replica receives replicated data from other HMCs that are in the role of primary or peer. Modifications to replicated data types on a replica HMC are disallowed.

Further, an HMC also can be disabled for Data Replication. An example of selection of the roles is shown in Figure 10-9 on page 420.

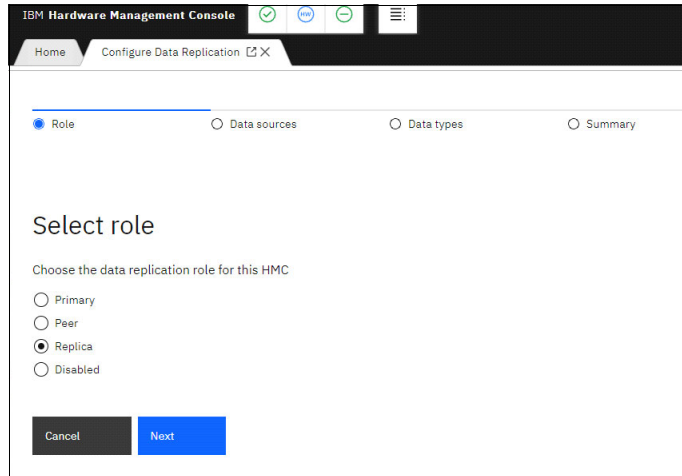


Figure 10-9 Selection of different roles for Data Replication on the HMC

The notification about whether you are on an HMC with the Replica role and open a window where Data Replication is involved were improved. An example of an HMC with the Replica role is shown in Figure 10-10.

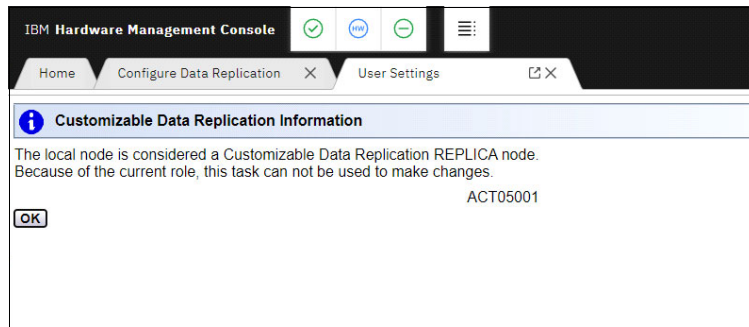


Figure 10-10 Notification for a task with relation to Data Replication on an HMC with Replica role

Also, the wizard that is used to manage the settings for Data Replication were improved.

► Remote Code Load

The Remote Code Load (RCL) for IBM Z allows IBM to upgrade a machine remotely by working with the customer to schedule a date and time for the code load and monitor the process to ensure that it completes successfully.

This feature allows you to schedule one or multiple Single Step Code Loads for an HMC or SE.

On an IBM z16 system with the HMA feature, RCL can be scheduled to update both HMCs. The firmware automatically manages Alternative SE switches to ensure that each HMC can be updated without the Primary SE being present.

In general, you first must generate a token on the HMC task Manage Remote Firmware Updates. Then, you can schedule an RCL on IBM Resource Link by selecting **Fixes** → **Licensed internal code** → **Remote Code Load request**.

Note: For IBM Z, IBM Support personnel do not connect to your IBM Z from outside the data center location to perform the RCL. Instead, the RCL is managed on your HMC.

For more information about RCL, see this IBM Resource Link [web page](#) (log in required).

► BCPii Query of Crypto information

Before IBM z16, automation support for querying Crypto information was provided with SNMP API interfaces only. With IBM z16, support is added for BPCII v2/HWIREST APIs.

► Crypto and OSA automatic toggling

In rare cases after a microcode update, the Crypto and OSA adapters must be configured off/on to activate the loaded firmware. With IBM z16, a new function is available with which you can select one or more Crypto and OSA adapters and perform an automated serialized update of each card.

Important: Configuring the off/on operation is concurrent to the operating system activities only if the Crypto and OSA adapters are configured redundantly. The automated process does not perform the redundancy check for you. If you are unsure about adapter redundancy, we recommend toggling each adapter manually off/on.

The Figure 10-11 and Figure 10-12 on page 422 show examples of the automatic firmware activation for Crypto and OSA adapters.

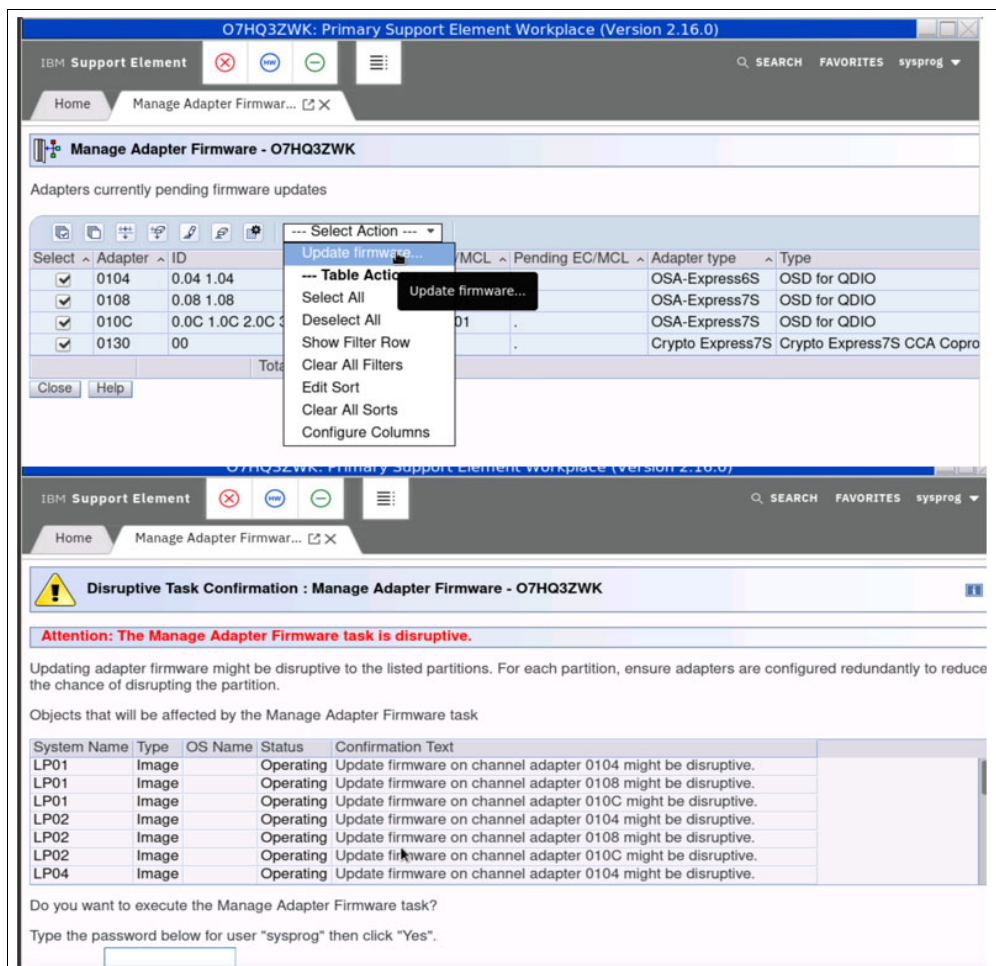


Figure 10-11 Crypto and OSA adapters selected for Update Firmware

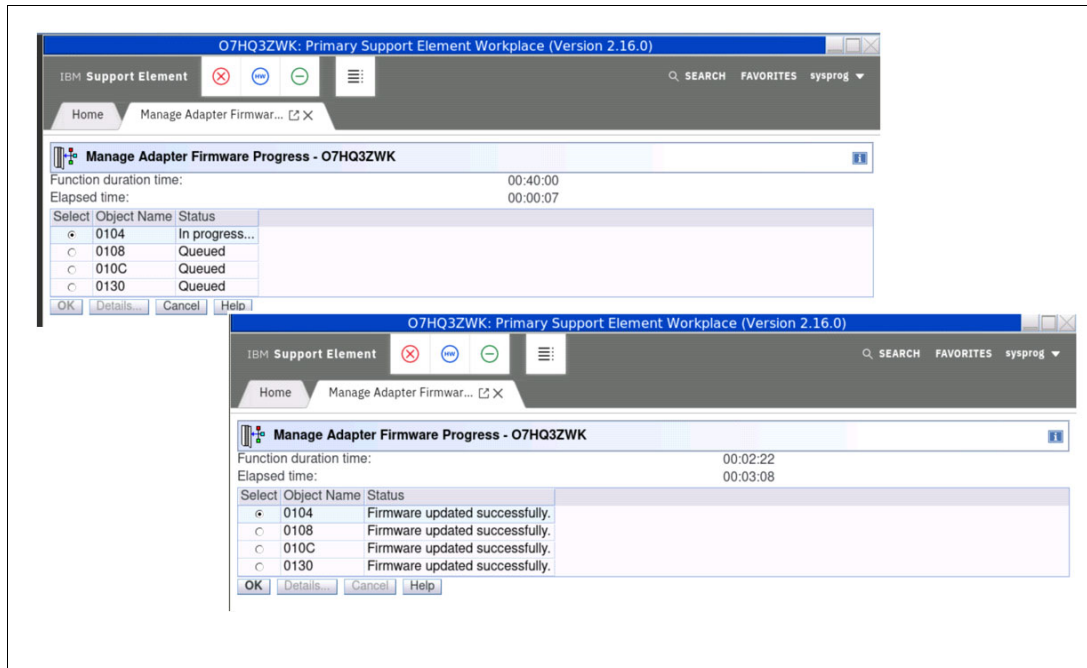


Figure 10-12 Crypto and OSA adapters concurrent firmware update results

► Default HMC and SE users security changes

With IBM z16, default users ADVANCED, OPERATOR, STORAGEADMIN, and SYSPROG no longer are preinstalled on the new shipped HMCs and SEs.

Default user roles for ADVANCED, OPERATOR, STORAGEADMIN, and SYSPROG are shipped and the corresponding user IDs can be created from those roles.

Any default user ID that was part of a previous HMC can be carried forward to the new HMCs as part of a MES upgrade or by using the tasks User Profile Data for the Save/Restore Customizable Console Data or Configure Data Replication.

At first log-on, the default password for the ACSADMIN and SERVICE user must be changed.

Note: Consider the following points:

- It is the customer's responsibility to maintain the passwords and user IDs.
- For the SERVICE user, the client must provide the password at any time to the IBM System Service Representative. The customer must have an established process to avoid service delays if they do not have the password available for the IBM technician.

► Report a Problem update

If your IBM Z encounters a hardware or microcode problem and no automatic call went out to IBM, you can open a case with the task Report a Problem (RaP). Before IBM z16, you this task was done by using the HMC (clicking **Service Management** → **Report a Problem**) or a CPC (clicking **Service** → **Report a Problem**).

Now, an LPAR can be selected for a RaP.

For better clarification, the RaP for the HMC calls now Report a Console Problem.

- ▶ CoD automation scripts

Statement of Direction: IBM z16 is planned to be the last server to support established CoD unique record type automation interfaces. For example, the older command **HWMCA_ACTIVATE_CBU_COMMAND** must change to **HWMCA_ADD_CAPACITY_COMMAND**.

We suggest you start now to change your automation scripts. For more information, see *Capacity on-Demand User's Guide*, SC28-7025.

10.2.2 Hardware Management Appliance

Starting with IBM z15, the two 1U rack-mounted servers on the top of the A frame provide increased hardware capacity, which allows instances of HMC and SE to run collocated on the same physical server. The SE code runs as a virtual guest of the HMC code.

The SE interface can be accessed from the HMC by using the Single Object Operation on the HMC.

The HMA feature FC 0129 consists of the HMC code that is installed on the two 1U rack-mounted servers on the top of the A frame, which are collocated with the SE code. The servers are configured with processor, memory, storage, and networking resources to support all processing and security requirements for running HMC and SE code.

The two HMCs (HMC1 and HMC2) from manufacturing (these names can be changed) are configured as independent HMCs. They are *not* Primary or Alternative HMCs. HMC Data Replication can be established, if wanted.

The SE code is running as a guest of the HMC. The two SE code instances are clustered for high availability. One SE code runs the Primary SE the other Alternative SE. These SEs perform data mirroring and their role can be switched for maintenance purposes.

Switching the Primary and Alternative SE roles is important because HMC microcode maintenance can be performed only on the server that runs the Alternative SE as a guest.

If the HMC, which receives microcode updates, runs the Primary SE guest, SE switchover must be performed. Figure 10-13 shows the HMA relation to the HMCs and SEs.

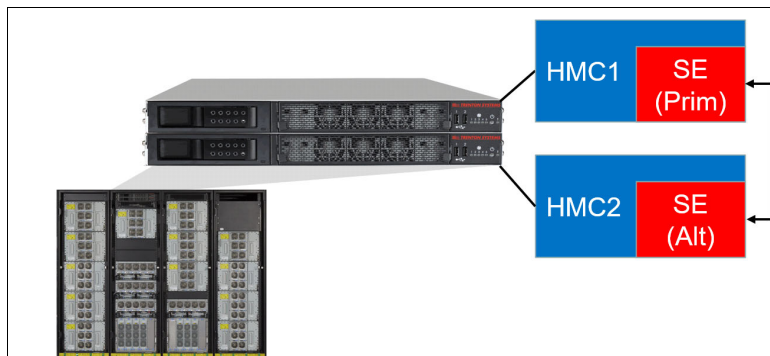


Figure 10-13 HMA: HMCs and SEs

10.2.3 Rack Mount HMC and Tower HMC (carry forward only to IBM z16)

For IBM z16, stand-alone HMCs (Tower or Rack Mount) can no longer be ordered.

The following HMC feature codes can be carried forward from previous orders:

- ▶ FC 0062
- ▶ FC 0063
- ▶ FC 0082
- ▶ FC 0083

With these HMC feature codes, Driver 51/Version 2.16.0 can be installed to support IBM z16. Also, Driver 51/Version 2.16.0 can be installed on the two HMCs that are provided with the HMA feature FC 0100 on IBM z15.

You also can use the IBM z16 with previous ordered HMCs and no HMA. It is possible to order the HMA FC 0129 later as an MES feature. It then provides new microcode, and no new hardware.

The HMCs can be accessed by using a remote web browser and can manage N-2 generations systems (IBM z16 A01, IBM z15 T02, IBM z15 T01, IBM z14 ZR1, and IBM z14 M0x).

Important: With the IBM HMA, shutdown or restart of the HMC that includes the Primary SE code as guest also restarts the Primary SE code. Only an application restart of the HMC is not disruptive to the guest SE code.

10.2.4 HMC and SE server

The two 1U rack-mounted hardware servers that are installed at the top of the IBM z16 A frame (as shown in Figure 10-14) are used for HMC (optional feature) and SE functions.



Figure 10-14 HMC and SE server location (front view)

HMC and Support Element Keyboard Mouse Monitor

With IBM z16, a Keyboard Mouse Monitor (KMM) device that is in the front of rack A under the 1U servers replaces the previous KMM assembly that was mounted on a swing gate in IBM z14.

The KMM device is shown in Figure 10-15.

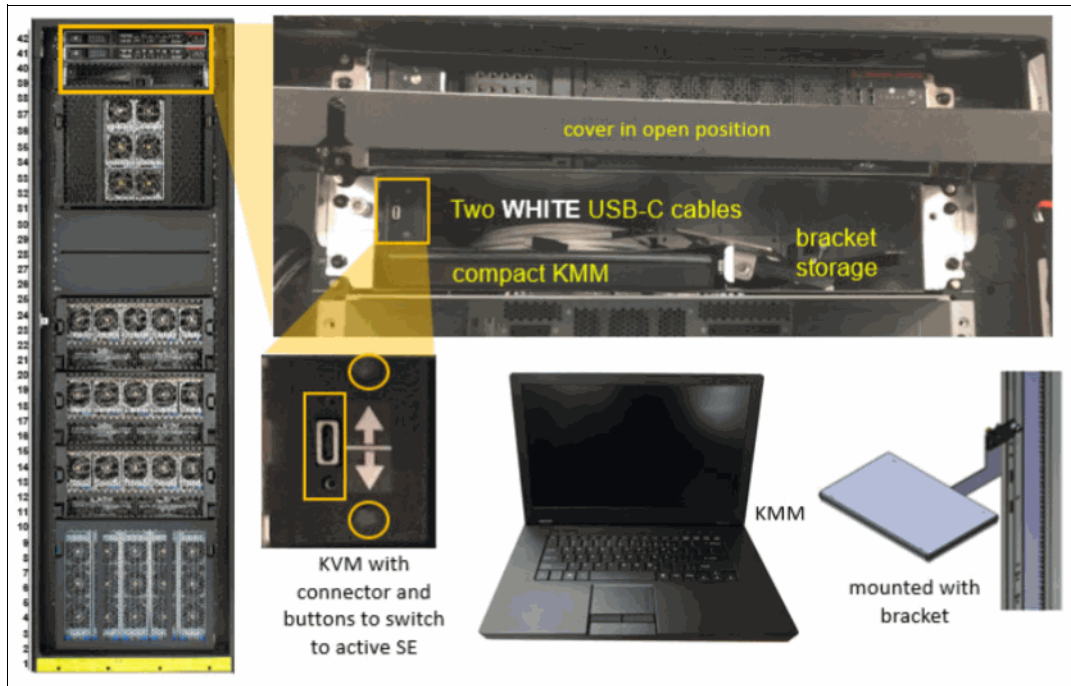


Figure 10-15 HMC / SE KMM device inside A frame

Consider the following points:

- ▶ The device is intended to be used by the IBM System Service Representative only. If remote access to the HMC and SE is not possible, the customer can use the KMM as an emergency option. It can be local or onsite and managed by the Virtual Support Element Management task, as shown in Figure 10-16.

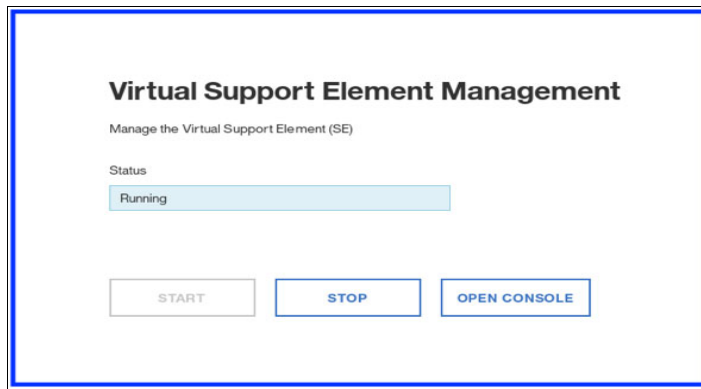


Figure 10-16 Local Virtual Support Element Management

- ▶ One KMM is provided.
- ▶ The KMM is stored at the front of the A frame, below the two 1U servers. A USB-C cable and mounting bracket are stored with the KMM.
- ▶ The USB cable can be used to plug the device into a KVM switch at the front or the rear of the rack when servicing the system.
- ▶ Switching between servers is done by using a button that is on the KMM. The KMM screen also indicates which server is selected.

- ▶ The KMM mounting bracket can be used to mount the device to any frame in the system (front or rear).
- ▶ The KMM can be used on any IBM z16 system (no affinity to the system with which it is shipped exists).

For more information about the mini-KMM and how to attach it to the A frame, see *3931 Installation Manual, GC28-7017*.

10.2.5 USB support for HMC and SE

Because a DVD drive is not available on the HMC or SE, this section describes two methods for service and functional operations for HMC Driver 51/Version 2.16.0.

Microcode load

Microcode can be loaded by using the following options:

- ▶ USB

If the HMC and SE code is included with a USB drive when a new system is ordered, the load procedure is similar that which was used with a DVD.

- ▶ Electronic

If USB load is not allowed, or if FC 0846 (No physical media options is ordered, an ISO image is used for a firmware load over a local area network (LAN). The ISO image can be downloaded through zRSF or an FTP (/FTPS/SFTP) server that is accessible by the LAN.

Important: The ISO image server *must* be in the same IP subnet with the target system to load the HMC or SE ISO.

Operating system load from removable media or server

z/OS, z/VM, z/VSE, and Linux on IBM Z are available by using a USB or network distribution. z/TPF does not use the HMC for code load.

10.2.6 SE driver and version support with the HMC Driver 51/Version 2.16.0

The driver of the HMC and SE is equivalent to a specific HMC and SE version:

- ▶ Driver 36 is equivalent to Version 2.14.1
- ▶ Driver 41 is equivalent to Version 2.15.0
- ▶ Driver 51 is equivalent to version 2.16.0

An HMC with Driver 51/Version 2.16.0 supports N-2 IBM Z server generations. Some functions that are available on Driver 51/Version 2.16.0 and later are supported only when the HMC is connected to an IBM Z with Driver 51/Version 2.16.0.

The SE drivers and versions that are supported by the HMC Driver 51/Version 2.16.0 are listed in Table 10-1.

Table 10-1 SE that is supported by HMC Driver 51/Version 2.16.0

IBM Z product name	Machine type	SE driver	SE version
IBM z16 A01	3931	51	2.16.0
IBM z15 T02	8562	41	2.15.0

IBM Z product name	Machine type	SE driver	SE version
IBM z15 T01	8561	41	2.15.0
IBM z14 ZR1	3907	36	2.14.1
IBM z14 M0x	3906	36	2.14.1

10.2.7 HMC feature codes

On IBM z16, two HMCs are delivered with the HMA FC 0129. The HMC code runs on the two integrated 1U rack-mounted servers on the top of the IBM z16 A frame. Stand-alone, outside the IBM z16 HMCs (Tower or Rack Mount) can no longer be ordered.

The following HMC feature codes can be carried forward from previous systems:

- ▶ Tower FC 0082
- ▶ Tower FC 0062
- ▶ 1U Rack Mount FC 0083
- ▶ 1U Rack Mount FC 0063

With these HMC feature codes, Driver 51/Version 2.16.0 can be installed to support IBM z16. On the HMCs of the HMA for IBM z15, FC 0100, Driver 51/Version 2.16.0 also can be installed.

10.3 HMC and SE connectivity

Security: The configuration of network components, such as routers or firewalls, is beyond the scope of this document. Whenever the networks are interconnected, security exposures can exist. For more information about HMC security, see *Hardware Management Console Security, SC28-7027*, and *Integrating the Hardware Management Console's Broadband Remote Support Facility into your Enterprise, SC28-7026*.

For more information about the HMC settings that are related to access and security, see [IBM Resource Link](#). At the web page, select **Library**, the applicable server and then, select **Hardware Management Console Operations Guide** or **Support Element Operations Guide**.

10.3.1 Hardware Management Appliance connectivity

On IBM z16, two HMCs are delivered with the HMA FC 0129. The HMC code runs on the two integrated 1U rack-mounted servers on the top of the A frame. Stand-alone HMCs (Tower or Rack Mount) can no longer be ordered.

With IBM z16 and HMA, the SE code runs virtualized on the two integrated HMCs on the two integrated 1U rack-mounted servers on the top of the IBM z16 A frame. One SE is the Primary SE (active) and the other is the Alternative SE (backup).

With the HMA, each HMC and each SE has its own two physical Ethernet RJ45 ports, as shown in Figure 10-17. The red lines highlight the Ethernet connectivity for the SEs; the green lines highlight the HMCs.

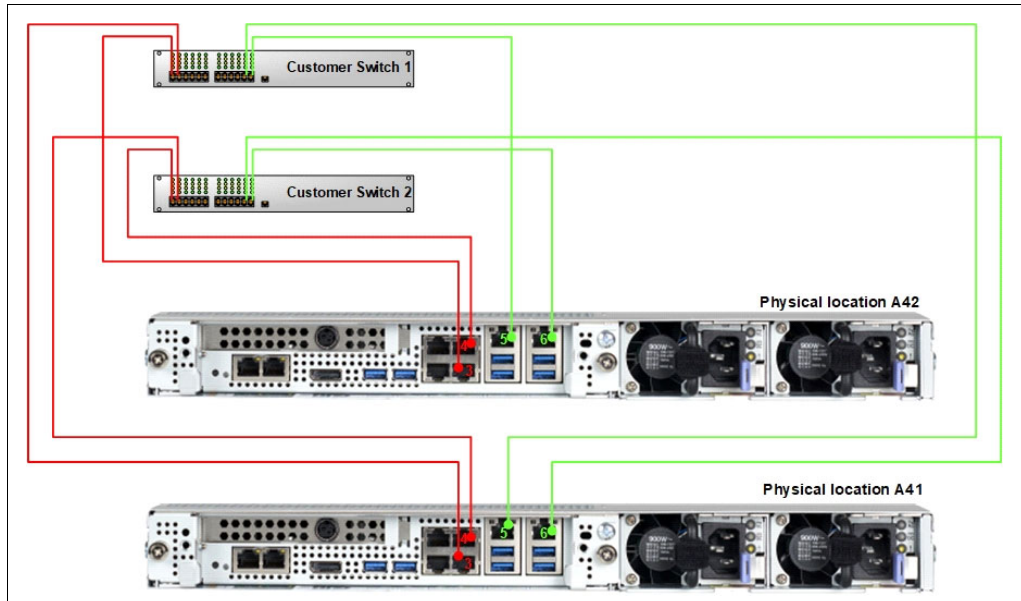


Figure 10-17 HMA connectivity

10.3.2 Stand-alone HMC connectivity

The following HMC feature codes can be carried forward from previous orders:

- ▶ FC 0062
- ▶ FC 0063
- ▶ FC 0082
- ▶ FC 0083

With these HMC feature codes, Driver 51/Version 2.16.0 can be installed to support IBM z16.

You can use the IBM z16 with previously ordered HMCs and no HMA. It is possible to order the HMA FC 0129 later as MES.

The HMC communicates with the SE is through a customer-supplied Ethernet switch (two switches are recommended for redundancy).

Each SE and each HMC has two Ethernet RJ45 ports. An example of these connections are made without an HMA is shown in Figure 10-18.

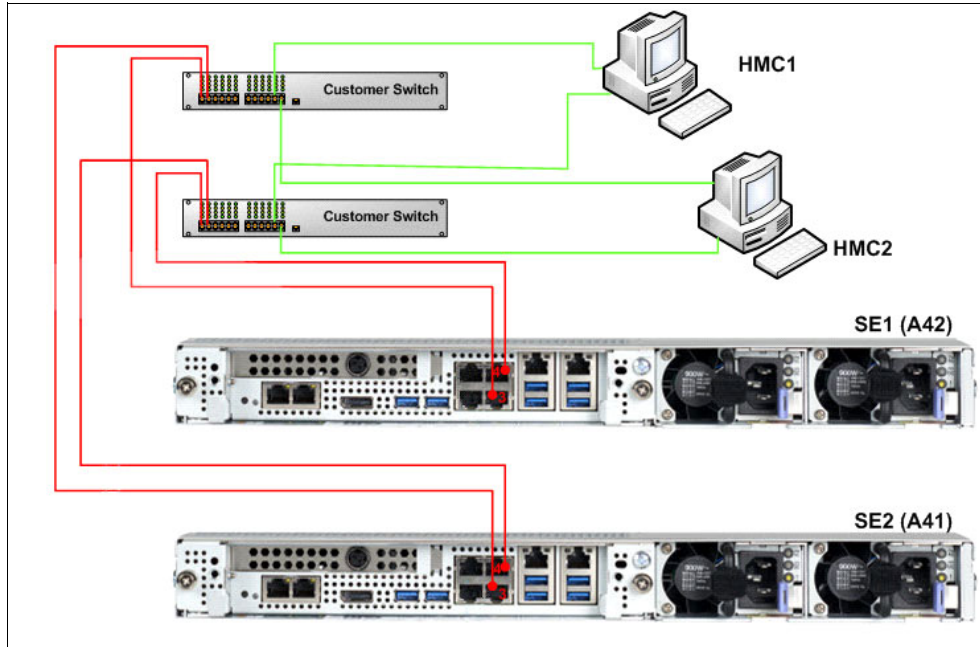


Figure 10-18 HMC / SE connectivity without HMA

Note: The HMC *must* be connected to the SEs by using a customer-provided switch. Direct connection between the HMC and the SEs is *not* supported.

The connectivity for multiple CPC generations and mixing stand-alone HMCs and HMAs environments (IBM z16 N-2 only) is shown in Figure 10-19.

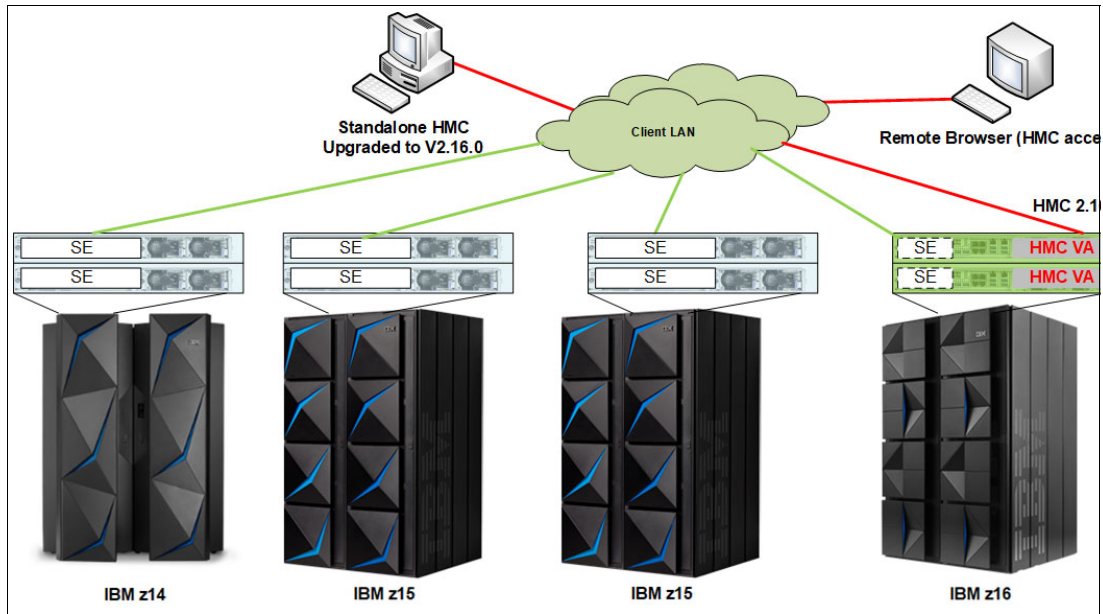


Figure 10-19 IBM z16 HMC/SE connectivity with multiple CPCs

Various methods are available for setting up the network. Designing and planning the HMC and SE connectivity is the customers' responsibility, based on the environment's connectivity and security requirements.

10.3.3 Network planning for the HMC and SE

Plan the HMC and SE network connectivity carefully to allow for current and future use. Many of the IBM Z capabilities benefit from the various network connectivity options.

The following functions are examples that depend on the HMC connectivity:

- ▶ Lightweight Directory Access Protocol (LDAP) support, which can be used for HMC user authentication
- ▶ Network Time Protocol (NTP)
- ▶ RSF through broadband
- ▶ HMC remote access and HMC Mobile
- ▶ RSA SecurID support
- ▶ MFA with Time-based One Time Password (TOTP)

HMC File Transfer support

FTP, FTPS, and SFTP protocols are supported on the HMC and SE. All three file transfer protocols require login ID and password credentials.

FTPS is based on Secure Sockets Layer (SSL) cryptographic protocol and requires certificates to authenticate the servers. SFTP is based on Secure Shell protocol (SSH) and requires SSH keys to authenticate the servers. Certificates and key pairs are hosted on the IBM z16 HMC.

The following FTP server requirements must be met:

- ▶ Passive data connections are supported
- ▶ A server configuration is available that allows the client to connect on an ephemeral port

The following FTPS server requirements must be met:

- ▶ Operates in “explicit” mode
- ▶ Allows a server to offer secure and unsecured connections
- ▶ Supports passive data connections
- ▶ Supports secure data connections

The SFTP server must support password-based authentication.

The file transfer server choices for HMC are shown in Figure 10-20.

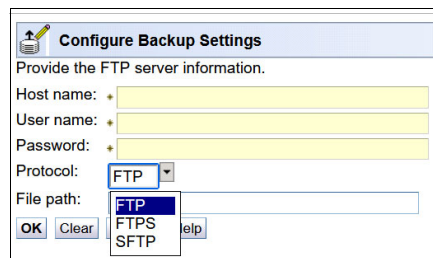


Figure 10-20 FTP protocol choices

FTP through HMC

It is recommended to keep the HMCs and SEs on an isolated network. This approach prevents SEs from starting FTP connections with outside networks. It also applies to all supported file transfer protocols (FTP, FTPS, and SFTP).

All FTP connections that originate from the SE are taken to the HMC. Secure FTP server credentials must be imported to one or more managing HMC consoles.

After the HMC console completes all FTP operations, the HMC console performs the FTP operation on the SE's behalf and returns the results. The IBM Z platform must be managed by at least one HMC to allow FTP operations.

Secure console-to-console communications

The IBM z16 HMC features an industry standard-based, password-driven cryptography system. The Domain Security Settings are used to provide authentication and high-quality encryption. We recommend that clients use unique Domain Security settings to provide maximum security. These settings provide greater security than anonymous cipher suites, even if the default settings are used.

To allow greater flexibility in password selection, the password limit was increased to 64 characters and special characters are allowed for IBM z16.

For more information about HMC networks, see the following resources:

- ▶ The HMC and SE Driver 51/Version 2.16.0 console help system
- ▶ [IBM Resource Link](#). At this web page, select **Library**, the applicable server and then, select **Hardware Management Console Operations Guide** or **Support Element Operations Guide**.
- ▶ *IBM Z 3931 Installation Manual for Physical Planning*, GC28-7015.

10.3.4 Hardware considerations

The following hardware considerations are important for IBM z16:

- ▶ IBM does not provide Ethernet cables with the system
- ▶ IBM does not provide Ethernet switches with the system for HMC and SE communication

Ethernet switches

Ethernet switches for HMC and SE connectivity are provided by the customer. Existing supported switches can still be used.

Ethernet switches and hubs often include the following characteristics:

- ▶ A total of 16 auto-negotiation ports
- ▶ 100/1000 Mbps data rate
- ▶ Full or half duplex operation
- ▶ Auto medium-dependent interface crossover (MDIX) on all ports
- ▶ Port status LEDs
- ▶ Copper RJ45 connections

Note: It is recommendation an Ethernet switch with 1000 Mbps/Full duplex support is used.

10.3.5 TCP/IP Version 6 on the HMC and SE

The HMC and SE can communicate by using IPv4, IPv6, or both.

IPv6 link-local addresses feature the following characteristics:

- ▶ Every IPv6 network interface is assigned a link-local IP address.

- ▶ A link-local address is used on a single link (subnet) only and is never routed.
- ▶ Two IPv6-capable hosts on a subnet can communicate by using link-local addresses, without having any other IP addresses assigned. If HMC-to-SE IPv6 link-local is working, the SE/CPC appears in **System Management** → **Unmanaged Systems** on the HMC.

10.3.6 Assigning TCP/IP addresses to the HMC, SE and ETS

Use the worksheet in the Installation Manuals, GC28-7041 (A02), GC28-7036 (AGZ) under “*Hardware Management Appliance and Support Element customer configuration requirements*”, and the *HMC and SE Network Information Worksheet*, GC28-7023, to plan your HMC, SE, and ETS IP configuration.

An HMC can have the following IP configurations:

- ▶ Statically assigned IPv4 or IPv6 addresses
- ▶ Dynamic Host Configuration Protocol (DHCP)-assigned IPv4 or DHCP-assigned IPv6 addresses
- ▶ Auto-configured IPv6:
 - Link-local is assigned to every network interface.
 - Router-advertised, which is broadcast from the router, can be combined with a Media Access Control (MAC) address to create a unique address.
 - Privacy extensions can be enabled for these addresses as a way to avoid the use of the MAC address as part of the address to ensure uniqueness.

An SE can have the following IP addresses:

- ▶ Statically assigned IPv4 or statically assigned IPv6
- ▶ Auto-configured IPv6 as link-local or router-advertised

IP addresses on the SE cannot be dynamically assigned through DHCP to ensure repeatable address assignments. DHCP privacy extensions are not used on the SE.

The HMC uses IPv4 and IPv6 multi-casting¹ to automatically discover the SEs. The HMC Network Diagnostic Information task can be used to identify the IP addresses (IPv4 and IPv6), which are used by the HMC to communicate to the SEs (of a CPC).

IPv6 addresses are easily identified. A fully qualified IPV6 address features 16 bytes. It is written as eight 16-bit hexadecimal blocks that are separated by colons, as shown in the following example:

```
2001:0db8:0000:0000:0202:b3ff:fe1e:8329
```

Because many IPv6 addresses are not fully qualified, shorthand notation can be used. In shorthand notation, the leading zeros can be omitted, and a series of consecutive zeros can be replaced with a double colon. The address in the previous example also can be written in the following manner:

```
2001:db8::202:b3ff:fe1e:8329
```

If an IPv6 address is assigned to the HMC for remote operations that use a web browser, browse to it by specifying that address. The address must be surrounded with square brackets in the browser’s address field, as shown in the following example:

```
https://[fdab:1b89:fc07:1:201:6cff:fe72:ba7c]
```

¹ For the customer-supplied switch, multicast must be enabled at the switch level.

The use of link-local addresses must be supported by your browser.

10.3.7 OSA Support Facility

When OSA/SF was moved from z/OS to the HMC/SE environment, it was noted that it is no longer easy to obtain a global view of all OSA PCHIDs and the monitoring and diagnostic information that was available in the Query Host command.

To address this issue, the following changes were made:

- ▶ If a CPC is targeted, the initial window provides a global view of all OSA PCHIDs.
- ▶ You can browse to various OSA Advanced Facilities subtasks from the initial window, which makes the process of getting to them less cumbersome.
- ▶ Today's View Port Parameters and Display OAT Entries support exporting data of one OSA PCHID. Also, the data for all OSA PCHIDs can be exported to USB or FTP from the View Port Parameters menu.
- ▶ The initial window was changed to display status information of all OSA PCHIDs (see Figure 10-21 on page 433).

Select	PCHID	Hardware Type	Status	CHPID Type	Code Level	Port 0 Status	Port 0 MAC Address	Port 1 Status	Port 1 MAC Address
<input checked="" type="radio"/>	010C	OSA-Express7S 10Gb SR Ethernet	Operating	OSD	0178	Enabled	140D4F888CEE		
<input type="radio"/>	0110	OSA-Express7S 10Gb SR Ethernet	Operating	OSD	0178	Enabled	140D4F888DA2		
<input type="radio"/>	0114	OSA-Express7S 25Gb SR Ethernet	Operating	OSD	0178	Enabled	140D4F888BC0		
<input type="radio"/>	0130	OSA-Express7S 1000Base-T Ethernet	Operating	OSC	0113	Enabled	140D4F888EAA	Enabled	140D4F888EAB
<input type="radio"/>	0134	OSA-Express7S 10Gb SR Ethernet	Operating	OSD	0178	Enabled	140D4F888C42		
<input type="radio"/>	0138	OSA-Express7S 10Gb SR Ethernet	Operating	OSD	0178	Enabled	140D4F888D6C		
<input type="radio"/>	013C	OSA-Express7S 1000Base-T Ethernet	Operating	OSD	0178	Enabled	140D4F888E1E	Enabled	140D4F888E1F
<input type="radio"/>	0140	OSA-Express7S 1000Base-T Ethernet	Operating	OSC	0113	Enabled	140D4F888ECC	Enabled	140D4F888ECD
<input type="radio"/>	0148	OSA-Express7S 10Gb SR Ethernet	Operating	OSD	0178	Enabled	140D4F888C6E		
<input type="radio"/>	015C	OSA-Express7S 10Gb SR Ethernet	Operating	OSD	0178	Enabled	140D4F888C20		
<input type="radio"/>	0170	OSA-Express7S 10Gb SR Ethernet	Operating	OSD	0178	Enabled	140D4F888C02		
<input type="radio"/>	0174	OSA-Express7S 10Gb SR Ethernet	Operating	OSD	0178	Enabled	140D4F888C80		

Total: 26 Filtered: 26 Selected: 1

Figure 10-21 OSA Advanced Facilities window

10.3.8 HMC multi-factor authentication

MFA is an optional and configurable feature on per-user, per-template basis. It enhances security by requiring what you know (the first factor) and what you have available, which means that only a person who owns a specific phone number can log in.

The MFA first factor is the combination of login ID and password; the second factor is TOTP (Time-based One-Time Password) that is sent to your smartphone, desktop, or application (for example, Google Authenticator or IBM Verify). This TOTP is defined in RFC 6238 standard and uses a cryptographic hash function that combines a secret key with the current time to generate a one-time password.

The secret key is generated by HMC/SE/TKE while the user is performing first factor log-on. The secret key is known only to HMC/SE/TKE and to the user's device. For that reason, it must be protected as much as your first factor password.

MFA code that was generated as a second factor is time-sensitive. Therefore, it is important to remember that it must be used as soon as possible after it is generated.

The algorithm within the HMC that is responsible for MFA code generation changes the code every 30 seconds. However, to ease the process, the HMC and SE console accepts current, previous, and next MFA codes.

It is also important to have HMC, SE, and device clocks synchronized. If the clocks are not synchronized, the MFA log-on attempt fails. Time zone differences are irrelevant because the MFA code algorithm uses UTC.

On IBM z15, HMC Driver 41/Version 2.15.0 provides the integration of HMC authentication and z/OS MFA support. Therefore, RSA SecurID authentication is achieved by way of centralized support from IBM MFA for z/OS, with the MFA policy defined in RACF and the HMC IDs assigned to RACF user IDs. The RSA SecurID passcode (from an RSA SecurID Token) is verified by the RSA authentication server. This authentication is supported on HMC only, *not* on the SE.

The following support was added with IBM z16 Driver 51/Version 2.16.0:

▶ Enhanced MFA functions

MFA by way of Time-based One-time Password (TOTP) or IBM Z MFA (z/OS) and RSA Secure ID is possible on the HMC.

New with Driver 51/Version 2.16.0 the following further MFA possibilities are supported:

- Certificates:
 - Personal Identity Verification (PIV)
 - Common Access Card (CAC)
 - Certificates on USB keys
- Generic Remote Authentication Dia-In User Service (RADIUS) allows for support of all various RADIUS factor types. Involves customer provided RADIUS server.

Also, Driver 51/Version 2.16.0 provides support of IBM Z MFA for Red Hat Enterprise Linux Server or SUSE Linux Enterprise Server that is running on z/VM or native in an LPAR.

10.4 Remote Support Facility

The HMC Remote Support Facility (RSF) provides important communication to a centralized IBM Support network for hardware problem reporting and service. The following types of communication are provided:

- ▶ Problem reporting and repair data
- ▶ Microcode Change Level (MCL) delivery
- ▶ Hardware inventory data, which is also known as vital product data (VPD)
- ▶ Health and diagnostic data
- ▶ On-demand enablement (CoD)

10.4.1 Security characteristics

The following security characteristics are in effect:

- ▶ RSF requests always are started from the HMC to IBM. An inbound connection is never started from the IBM Service Support System.

- ▶ All data that is transferred between the HMC and the IBM Service Support System is encrypted with high-grade SSL/Transport Layer Security (TLS) encryption.
- ▶ When starting the SSL/TLS-encrypted connection, the HMC validates the trusted host with the digital signature that is issued for the IBM Service Support System.
- ▶ Data that is sent to the IBM Service Support System consists of hardware problems and configuration data.

For more information about the benefits of Broadband RSF and the SSL/TLS-secured protocol, and a sample configuration for the Broadband RSF connection, see *Integrating the HMC Broadband Remote Support Facility into Your Enterprise*, SC28-7026.

10.4.2 RSF connections to IBM and Enhanced IBM Service Support System

To have the best availability and redundancy and to be prepared for the future, the HMC must access IBM by using the internet through RSF in the following manner: Transmission to the enhanced IBM Support System requires a domain name server (DNS). The DNS must be configured on the HMC if a proxy for RSF is not used. If a proxy for RSF is used, the proxy must provide the DNS.

The following hostnames and IP addresses are used and your network infrastructure must allow the HMC to access RSF:

- ▶ esupport.ibm.com on port 443
- ▶ The use of IPv4 requires outbound connectivity to the following IP addresses:
 - 129.42.54.189
 - 129.42.56.189
 - 129.42.60.189
- ▶ The use of IPv6 requires outbound connectivity to the following IP addresses:
 - 2620:0:6c0:200:129:42:54:189
 - 2620:0:6c2:200:129:42:56:189
 - 2620:0:6c4:200:129:42:60:189

Note: All other previous IP addresses are no longer supported.

10.5 HMC and SE capabilities

The HMC and SE features many capabilities. This section describes the key areas.

For more information about these capabilities, see the HMC and SE Driver 51/Version 2.16.0 console help system or see the [IBM Resource Link](#). At this web page, select **Library**, the applicable server and then, select **Hardware Management Console Operations Guide** or **Support Element Operations Guide**.

With the introduction of the DPM mode mainly for LinuxONE management, the user interface and user interaction with the HMC changed significantly, although the capabilities are remained the same. The figures and descriptions in this section cover only the traditional Processor Resource/Systems Manager (PR/SM) mode.

10.5.1 Central processor complex management

The HMC is the primary place for CPC control. For example, the input/output configuration data set (IOCDs) includes definitions of LPARs, channel subsystems, control units, and devices, and their accessibility from LPARs. IOCDs can be created and put into production from the HMC.

The HMC is used to start the power-on reset (POR) of the system. During the POR, processor units (PUs) are characterized and placed into their respective pools, memory is put into a single storage pool, and the IOCDs is loaded into and started in the hardware system area (HSA).

The hardware messages task displays hardware-related messages at the CPC, LPAR, or SE level. It also displays hardware messages that relate to the HMC.

10.5.2 LPAR management

Use the HMC to define LPAR properties, such as the number of processors of each type, how many are reserved, and how much memory is assigned to it. These parameters are defined in LPAR profiles and stored on the SE.

Because PR/SM must manage LPAR access to processors and the initial weights of each partition, weights are used to prioritize partition access to processors.

You can use the Load task on the HMC to perform an IPL of an operating system. This task causes a program to be read from a designated device, and starts that program. You can perform the IPL of the operating system from storage, the USB flash memory drive (UFD), or an FTP server.

When an LPAR is active and an operating system is running in it, you can use the HMC to dynamically change certain LPAR parameters. The HMC provides an interface to change partition weights, add logical processors to partitions, and add memory.

LPAR weights also can be changed through a scheduled operation. Use the Customize Scheduled Operations task to define the weights that are set to LPARs at the scheduled time.

Channel paths can be dynamically configured on and off (as needed for each partition) from an HMC.

The Change LPAR Controls task for IBM z16 can export the Change LPAR Controls table data to a comma-separated value (.csv)-formatted file. This support is available to a user when they are remotely connected to the HMC by a web browser.

Partition capping values can be scheduled and are specified on the Change LPAR Controls scheduled operation support. Viewing more information about a Change LPAR Controls scheduled operation is available on the SE.

One example of managing the LPAR settings is the absolute physical hardware LPAR capacity setting. Driver 15 (zEC12/zBC12) introduced the capability to define (in the image profile for shared processors) the absolute processor capacity that the image is allowed to use (independent of the image weight or other cappings).

To indicate that the LPAR can use the nondedicated processors absolute capping, select **Absolute capping** on the Image Profile Processor settings to specify an absolute number of processors at which to cap the LPAR's activity. The absolute capping value can be "None" or a value for the number of processors (0.01 - 255.0).

Following on to LPAR absolute capping, LPAR group absolute capping uses a similar method to enforce the following components:

- ▶ Customer licensing
- ▶ Non-z/OS partitions where group soft capping is not an option
- ▶ z/OS partitions where ISV does not support software capping

A group name, processor capping value, and partition membership are specified at the hardware console, along with the following properties:

- ▶ Set an absolute capacity cap by CPU type on a group of LPARs.
- ▶ Allow each of the partitions to use capacity up to their individual limits if the group's aggregate consumption does not exceed the group absolute capacity limit.
- ▶ Include updated SysEvent QVS support (used by vendors who implement software pricing).
- ▶ Only shared partitions are managed in these groups.
- ▶ Specify caps for one or more processor types in the group.
- ▶ Specify in absolute processor capacity (for example, 2.5 processors).
- ▶ Use Change LPAR Group Controls (as with windows that are used for software group-defined capacity), as shown in Figure 10-22.

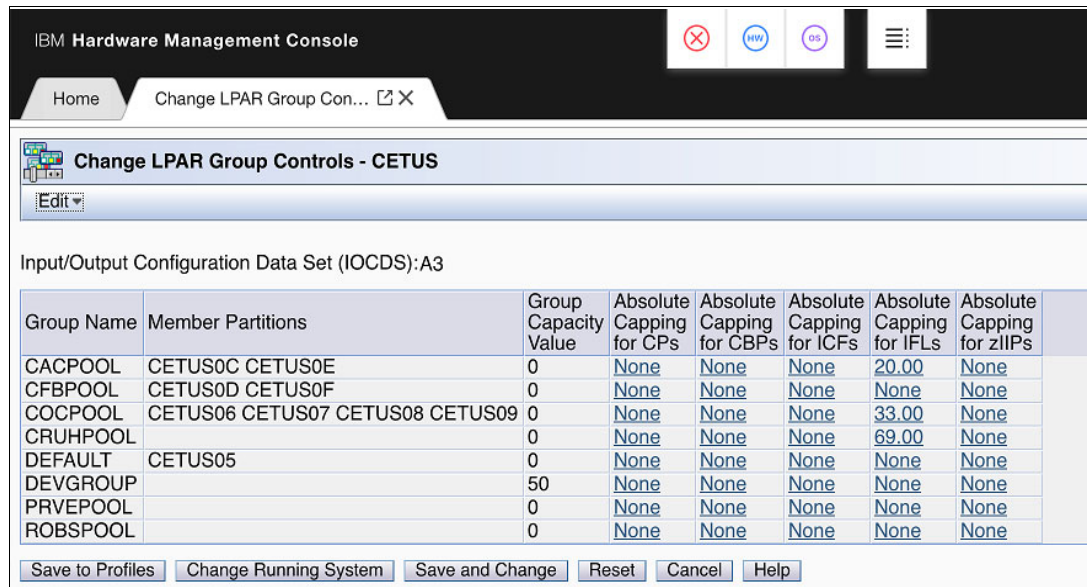


Figure 10-22 Change LPAR Group Controls: Group absolute capping

Absolute capping is specified as an absolute number of processors to which the group's activity is capped. The value is specified to hundredths of a processor (for example, 4.56 processors) worth of capacity.

The value is not tied to the Licensed Internal Code (LIC) configuration code (LICCC). Any value 0.01 - 255.00 can be specified. This configuration makes the profiles more portable,

which means that you do not encounter problems when profiles are migrated to new machines.

Although the absolute cap can be specified to hundredths of a processor, the exact amount might not be that precise. The same factors that influence the “machine capacity” also influence the precision with which the absolute capping works.

LPAR absolute capping can be changed through scheduled operations start.

10.5.3 HMC and SE remote operations

Because stand-alone, outside the IBM z16 HMCs (Tower or Rack Mount) can no longer be ordered with IBM z16, connections to the HMC (and SE) are made by way of a browser. However, because the SE cannot be directly accessed by using a browser the Single Object Operations (SOO) task on the HMC must be used.

The following HMC feature codes can be carried forward from previous orders:

- ▶ FC 0062
- ▶ FC 0063
- ▶ FC 0082
- ▶ FC 0083

With these HMC feature codes, Driver 51/Version 2.16.0 can be installed to support IBM z16. Also, Driver 51/Version 2.16.0 can be installed on the two HMCs that are provided with the HMA FC 0100 on IBM z15. With these HMCs, you can still work local at an HMC.

Note: Remote web browser access is the default for the HMA HMCs.

Access to the USB Device on HMC and SE requires physical access to the HMC/SE.

Log-on security for a web browser is provided by the local HMC user log-on procedures. Certificates for secure communications are provided and can be changed by the user.

Web browser access can be limited by specifying an IP address from the Customize Console Services task. To enable or disable the Remote operation service, click **Change...** in the Customize Console Services window, as shown in Figure 10-23.

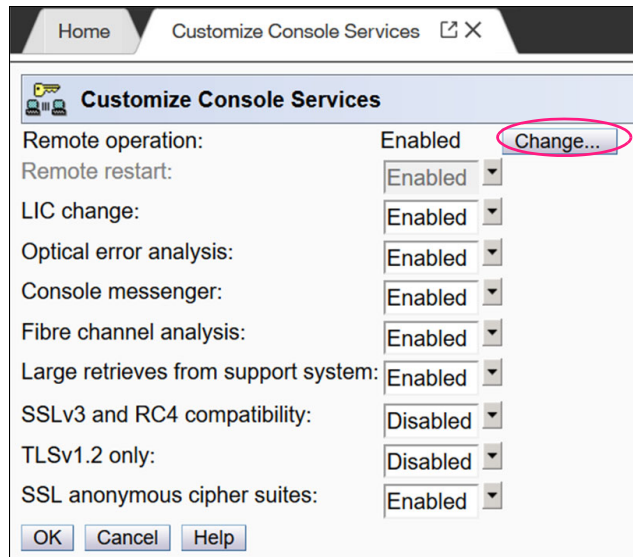


Figure 10-23 Customizing HMC remote operation

Note: If the setting in **Change Remote Access Setting** → **IP Access Control** is set to Allow specific IP addresses, but none or incorrect IP addresses are in the list, a remote HMC connection is not available by using a web browser.

Microsoft Internet Explorer, Microsoft Edge, Mozilla Firefox, Safari, and Google Chrome were tested as remote web browsers. For more information about web browser requirements, see the HMC and SE console help system or see the [IBM Resource Link](#). At this web page, select **Library**, the applicable server and then, select **Hardware Management Console Operations Guide** or **Support Element Operations Guide**.

Single Object Operations

It is not necessary to be physically close to a SE to use it. The HMC can be used to access the SE remotely by using the SOO task. The interface is the same as the interface that is used on the SE. For more information, see the [IBM Resource Link](#). At this web page, select **Library**, the applicable server and then, select **Hardware Management Console Operations Guide** or **Support Element Operations Guide**.

Note: With HMC Driver 41/Version 2.15.0 and Driver 51/Version 2.16.0, specific tasks that required in the past to access to the SE in SOO mode were implemented as HMC tasks. With this enhancement, the HMC runs the tasks on the SE directly, without the need to lock the SE in SOO mode.

IBM HMC Mobile

IBM HMC Mobile is an iOS and Android application with which you can monitor all of your IBM Z systems and partitions. You also can receive alerts when messages or status changes occur.

You also can start, stop, or change the activation profile for a partition.

A full set of granular security controls is provided from the HMC, including MFA. This mobile interface is optional and is disabled by default. More functions from the HMC also are planned to be available on IBM HMC Mobile.

For more information about HMC Mobile, see the following resources:

- ▶ This [IBM video](#)
- ▶ The HMC Mobile [website](#)

10.5.4 Operating system communication

The Operating System Messages task displays messages from an LPAR. You also can enter operating system commands and interact with the system. This feature is especially valuable for entering Coupling Facility Control Code (CFCC) commands.

The HMC also provides integrated 3270 and ASCII consoles. These consoles allow an operating system to be accessed without requiring other network or network devices, such as TCP/IP or control units.

Updates to x3270 support

The Configure 3270 Emulators task on the HMC and TKE consoles was enhanced with Driver 15 to verify the authenticity of the certificate that is returned by the 3270 server when a secure and encrypted SSL connection is established to an IBM host. This 3270 Emulator with encrypted connection is also known as *Secure 3270*.

Use the Certificate Management feature if the certificates that are returned by the 3270 server are not signed by a well-known trusted certificate authority (CA) certificate, such as VeriSign or Geotrust. An advanced action within the Certificate Management task, Manage Trusted Signing Certificates, is used to add trusted signing certificates.

For example, if the certificate that is associated with the 3270 server on the IBM host is signed and issued by a corporate certificate, it must be imported, as shown in Figure 10-24.

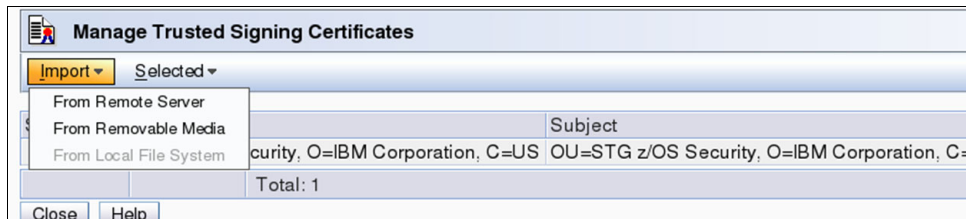


Figure 10-24 Manage Trusted Signing Certificates

The import from the remote server option can be used if the connection between the console and the IBM host can be trusted when the certificate is imported, as shown in Figure 10-25. Otherwise, import the certificate by using removable media.

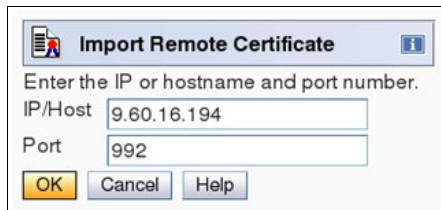


Figure 10-25 Import Remote Certificate example

A secure Telnet connection is established by adding the prefix L: to the IP address:port of the IBM host, as shown in Figure 10-26.

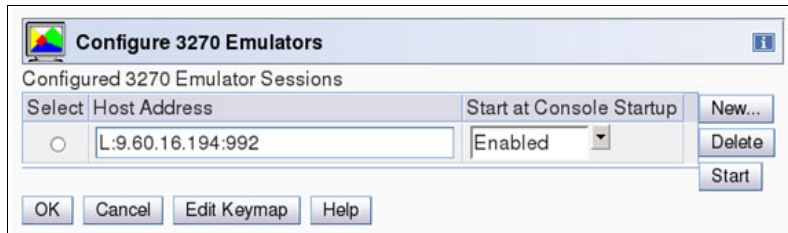


Figure 10-26 Configure 3270 Emulators

10.5.5 HMC and SE microcode

The microcode for the HMC, SE, and CPC is included in the driver or version. The HMC provides the management of the driver upgrade through Enhanced Driver Maintenance (EDM). EDM also provides the installation of the latest functions and the patches (MCLs) of the new driver.

When a driver is upgraded, always check the Driver (51) Customer Exception Letter option in the Fixes section at the IBM Resource Link.

Microcode Change Level

Regular installation of Microcode Change Levels (MCLs) is key for RAS, optimal performance, and the following new functions:

- ▶ Install MCLs on a quarterly basis at a minimum.
- ▶ Review hiper MCLs continuously to decide whether to wait for the next scheduled fix application session or to schedule one earlier if the risk assessment warrants.
- ▶ Sign on to the IBM Z Security Portal website and review for security alerts and related MCL fixes.

Tip: The IBM Resource Link provides access to the system information for your IBM Z system according to the system availability data that is sent on a scheduled basis. It provides more information about the MCL status of your IBM Z. At the [IBM Resource Link](#) web page, click **Tools** → **Machine Information**, select your IBM Z system and then, click **EC/MCL**.

Microcode terms

The microcode features the following characteristics:

- ▶ The driver contains engineering change (EC) streams.
- ▶ Each EC stream covers the code for a specific component of IBM z16. It includes a specific name and an ascending number.
- ▶ The EC stream name and a specific number are one MCL.
- ▶ MCLs from the same EC stream must be installed in sequence.
- ▶ MCLs can include installation dependencies on other MCLs.
- ▶ Combined MCLs from one or more EC streams are in one Bundle.
- ▶ An MCL contains one or more Microcode Fixes (MCFs).

How the driver, bundle, EC stream, MCL, and MCFs interact with each other, is shown in Figure 10-27.

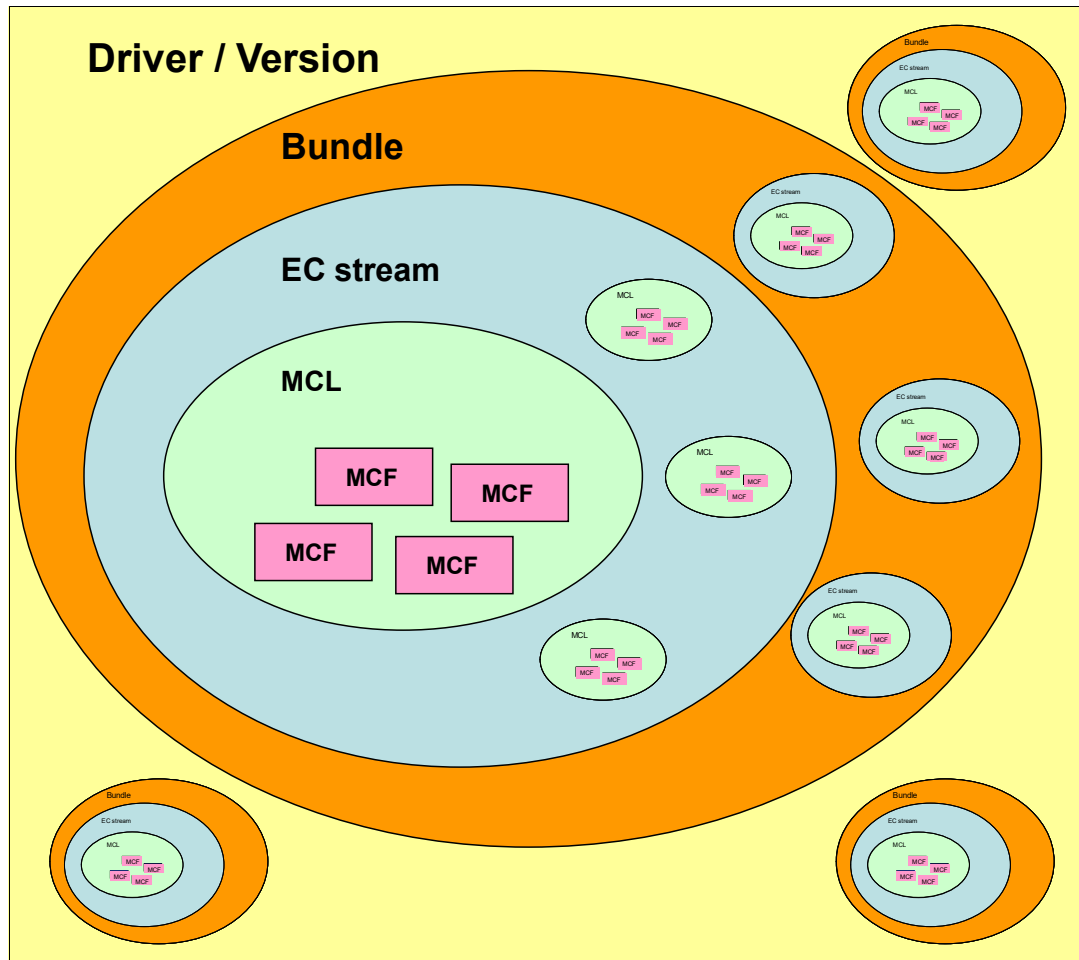


Figure 10-27 Microcode terms and interaction

MCL Activation

By design and with planning, MCLs can be activated concurrently. Consider the following points:

- ▶ Most MCLs activate concurrently when applied.
- ▶ Some MCLs need a disruptive configure off/on to activate the new loaded microcode.
- ▶ Activate traditional I/O Feature Pended MCL – LIC on the hardware feature:
 - Display Pending MCLs by using HMC function or Resource Link Machine Information Reports
 - Activate by using HMC function on a feature basis by PCHID individually – disruptive: CONFIG the CHPID OFF to all sharing LPARs, activate, and then CONFIG ON to all
- ▶ Activate Native PCIe Pended MCL – LIC on a hardware feature OR Resource Group (RG) LIC:
 - Display Pending MCLs by using HMC function or Resource Link Machine Information Reports

- Feature LIC: Activate by using HMC function on a one feature (PCHID) at a time basis
 - disruptive: CONFIG FUNCTIONS mapped to the feature OFF to all LPARs, activate, and then CONFIG ON
- RG LIC: Activate by using HMC function to each RG in turn – disruptive to all PCHIDs in the RG: CONFIG all FUNCTIONS mapped to all PCHIDs in RG1 OFF, activate, then CONFIG ON. Repeat for all PCHIDs in RG2, RG3, RG4

Note: For hardware that does not need CHPID or a FUNCTION definition (for example, Crypto Express), a different method that is specific to the feature is used.

- ▶ Alternative: Apply and activate all Pended MCLs disruptively with a scheduled Power On Reset (POR)

To discover this “Pended” situation, the following actions are completed whenever an MCL is applied:

- ▶ Log on to the HMC and select **System Management** → **CPC**
- ▶ Change Management
- ▶ System Information
- ▶ Query Additional Actions

Or:

- ▶ Log on to the SE and select **System Management** → **CPC**
- ▶ Change Management
- ▶ Query Channel/Crypto Configure Off/On Pending

Microcode installation by MCL Bundle target

A *Bundle* is a set of MCLs that are grouped during testing and released as a group on the same date. You can install an MCL to a specific target Bundle level.

The System Information window is enhanced to show a summary Bundle level for the activated level, as shown in Figure 10-28.

Select	EC Number	Retrieved Level	Installable Concurrent	Activated Level	Accepted Level	Description
<input type="radio"/>	P46598	456	456	456	439	SE Framework
<input type="radio"/>	P46599					Concurrent Upgrade Sync Point
<input type="radio"/>	P46600	112	112	112	105	SE Licensed Internal Code Alerts
<input type="radio"/>	P46601	146	146	146	144	I390/PU-ML LIC
<input type="radio"/>	P46602	009	009	009	008	LPAR HV LIC
<input type="radio"/>	P46603	008	008	008	007	CFCC (COUPLING) LIC
<input type="radio"/>	P46604	001	001	001	001	PCX LIC
<input type="radio"/>	P46605					SCSI IPL Machine Loader
<input type="radio"/>	P46606	062	062	062	060	PSCN SE Microcode
<input type="radio"/>	P46607	095	095	095	091	CEC Microcode
<input type="radio"/>	P46608					MISR DATA LIC
<input type="radio"/>	P46609	062	062	062	060	Cage Controller

Figure 10-28 System Information: Bundle level

10.5.6 Monitoring

This section describes monitoring considerations.

Monitor task group

The Monitor task group on the HMC and SE includes monitoring-related tasks for IBM Z CPCs, as shown in Figure 10-29.

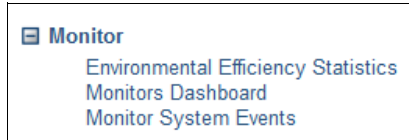


Figure 10-29 HMC Monitor Task Group

Monitors Dashboard

The Monitors Dashboard in the Monitor group provides a tree-based view of resources.

Multiple graphical views are available for displaying data, including history charts. The Monitors Dashboard monitors processor and channel usage. It also produces data that includes power monitoring information, power consumption, and the air input temperature for the system.

You can display more information for the following components:

- ▶ Power consumption
- ▶ Environmental
- ▶ Aggregated processors
- ▶ Processors (with SMT information)
- ▶ System Assist Processors
- ▶ Logical Partitions
- ▶ Channels
- ▶ Adapters: Crypto use percentage is displayed according to the physical channel ID (PCHID number)

Environmental Efficiency Statistics

The Environmental Efficiency Statistics is part of the Monitor group. It provides historical power consumption and thermal information for the IBM Z CPC, and is available on the HMC.

The data is presented in table format and graphical “histogram” format. The data also can be exported to a .csv-formatted file so that the data can be imported into a spreadsheet. For this task, you must use a web browser to connect to an HMC.

Monitor System Events

The Monitor System Events task allows you to create and manage event monitors. An event monitor listens for events from managed objects. When an event is received, the monitor tests it with user-defined criteria. If the event passes the tests, the monitor enables an email to be sent to interested users.

An example of the settings for Event Monitor Summary can be seen on Figure 10-30.

Event Monitor Summary - PAVO

Provide the Simple Mail Transfer Protocol (SMTP) server information to enable monitoring. Create monitors by editing the samples or adding new ones and then enabling them.

SMTP Settings

Server:

Port:

Send Mail As:

Notification delay (seconds):*

Monitors

Select	Name	Description	Last Event	Enabled
<input checked="" type="radio"/>	Accelerator	Example accelerator metrics.		<input type="checkbox"/>
<input type="radio"/>	Crypto	Example cryptographic coprocessor metrics.		<input type="checkbox"/>
<input type="radio"/>	HW Msg Example	Example hardware message monitor.		<input type="checkbox"/>
<input type="radio"/>	Hardware Messages to HAIMO		Feb 20, 2022, 8:00:50 AM	<input checked="" type="checkbox"/>
<input type="radio"/>	Network	Example network metrics.		<input type="checkbox"/>
<input type="radio"/>	OS Msg Example	Example operating system message monitor.		<input type="checkbox"/>
<input type="radio"/>	Partition	Example partition processor, NIC, HBA & accelerator metrics.		<input type="checkbox"/>
<input type="radio"/>	Processor (CPU)	Example processor metrics.		<input type="checkbox"/>
<input type="radio"/>	Security Log Example	Example security log monitor.		<input type="checkbox"/>
<input type="radio"/>	State Change Example	This is example of a state change monitor.		<input type="checkbox"/>
<input type="radio"/>	Storage	Example storage metrics.		<input type="checkbox"/>

Add... Edit... Delete

OK Cancel Test... Help

Figure 10-30 Event Monitor Summary

10.5.7 Capacity on-demand support

All capacity on demand (CoD) upgrades are performed by using the Perform a Model Conversion task on the HMC or SE. Use the task to retrieve and activate a permanent upgrade, and to retrieve, install, activate, and deactivate a temporary upgrade. The task shows a list of all installed or staged LICCC records to help you manage them. It also shows a history of recorded activities.

The HMC for IBM z16 features the following CoD capabilities:

- ▶ SNMP API support:
 - API interfaces for granular activation and deactivation
 - API interfaces for enhanced CoD query information
 - API event notification for any CoD change activity on the system
 - CoD API interfaces, such as On/Off CoD and Capacity Back Up (CBU)
- ▶ SE window features (accessed through HMC Single Object Operations):
 - Window controls for granular activation and deactivation
 - History window for all CoD actions
 - Description editing of CoD records
- ▶ HMC/SE provides the following CoD information:
 - Millions of service units (MSU) and processor tokens
 - Last activation time
 - Pending resources that are shown by processor type instead of only a total count
 - Option to show more information about installed and staged permanent records
 - More information for the Attention state by providing seven more flags

HMC and SE are a part of the z/OS Capacity Provisioning environment. The Capacity Provisioning Manager (CPM) communicates with the HMC through IBM Z APIs, and enters CoD requests. For this reason, SNMP must be configured and enabled by using the Customize API Settings task on the HMC.

Statement of Direction: IBM z16 is planned to be the last server to support established CoD unique record type automation interfaces. For example, the older command `HWMCA_ACTIVATE_CBU_COMMAND` changed to `HWMCA_ADD_CAPACITY_COMMAND`. We suggest that you change your automation scripts now.

For more information, see *Capacity on-Demand User's Guide*, SC28-7025.

For more information about the use of and setting up CPM, see the following publications:

- ▶ *z/OS MVS Capacity Provisioning User's Guide*, SC34-2661
- ▶ *Capacity on-Demand User's Guide*, SC28-7025

10.5.8 Server Time Protocol support

Important: The Sysplex Time task on the SE was discontinued with IBM z15. Therefore, an HMC with Driver 51/Version 2.16.0 is required to access the Manage System Time task for IBM z16 A01, IBM z15 T01, and IBM z15 T02 CPCs.

IBM z16 implements the following major enhancements in support of the Server Time Protocol function:

- ▶ CPC direct Ethernet connectivity for the external time source (ETS)

In previous generation IBM Z, the ETS for the STP was provided by connecting the Support element to the client network.

With IBM z16 the ETS, PTP (IEEE 1588) or NTP network connectivity is provided by using the IBM z16 CPC oscillator (OSC) cards dedicated network ports (RJ45) to client LAN for accessing the time synchronization information.

Pulse-per-second connectivity also is provided for the highest timing information accuracy. Connection of the ETS direct to the IBM Z CPC provides less delay in accessing the time source than connection through the Support Element.

- ▶ n-mode Power STP Imminent Disruption Signal option

On IBM Z, losing a Preferred Time Server (PTS) has significant consequences to the timing network and the overall workload execution environment of the IBM Z sysplex. The IBM Z and the HMC feature longtime automated failover protection for various cases that can arise.

New for IBM z16 because an integrated battery facility no longer is available, support was added by the HMC to allow the customer to configure an option to monitor for n-mode power conditions (wall power or power cord loss). If detected, an automated failover occurs to the Backup Time Server (BTS).

Note: Provide some backup power method to hold power for 60 seconds on the PTS to allow failover to successfully complete.

Manage System Time user interface controls are available to manage failback to the PTS when the full power state is restored.

ETS direct connectivity to the IBM z16 CPC is provided for both supported ETS protocols: NTP and PTP.

With the Server Time Protocol (STP) functions, the role of the HMC is extended to provide the user interface for managing the Coordinated Timing Network (CTN).

Consider the following points:

- ▶ IBM Z CPCs rely on STP for time synchronization, and continue to provide support of a pulse per second (PPS) port. Consider the following points:
 - STP can be configured to use Precision Time Protocol (PTP, IEEE 1588) as external time source. Current implementation requires that the support element is connected to a PTP-capable network infrastructure and can access a PTP server.
 - An STP that uses Network Time Protocol (NTP) or PTP as ETS server *with* PPS maintains an accuracy of 10 ms.
 - An STP that uses ETS *without* PPS maintains accuracy of 100 ms.
- ▶ The IBM z16 cannot be in the same CTN with z13, z12s, or earlier systems and cannot become member of a mixed CTN.
- ▶ The Primary Time Server and the Backup Time Server must be IBM z16 to use the failover mechanism that is triggered by the n-mode STP Imminent Disruption Signal option.

An STP-only CTN can be managed by using different HMCs. However, the HMC must be at the same driver level (or later) than any SE that is to be managed. Also, all SEs to be managed must be known (defined) to that HMC. In a STP-only CTN, the HMC can be used to perform the following tasks:

- ▶ Start or modify the CTN ID.
- ▶ Start the time (manually or by contacting an NTP server).
- ▶ Start the time zone offset, Daylight Saving Time offset, and leap second offset.
- ▶ Assign the roles of preferred, backup, and current time servers, and arbiter.
- ▶ Adjust time by up to plus or minus 60 seconds.
- ▶ Schedule changes to the offsets listed. STP can automatically schedule Daylight Saving Time, based on the selected time zone.
- ▶ Monitor the status of the CTN.
- ▶ Monitor the status of the coupling links that are started for STP message exchanges.
- ▶ For diagnostic purposes, the PPS port state on an IBM z16 can be displayed and fenced ports can be reset individually.

STP changes and enhancements

Important: The Sysplex Time task on the SE was discontinued for IBM z15. Therefore, an HMC at Version 2.15.0 is required to manage system time for IBM z15 CPCs.

Detailed instructions and guidelines are provided within task workflow. IBM z15 HMC provides a visual representation of the CTN topology. A preview of any configuration action is also shown in topological display. An example of the topology view is shown in Figure 10-31.

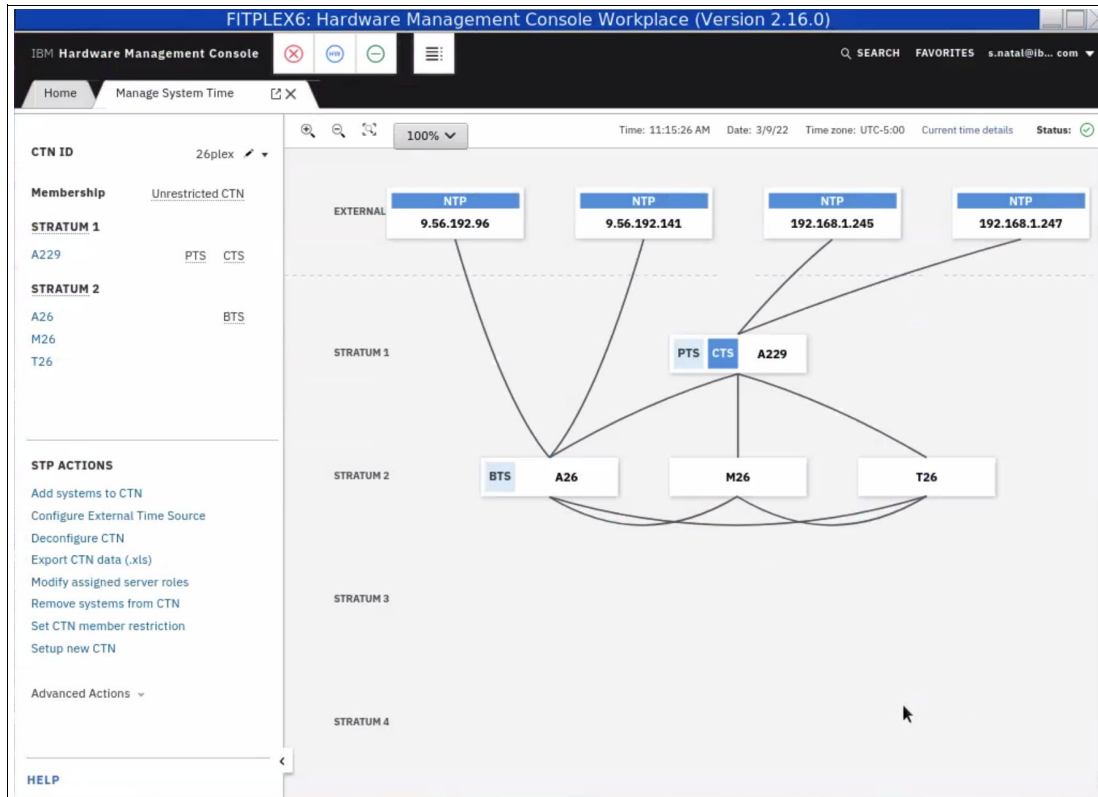


Figure 10-31 CTN topology visible on HMC Manage System Time window

N-mode power sensing for STP recovery

For previous IBM Z server generations, specific configurations that use Bulk Power Adapter (BPA) with IBF can sense an “operating on battery condition” if a power interruption occurs on any power cord.

For STP, if CPC1 (Primary Time Server and Current Time Server) senses a shift to an on-battery power condition, a signal indicating potential imminent server disruption of CPC1 is sent to CPC2 (the Backup Time Server).

If within 30 seconds the BTS (CPC2) does not receive a signal that power is back to fully redundant on CPC1, CPC2 takes over as CTS. After normal power is restored to CPC1, CPC1 can automatically return to the CTS role.

With IBM z16, the IBF was discontinued. As such, Coupling Facility Nonvolatility requires Room-level, Row-level, or System-Level UPS for protecting against power failures.

New STP PTS/BTS methods enable better coverage across both BPA and iPDU configurations for a much broader scope of clients that can take advantage of STP high-reliability functions. The new strategy allows clients with UPS to more effectively monitor and manage their power efficiency across their data center.

STP resiliency for PTS/CTS transition IBM Z from IBF Sensing to N-Mode Power Sensing.

To enable the N-Mode Power Sensing, a one-time setup step is required. In the HMC Manage System Time task, a customer enables the automatic switch over function from CPC1 to CPC2 for STP. After the function is enabled, the power subsystem (BPA and iPDU) detects any power source loss (at the power cord or power side level).

This detection generates a signal from CPC1 to CPC2 in the same way as done for systems with IBF. The generation of this signal can take up to 30 seconds, depending on conditions.

If within 30 seconds CPC2 does not receive a signal that power is back to fully redundant on CPC1, CPC2 takes over as CTS. After normal power is restored to CPC1, CPC1 can automatically return to the CTS role.

Enhanced Console Assisted Recovery

Enhanced Console Assisted Recovery (ECAR) speeds up the process of BTS takeover by performing the following steps:

1. When the PTS/CTS detects a checkstop condition, the CEC informs its SE and HMC.
2. The PTS SE recognizes the checkstop pending condition, and calls the PTS SE STP code.
3. The PTS SE sends an ECAR request thorough HMC to the BTS SE.
4. The BTS SE communicates with the BTS to start the takeover.

ECAR support is faster than the original CAR support because the console path changes from a 2-way path to a 1-way path. Also, almost no lag time is incurred between the system checkstop and the start of CAR processing. Because the request is generated from the PTS before system logging, it avoids the potential of recovery being held up.

Attention: IBM z16, IBM z15, and IBM z14 ZR1 do not support InfiniBand connectivity. Although IBM z14 M0x supports InfiniBand, InfiniBand coupling and timing links cannot be configured in a Sysplex/CTN with IBM z16.

For more information about planning and setup, see *IBM Z Server Time Protocol Guide*, [SG24-8480](#).

10.5.9 CTN split and merge

IBM z16, IBM z15, IBM z14 ZR1, and IBM z14 support CTN split and CTN merge.

For more information, see *IBM Z Server Time Protocol Guide*, [SG24-8480](#).

CTN split

The HMC menus for Server Time Protocol (STP) provide support when one or more systems must be split in to a separate CTN without interruption in the clock source.

The task is available under the Advanced Actions menu in the Manage System Time task. Several checks are performed to avoid potential disruptive actions. If targeted CTN includes only members with the roles, the task start fails with an error message.

If targeted CTN includes at least one system without any roles, the task starts. An informational warning is presented to the user to acknowledge that sysplex workloads are divided suitably.

Merging two CTNs

When two separate CTNs must be merged in to the single CTN without interruption in the clock source, the system administrator must perform the Join existing CTN action, which is available in the Advanced Actions menu.

Note: After joining the selected CTN, all systems within the current CTN are synchronized with the Current Time Server of the selected CTN. A coupling link must be in place that connects the CTS of the selected CTN and the CTS of the current CTN.

During the transition state, most of the STP actions for the two affected CTNs are disabled. After the merge is completed, STP actions are enabled again.

For more information about planning and understanding STP server roles, see the following publications:

- ▶ *IBM Z Server Time Protocol Guide*, [SG24-8480](#)
- ▶ *Server Time Protocol Planning Guide*, [SG24-7280](#)
- ▶ *Server Time Protocol Implementation Guide*, [SG24-7281](#)
- ▶ *Server Time Protocol Recovery Guide*, [SG24-7380](#)

10.5.10 NTP client and server support on the HMC

The NTP client support allows a STP-only CTN to use an NTP server as an ETS. This capability addresses the following requirements:

- ▶ Customers who want time synchronization for the servers members of the STP-only CTN
- ▶ Customers who use a common time reference across heterogeneous systems

The NTP server becomes the single time source (the ETS) for STP and other servers that are not IBM Z (such as AIX® and Microsoft Windows) that include NTP clients.

The HMC can act as an NTP server. With this support, the IBM z15 can receive the time from the HMC without accessing a LAN other than the HMC and SE network. When the HMC is used as an NTP server, it can be configured to receive the NTP source from the internet. For this type of configuration, a LAN that is separate from the HMC/SE LAN can be used.

Note: For IBM z16, STP External Time Source (Ethernet) is connected directly to the CPC drawer by using a dedicated LAN port. When HMC is configured as an NTP server, it must be connected to the same client network with the dedicated CPC LAN port.

HMC NTP broadband authentication support

HMC NTP authentication can be used since HMC Driver 15 (zEC12/zBC12).

Authentication support with a proxy

Some client configurations use a proxy for external access outside the corporate data center. NTP requests are User Datagram Protocol (UDP) socket packets and cannot pass through the proxy. The proxy must be configured as an NTP server to get to target servers on the web. Authentication can be set up on the client's proxy to communicate with the target time sources.

Authentication support with a firewall

If you use a firewall, HMC NTP requests can pass through it. Use HMC authentication to ensure untampered timestamps.

NTP symmetric key and autokey authentication

With symmetric key and autokey authentication, the highest level of NTP security is available. HMC Level 2.12.0 and later provide windows that accept and generate key information to be configured into the HMC NTP configuration. They also can issue NTP commands.

The HMC offers the following symmetric key and autokey authentication and NTP commands:

- ▶ Symmetric key (NTP V3-V4) authentication

Symmetric key authentication is described in RFC 1305, which was made available in NTP Version 3. Symmetric key encryption uses the same key for encryption and decryption. Users that are exchanging data keep this key to themselves.

Messages that are encrypted with a secret key can be decrypted only with the same secret key. Symmetric key authentication supports network address translation (NAT).

- ▶ Symmetric key autokey (NTP V4) authentication

This autokey uses public key cryptography, as described in RFC 5906, which was made available in NTP Version 4. You can generate keys for the HMC NTP by clicking **Generate Local Host Key** in the Autokey Configuration window. This option issues the **ntp-keygen** command to generate the specific key and certificate for this system. Autokey authentication is not available with the NAT firewall.

- ▶ Issue NTP commands

NTP command support is added to display the status of remote NTP servers and the current NTP server (HMC).

For more information about planning and setup for STP and NTP, see the following publications:

- ▶ *IBM Z Server Time Protocol Guide*, [SG24-8480](#)
- ▶ *Server Time Protocol Planning Guide*, [SG24-7280](#)
- ▶ *Server Time Protocol Implementation Guide*, [SG24-7281](#)
- ▶ *Server Time Protocol Recovery Guide*, [SG24-7380](#)

10.5.11 Security and user ID management

This section addresses security and user ID management considerations.

HMC and SE HD encryption

Consider the following points about IBM z16 (with continued emphasis on encryption):

- ▶ Passwords are never stored in clear (one-way hash)
- ▶ HMC/SE is a closed appliance; no means exist to get HDD
- ▶ *All* network traffic is TLS encrypted
- ▶ HMC and SE feature embedded firewall
- ▶ Firmware is digitally signed and validated for delivery
- ▶ Firmware Integrity Monitoring is used for any attempted tempering post delivery

For HMC and SE Driver 51/Version 2.16.0, HDD encryption uses Trusted Platform Module (TPM) and Linux Unified Key Setup (LUKS) technology.

HMC and SE security audit improvements

With the Audit and Log Management task, audit reports can be generated, viewed, saved, and offloaded. The Customize Scheduled Operations task allows you to schedule audit report generation, saving, and offloading.

The Monitor System Events task allows Security Logs to send email notifications by using the same type of filters and rules that are used for hardware and operating system messages.

With IBM z16, you can offload the following HMC and SE log files for customer audit:

- ▶ Console event log
- ▶ Console service history
- ▶ Tasks performed log
- ▶ Security logs
- ▶ System log

Full log offload and delta log offload (since the last offload request) are provided. Offloading to removable media and to remote locations by FTP is available. The offloading can be manually started by the new Audit and Log Management task or scheduled by the Customize Scheduled Operations task. The data can be offloaded in the HTML and XML formats.

HMC user ID templates and LDAP user authentication

Lightweight Directory Access Protocol (LDAP) user authentication and HMC user ID templates enable the addition and removal of HMC users according to your own corporate security environment. These processes use an LDAP server as the central authority.

Each HMC user ID template defines the specific authorization levels for the tasks and objects for the user who is mapped to that template. The HMC user is mapped to a specific user ID template by user ID pattern matching. The system then obtains the name of the user ID template from content in the LDAP server schema data.

Default HMC user IDs

For HMC V2.16.0 the default user IDs are limited to ACSADMIN and SERVICE.

ADVANCED, OPERATOR, STORAGEADMIN, and SYSPROG default users are no longer shipped. Default user roles for ADVANCED, OPERATOR, STORAGEADMIN, and SYSPROG are provided, and user IDs can be created from those roles.

Any default user IDs that are part of a previous HMC level can be carried forward to new HMC levels as part of a MES Upgrade or by way of selecting User Profile Data for the Save/Restore Customizable Console Data or Configure Data Replication tasks.

HMC and SE secure FTP support

You can use a secure FTP connection from a HMC/SE FTP client to a customer FTP server location. This configuration is implemented by using the Secure Shell (SSH) File Transfer Protocol, which is an extension of SSH. You can use the Manage SSH Keys console feature that is available to the HMC and SE to import public keys that are associated with a host address.

The Secure FTP infrastructure allows HMC and SE applications to query whether a public key is associated with a host address and to use the Secure FTP interface with the suitable public key for a host. Tasks that use FTP now provide a selection for the secure host connection.

When selected, the task verifies that a public key is associated with the specified hostname. If a public key is not provided, a message window opens that points to the Manage SSH Keys task to enter a public key. The following tasks provide this support:

- ▶ Import/Export IOCDs
- ▶ Advanced Facilities FTP IBM Content Collector Load
- ▶ Audit and Log Management (Scheduled Operations only)
- ▶ FCP Configuration Import/Export

- ▶ OSA view Port Parameter Export
- ▶ OSA-Integrated Console Configuration Import/Export

10.5.12 System Input/Output Configuration Analyzer on the SE and HMC

The System Input/Output Configuration Analyzer supports the system I/O configuration function.

The information that is needed to manage a system's I/O configuration must be obtained from many separate sources. The System Input/Output Configuration Analyzer task enables the system hardware administrator to access, from one location, the information from those sources. Managing I/O configurations then becomes easier, particularly across multiple systems.

The System Input/Output Configuration Analyzer runs the following functions:

- ▶ Analyzes the current active IOCDs on the SE.
- ▶ Extracts information about the defined channel, partitions, link addresses, and control units.
- ▶ Requests the channels' node ID information. The Fibre Channel connection (FICON) channels support remote node ID information, which is also collected.

The System Input/Output Configuration Analyzer is a view-only tool. It does not offer any options other than viewing. The tool provides various sort options, and data can be exported to a UFD for later viewing.

By using the tool, data is formatted and displayed in the following views:

- ▶ PCHID Control Unit View
Shows PCHIDs, channel subsystems (CSS), CHPIDs, and their control units.
- ▶ PCHID Partition View
Shows PCHIDS, CSS, CHPIDs, and the partitions in which they exist.
- ▶ Control Unit View
Shows the control units, their PCHIDs, and their link addresses in each CSS.
- ▶ Link Load View
Shows the Link address and the PCHIDs that use it.
- ▶ Node ID View
Shows the Node ID data under the PCHIDs.

10.5.13 Automated operations

As an alternative to manual operations, an application can interact with the HMC and SE through an API. The interface allows a program to monitor and control the hardware components of the system in the same way a user performs these tasks.

On IBM z16, the HMC APIs provide monitoring and control functions through SNMP. The API can get and set a managed object's attributes, issue commands, receive asynchronous notifications, and generate SNMP traps.

The older system, such as IBM z13's HMC, supports the CIM as an extra systems management API. Starting with IBM z14, the CIM support is removed.

For more information about APIs, see *SNMP Application Programming Interfaces*, SB10-7179.

10.5.14 Cryptographic support

This section describes the cryptographic management and control functions that are available in the HMC and SE.

Cryptographic hardware

IBM z16 systems include standard cryptographic hardware and optional cryptographic features for flexibility and growth capability.

The HMC/SE interface provides the following capabilities:

- ▶ Defining the cryptographic controls
- ▶ Dynamically adding a Crypto feature to a partition:
 - For the first time
 - That already uses Crypto
- ▶ Dynamically removing a Crypto feature from a partition

The Crypto Express8S, which is a new Peripheral Component Interconnect Express (PCIe) cryptographic coprocessor, is an optional IBM z16 exclusive feature. Crypto Express8S provides a secure programming and hardware environment on which crypto processes are run.

Each Crypto Express8S adapter can be configured by the installation as a Secure IBM CCA coprocessor, a Secure IBM Enterprise Public Key Cryptography Standards (PKCS) #11 (EP11) coprocessor, or an accelerator.

When EP11 mode is selected, a unique Enterprise PKCS #11 firmware is loaded into the cryptographic coprocessor. It is separate from the Common Cryptographic Architecture (CCA) firmware that is loaded when a CCA coprocessor is selected. CCA firmware and PKCS #11 firmware cannot coexist in a card.

The Trusted Key Entry (TKE) Workstation with smart card reader feature is required to support the administration of the Crypto Express8S when configured as an Enterprise PKCS #11 coprocessor.

The TKE10.0 is needed to support the new Crypto Express8S card. An example of the Cryptographic Configuration window is shown in Figure 10-32.

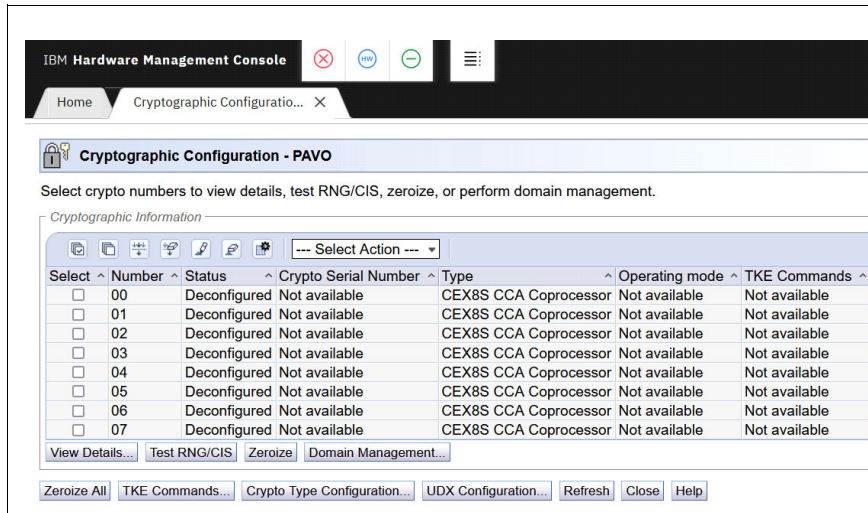


Figure 10-32 Cryptographic Configuration window

The Usage Domain Zeroize feature is provided to clear the suitable partition crypto keys for a usage domain when you remove a crypto card from a partition. Crypto Express8/7/6S in EP11 mode is configured to the standby state after the Zeroize process.

For more information, see *IBM z16 (3931) Configuration Setup*, [SG24-8960](#).

Digitally signed firmware

Security and data integrity are critical issues with firmware upgrades. Procedures are in place to use a process to digitally sign the firmware update files that are sent to the HMC, SE, and TKE. By using a hash algorithm, a message digest is generated that is then encrypted with a private key to produce a digital signature.

This operation ensures that any changes that are made to the data are detected during the upgrade process by verifying the digital signature. It helps ensure that no malware can be installed on IBM Z products during firmware updates. It also enables the IBM z16 Central Processor Assist for Cryptographic Function (CPACF) functions to comply with Federal Information Processing Standard (FIPS) 140-3 Level 1 planned for Cryptographic LIC changes. The enhancement follows the IBM Z focus of security for the HMC and the SE.

The Crypto Express8S (CEX8S) is compliant with CCA PCI HSM. TKE workstation is optional when used to manage a Crypto Express8S feature that is defined as a CCA coprocessor in normal mode.

However, it is mandatory when it is used to manage a Crypto Express8S feature that is defined as a CCA coprocessor in PCI-HSM mode or is defined as an EP11 coprocessor (CCA in PCI-HSM mode and EP11 also require a smart card reader plus smart cards with FIPS certification).

10.5.15 Installation support for z/VM that uses the HMC

Starting with z/VM V5R4 and z10, Linux on IBM Z can be installed in a z/VM virtual machine from HMC workstation media. This Linux on IBM Z installation can use the communication path between the HMC and the SE. No external network or extra network setup is necessary for the installation.

10.5.16 Dynamic Partition Manager

DPM is an administrative mode (front end to PR/SM) that was introduced for Linux-only systems for IBM z13 and following systems. With DPM, you can use your Linux and virtualization skills while taking advantage of the full value of IBM Z hardware, robustness, and security in a workload optimized environment.

A system can be configured in DPM mode or in PR/SM mode (POR is required to switch modes). In general, DPM supports the following functions:

- ▶ Create, provision, and manage partitions (processor, memory, and adapters) and storage
- ▶ Monitor and troubleshoot the environment

The following LPAR modes are available for DPM:

- ▶ z/VM
- ▶ Linux on IBM Z (also used for KVM deployments)
- ▶ Secure Service Container

If DPM is enabled, the IBM z16 system cannot run z/OS, IBM z/VSE, and z/TPF LPARs.

The IBM z16 can be initialized in PR/SM mode or in DPM mode, but not both.

DPM provides a GUI for PR/SM (to manage resources). Tools, such as HCD are in DPM mode and are not necessary.

This IBM Redbooks publication does not cover scenarios that use DPM.

For more information about the use of DPM, see *IBM Dynamic Partition Manager (DPM) Guide*, SB10-7182.

Important: Consider the following points:

- ▶ The Enabling DPM function is run on the SE and is performed by your IBM system Service Representative at installation time.
- ▶ If DPM is enabled, the IBM z16 system cannot run z/OS, IBM z/VSE, and z/TPF LPARs.



Environmental requirements

This chapter describes the environmental requirements for IBM z16 servers. It also lists the dimensions, weights, power, and cooling requirements that are needed to plan for the installation of an IBM z16.

Naming: Throughout this chapter, *IBM z16* refers to IBM z16 Model A01 (Machine Type 3931), unless otherwise specified.

This chapter includes the following topics:

- ▶ 11.1, “Introduction” on page 458
- ▶ 11.3, “Physical specifications” on page 467
- ▶ 11.4, “Physical planning” on page 468
- ▶ 11.5, “Energy management” on page 472

11.1 Introduction

The following options are available for physically installing the server:

- ▶ Air or water cooling
- ▶ Power Distribution Unit (PDU) or Bulk Power Assembly (BPA) for power
- ▶ On a raised floor or nonraised floor
- ▶ I/O and power cables can exit under the raised floor or off the top of the server frames

Removal of support for Bulk Power Assembly (BPA)^a: IBM z16 is planned to be the last generation of IBM Z server to support BPA.

- a. Statements by IBM regarding its plans, directions, and intent are subject to change or withdrawal without notice at the sole discretion of IBM. Information regarding potential future products is intended to outline general product direction and should not be relied on in making a purchasing decision.

For more information about physical planning, see *3931 Installation Manual for Physical Planning*, GC28-7015.

11.2 Power and cooling

The IBM z16 server can be a 1 - 4 19-inch rack system, depending on the configuration. Frames are shipped separately in Arbo crates, along with separate front and rear cover sets for each frame boxed on a shipping pallet. The frames are bolted together during the installation procedure.

IBM z16 servers support installation on a raised floor or nonraised floor and are available in the following power and cooling options:

- ▶ Intelligent Power Distribution Unit-based power (iPDU) or PDU
- ▶ Bulk Power Assembly-based power (BPA)

All IBM z16 models include radiator-based cooling (air cooled system).

11.2.1 Intelligent Power Distribution Unit

The iPDU can be ordered as the following feature codes (FCs), per customer data center power infrastructure requirements:

- ▶ 60A/3-Phase “Delta” PDU FC 0645
- ▶ 32A/3-Phase “Wye” PDU FC 0646

A PDU-based system can have 2 - 8 power cords, depending on the configuration. The use of iPDU on IBM z16 might enable fewer frames, which allows for more I/O slots to be available and improves power efficiency to lower overall energy costs. It also offers some standardization and ease of data center installation planning, which allows the IBM z16 to easily coexist with other platforms within the data center.

Power requirements

the IBM z16 is designed with a fully redundant power system. To make full use of the redundancy that is built into the server, the PDUs within one pair must be powered from different power distribution panels. In that case, if one PDU in a pair fails, the second PDU ensures continued operation of the server without interruption.

The second, third, and fourth PDU pairs are installed dependent on other CPC or PCIe+ I/O drawers installed. The locations of the PDU pairs and frames are listed in Table 11-1.

Table 11-1 PDU pairs and frames location

Frame C	Frame B	Frame A
N/A	N/A	PDU A3 / A4
PDU C1 / C2	PDU B1 / B2	PDU A1 / A2

Power cords for the PDUs are attached to the options that are listed in Table 11-2.

Table 11-2 Power cords for PDUs

Supply type	Input voltage	Input frequency	Input current rating
2, 4, 6, or 8, 3-phase power cords	200 - 240 V AC	50/60 Hz (47 - 63 Hz with tolerance)	48 A
2, 4, 6, or 8, 3-phase power cords	380 - 415 V AC	50/60 Hz (47 - 63 Hz with tolerance)	24 A

A rear view of a maximum configured PDU-powered system with four CPC drawers and 12 PCIe+ I/O drawers is shown in Figure 11-1 on page 460.

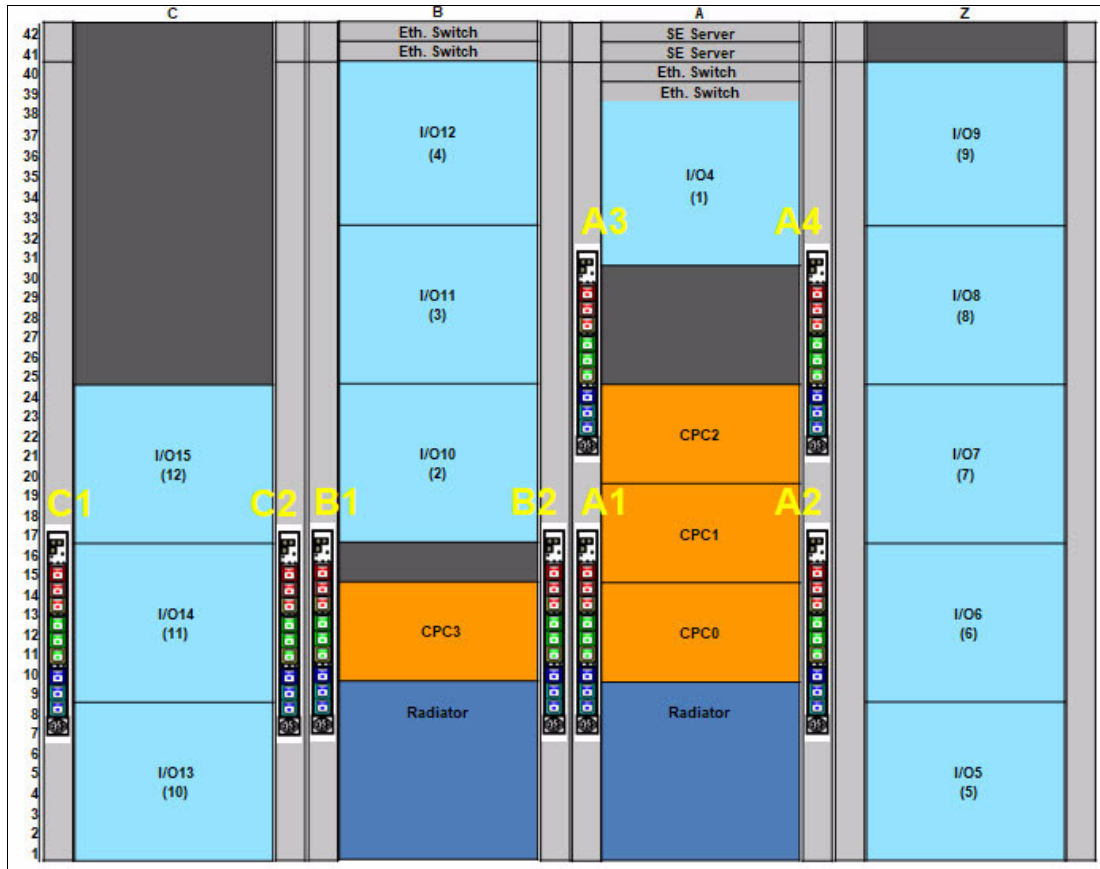


Figure 11-1 Rear View of maximum configured PDU system

The number of PDUs and power cords that are required based on the number of CPC drawers and PCIe+ I/O drawers are in Table 11-3.

Table 11-3 Number of PDUs installed

Number of CPCs	Number of PCIe+ I/O drawers												
	0	1	2	3	4	5	6	7	8	9	10	11	12
1	2	2	2	2						6	6	6	6
2	4	4	4	4	4	4	4	4	6	6	6	6	6
3	4	4	4	4	4	4	4	6	6	6	6	6	N/A
4	6	6	6	6	6	6	6	6	6	6	8	8	8

Power consumption

The utility power consumption for the IBM z16 for PDU option is listed in Table 11-4.

Table 11-4 IBM z16 utility power consumption for PDU

FC CPC number	Number of PCIe+ I/O drawers												
	0	1	2	3	4	5	6	7	8	9	10	11	12
max39 FC0667	5.1 kw	6.0 kw	7.0 kw	7.9 kw	8.8 kw	9.7 kw	10.6 kw	N/A	N/A	N/A	N/A	N/A	N/A

FC CPC number	Number of PCIe+ I/O drawers												
	0	1	2	3	4	5	6	7	8	9	10	11	12
max82 FC0668	8.8 kw	9.8 kw	10.8 kw	11.7 kw	12.6 kw	13.5 kw	14.5 kw	15.4 kw	16.4 kw	17.3 kw	18.2 kw	19.1 kw	20.0 kw
max125 FC0669	12.7 kw	13.7 kw	14.6 kw	15.6 kw	16.5 kw	17.4 kw	18.3 kw	19.3 kw	20.2 kw	21.1 kw	22.0 kw	22.9 kw	N/A
max168 FC0670	13.5 kw	14.5 kw	15.6 kw	16.6 kw	17.7 kw	18.7 kw	19.8 kw	20.8 kw	21.9 kw	22.9 kw	24.0 kw	25.0 kw	25.8 kw
max200 FC0671	17.1 kw	18.1 kw	19.0 kw	20.0 kw	20.9 kw	21.8 kw	22.7 kw	23.6 kw	24.5 kw	25.4 kw	26.3 kw	27.2 kw	28.1 kw

Note: Consider the following points:

- ▶ The power values that are listed in this table assume the CPC process drawer and PCIe+ I/O drawers are plugged to the maximum with highest power features (that is, memory and I/O adapters and fan-outs). Also assumed is that maximum ambient temperature is used.
- ▶ Typical configurations and data center conditions result in lower power. A calculator available on Resource Link calculates power and weight for specific configurations and environmental conditions.

Considerations: Power consumption is lower in a normal ambient temperature room, and for configurations that feature a lesser number of I/O slots, smaller amount of memory, and fewer PUs.

Power estimation for any configuration, power source, and room condition can be obtained by using the power estimation tool that is available at the [IBM Resource Link website](#) (login required).

On the Resource Link page, click **Tools** → **Power and weight estimation**.

11.2.2 Bulk power assembly

The bulk power assembly (BPA) consists of the following features:

- ▶ BPA (FC 0648)
- ▶ Balanced Power Plan ahead (FC 3003)
- ▶ Bulk Power Regulator (BPR) (FC 3017)

Removal of IBF support: IBM z16 cannot be configured with an internal battery feature (IBM). Extra support for data center power planning can be requested through your IBM Sales contact.

The BPA option is required for customers who order an Internal Battery Feature (IBF), Water Cooling Unit (WCU), or Balanced Power. The BPA requires two or four power cords. All BPAs are concurrently repairable in the field.

Power requirements

The 3931 operates from 2 or 4 fully redundant power supplies. These redundant power supplies each have their own power cords, or pair of power cords, which allows the system to survive the loss of customer power to either power cord or power cord pair.

If power is interrupted to one of the power supplies, the other power supply assumes the entire load and the system continues to operate without interruption. Therefore, the power cords for each power supply must be wired to support the entire power load of the system.

For the most reliable availability, the power cords in the rear of the frame should be powered from different PDUs. All power cords exit through the rear of the frame. The utility current distribution across the phase conductors (phase current balance) depends on the system configuration. Each front-end power supply is provided with phase switching redundancy.

The loss of an input phase is detected and the total input current is switched to the remaining phase pair without any power interruption. Depending on the configuration input power draw, the system can run from several minutes to indefinitely in this condition. Because most single phase losses are transients that recover in seconds, this redundancy provides protection against virtually all single phase outages.

Power cords for the BPAs are attached to the options that are listed in Table 11-5.

Table 11-5 Power cords for the BPAs

Supply type	Nominal voltage range	Voltage tolerance	Frequency range
Two or four redundant 3-phase power cords	200 - 480 V AC	180 - 508 V AC	50 / 60 Hz

The source power cords ratings for BPA systems are listed in Table 11-6.

Table 11-6 Source power cords for BPA

Source type	Frequency	Input voltage range	Rated input current
Three-phase (60A plug)	50/60 Hz	200 V ^a	50 A
Three-phase (60A plug)	50/60 Hz	208 - 240 V ^b	48 A
Three-phase (30A plug)	50/60 Hz	380 V - 415 V ^c	24 A
Three-phase (30A plug)	60 Hz	480 V ^d	20 A
Three-phase (63A no plug)	50/60 Hz	220 V - 480 V	48 A
Three-phase (32A no plug)	50/60 Hz	380 V - 415 V	25 A

- a. Japan (same physical cord as Note b)
- b. US and Canada (same physical cord as Note a)
- c. US and Canada only
- d. US only

A rear view of a maximum configured BPA powered system with two BPA pairs, IBF, four CPC drawers, and 10 PCIe+ I/O drawers is shown in Figure 11-2.

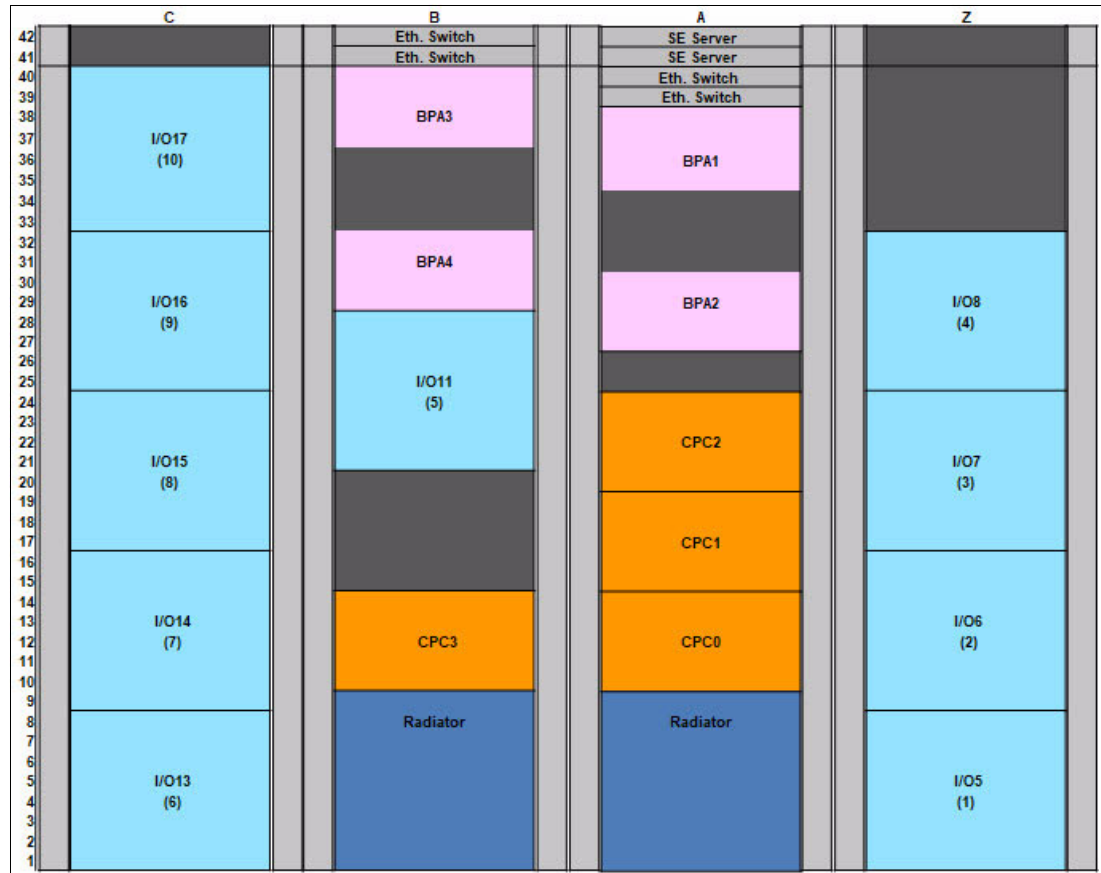


Figure 11-2 Rear view of maximum configured BPA system

The number of power cords that are required based on the number of CPC drawers and PCIe+ I/O drawers are listed in Table 11-7.

Table 11-7 Number of power cords installed

Number of CPCs	Number of PCIe+ I/O drawers										
	0	1	2	3	4	5	6	7	8	9	10
1	1	1	2	2	2	2	2	3	3	3	4
2	1	2	2	2	2	2	3	3	3	4	4
3	1	2	2	2	2	2	3	3	3	4	4
4	2	2	3	3	3	3	3	4	4	4	4

The number of power cords and number of Bulk Power Regulators that are required are based on the number of CPC processor drawers and number of PCIe+ I/O drawers in the configuration is shown in Table 11-8.

Table 11-8 Number of BPRs installed per BPA

	Number of PCIe+ I/O drawers						
	0	1	2	3	4	5	6
1 CPC	1	1	2	2	2	2	2
2 CPC	2	2	2	2	2	3	3
3 CPC	2	2	3	3	3	3	-
Note: Balanced power feature includes all BPRs that are plugged in all BPAs in the system.							

Power consumption

The utility power consumption for the IBM z16 for the BPA system is listed in Table 11-9.

Table 11-9 Utility Power consumption (BPA) for radiator-cooled systems

CPC Feature Code		Number of PCIe+ I/O drawers										
		0	1	2	3	4	5	6	7	8	9	10
max39 FC0667	1	7.0 kw	8.0 kw	9.0 kw	9.9 kw	10.8 kw	11.7 kw	14.0 kw	N/A	N/A	N/A	N/A
max82 FC0668	2	10.7 kw	11.6 kw	12.5 kw	13.4 kw	14.3 kw	16.6 kw	17.9 kw	19.0 kw	20.1 kw	21.1 kw	22.1 kw
max125 FC0669	3	14.1 kw	15.1 kw	16.1 kw	17.1 kw	18.0 kw	20.4 kw	21.7 kw	18.7 kw	23.9 kw	24.9 kw	25.9 kw
max168 FC0670	4	20.6 kw	21.6 kw	22.6 kw	23.6 kw	24.6 kw	25.5 kw	26.5 kw	27.4 kw	28.3 kw	29.2 kw	30.0 kw
max200 FC0671	4	20.6 kw	21.6 kw	22.6 kw	23.6 kw	24.6 kw	25.5 kw	26.5 kw	27.4 kw	28.3 kw	29.2 kw	30.0 kw

Note: Consider the following points:

- ▶ The power values that are listed in this table assume the CPC process drawer and PCIe+ I/O drawers are plugged to the maximum with highest power features (that is, memory and I/O adapters and fan-outs). Also assumed is that maximum ambient temperature is used.
- ▶ Typical configurations and data center conditions result in lower power. A calculator that is available on Resource Link calculates power and weight for specific configurations and environmental conditions.

Balanced Power Plan Ahead feature

Phase currents are minimized when they are balanced among the three input phases. Balanced Power Plan Ahead (FC 3003) is designed to allow you to order the full complement of bulk power regulators (BPRs) on any configuration to help ensure that the configuration is in a balanced power environment.

Consideration: Power consumption is lower when in a normal ambient temperature room, and for configurations that feature a lesser number of I/O slots, smaller amount of memory, and fewer processors.

Power estimation for any configuration, power source, and room condition can be obtained by using the power estimation tool at [IBM Resource Link website](#) (authentication required).

On the Resource Link page, click **Tools** → **Power and weight estimation**.

11.2.3 Cooling requirements

The IBM z16 cooling system is manufactured as a radiator (air) cooled system. The dual chip modules (DCMs) are cooled with an internal water loop. The liquid in the internal water circuit is cooled by using a radiator. I/O drawers, PCIe I/O drawers, power enclosures, and CPC drawers are cooled by chilled air with blowers.

The IBM z16 servers include a recommended (long-term) ambient temperature range of 18°C (64.4°F) - 27°C (80.6°F). The minimum allowed ambient temperature is 5°C (41°F); the maximum allowed temperature is 40°C (104°F).

For more information about cooling requirements, see *3931 Installation Manual for Physical Planning*, GC28-7015.

Radiator (air) cooling

The following radiator (air) cooling options are available:

- ▶ A-Frame radiator air-cooled feature code (FC 4040)
- ▶ B-Frame radiator air-cooled feature code (FC 4041)

The radiator cooling system requires chilled air to fulfill the air-cooling requirements. IBM z16 system airflow is from the front (intake, chilled air) to the rear (exhausts, warm air) of the frames. The chilled air is provided through perforated floor panels in front of the system

The hot and cold airflow and the arrangement of server aisles are shown in Figure 11-3.

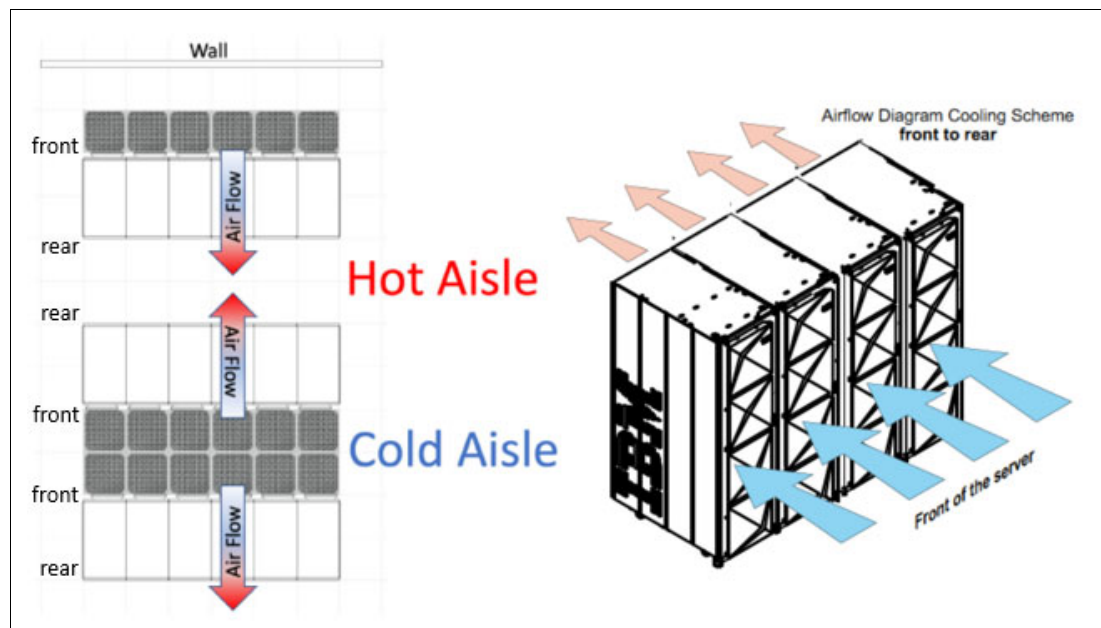


Figure 11-3 Hot and cold aisles

As shown in Figure 11-3, rows of servers must be placed front-to-front. Chilled air is provided through perforated floor panels that are placed in rows between the fronts of servers (the cold aisles). Perforated tiles generally are not placed in the hot aisles.

If your computer room causes the temperature in the hot aisles to exceed a comfortable temperature, add as many perforated tiles as necessary to create a satisfactory comfort level. Heated exhaust air exits the computer room above the computing equipment.

For more information about the requirements for air-cooling options, see *3931 Installation Manual for Physical Planning*, GC28-7015.

11.3 Physical specifications

This section describes the weights and dimensions of IBM z16 server.

The IBM z16 can be installed on a raised or nonraised floor. (For more information about weight distribution and floor loading tables, see *IBM 3931 Installation Manual for Physical Planning*, GC28-7015). This data is used with the maximum frame weight, frame width, and frame depth to calculate the floor loading.

Weight estimates for the maximum system configurations on the 3931 PDU-based system are listed in Figure 11-10 on page 473.

Table 11-10 Weights for maximum machine configurations (PDU)

Frame configurations	Individual frame weights kg (lbs)				Total weight kg (lbs)
	Z Frame	A Frame	B Frame	C Frame	
A	-	795 kg (1753 lbs)	-	-	795 kg (1753 lbs)
ZA	712 kg (1569 lbs)	739 kg (1629 lbs)	-	-	1451 kg (3198 lbs)
ZAC	712 kg (1569 lbs)	720 kg (1587 lbs)	-	740 kg (1632 lbs)	2172 kg (4788 lbs)
AB	-	739 kg (1629 lbs)	704 kg (1552 lbs)	-	1443 kg (3181 lbs)
ZAB	712 kg (1569 lbs)	720 kg (1587 lbs)	704 kg (1552 lbs)	-	2136 kg (4709 lbs)
ZABC	712 kg (1569 lbs)	720 kg (1587 lbs)	685 kg (1510 lbs)	550 kg (1213 lbs)	2667 kg (5880 lbs)
<p>Notes: Consider the following points:</p> <ul style="list-style-type: none"> ▶ Weight is based on the maximum system configuration. ▶ All weights are approximate and do not include Earthquake Kit hardware. ▶ Ensure that the raised floor on which you are installing the server can support the weight. 					

The power and weight estimation tool for IBM Z servers on [IBM Resource Link](#) (log in required) covers the estimated weight for your designated configuration.

On the Resource Link web page, click **Tools** → **Power and weight estimation**.

11.4 Physical planning

This section describes the floor mounting, power, and I/O cabling options. For more information, see *IBM 3931 Installation Manual for Physical Planning*, GC28-7015.

11.4.1 Raised floor or nonraised floor

IBM z16 servers can be installed on a raised or nonraised floor.

Note: On the IBM z16, all I/O cabling and power cords enter the rear of the machine; therefore, all related features for Bottom and Top Exit cabling are in the rear of the frame.

Raised floor

The IBM z16 server can be installed in a raised floor environment. You can select top exit features to manage I/O cables from the top frame of the IBM z16.

The following top exit options are available for z16 servers:

- ▶ Top Exit I/O cabling without Tophat feature code (FC 7816)
- ▶ Bottom Exit cabling feature code (FC 7899)
- ▶ Top Exit Cabling with Tophat feature code (FC 7898)

11.4.2 Top Exit cabling feature (optional)

The optional Top Exit cabling feature (FC 7816) allows for I/O cabling and power cords to exit the top of the frame. This feature adds cable management options, such as trunking and retainer brackets, as shown in Figure 11-4.

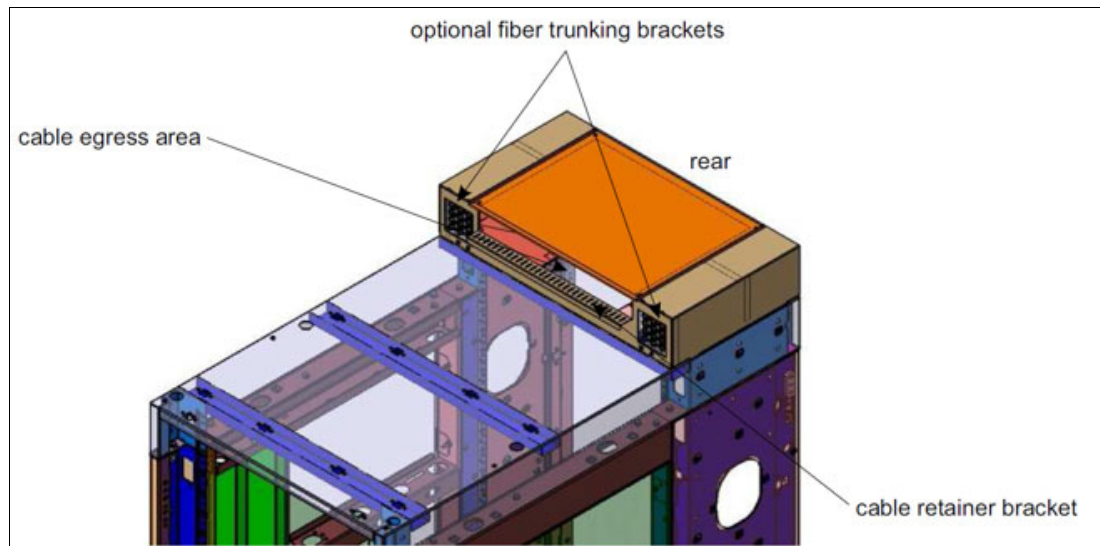


Figure 11-4 Top Exit cabling feature

The Top Exit cabling feature can be placed as shown in Figure 11-4, with the exit area toward the front of the frame, or with the exit area toward the rear of the frame.

Note: The feature provides the same extra hardware for every frame in the configuration.

The Top Exit cabling feature adds 117.5 mm (4.63 in.) to the height of the frame and approximately 5.4 kg (12 lbs) to the weight.

If the Top Exit cabling feature is not ordered, two sliding plates are available on the top of the frame (one on each side of the rear of the frame) that can be partially opened. By opening these plates, I/O cabling and power cords can exit the frame. The plates should be removed to install the Top Exit cabling feature as shown in Figure 11-5.

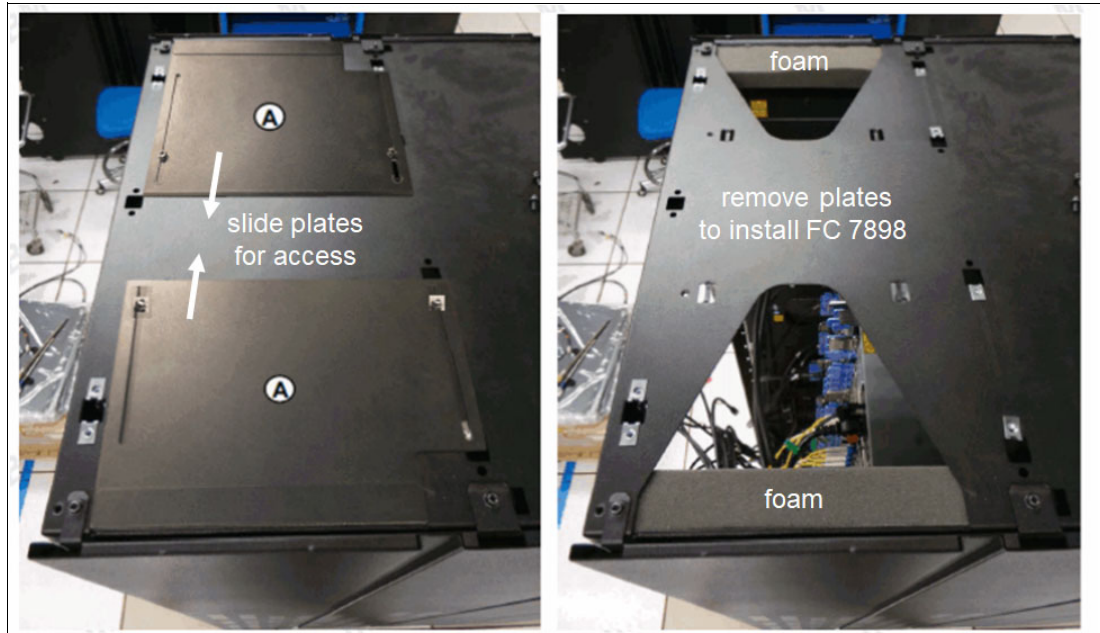


Figure 11-5 Top Exit access plates

11.4.3 Top or bottom exit cables

Features allow for Top Exit Cabling (FC 7917) or Bottom Exit Cabling (FC 7919) cabling, or a combination of both. These features are independent of raised floor or nonraised floor installations and offer flexible possibilities for the data center.

All external cabling enters the rear of the rack from under floor or from above the rack. Different from previous IBM Z, no cabling access or cable plugging is available at the front of the rack. The top view of the rack with and without FC 7917 is shown in Figure 11-6.

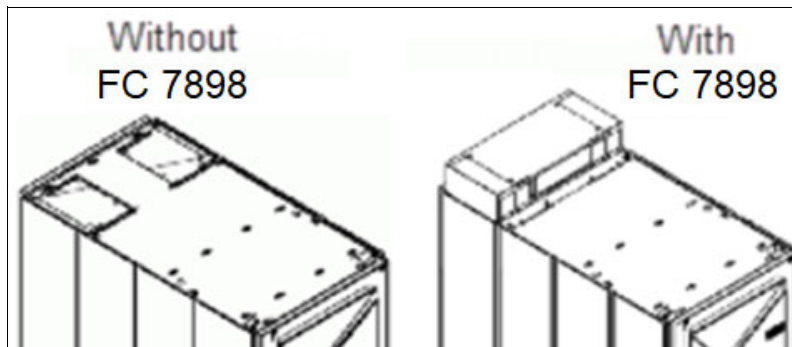


Figure 11-6 With and without FC 7898

The Top Exit Cabling feature provides new hardware. The new hardware resembles a rectangular box with an open side that faces the front or rear of the rack. It includes other hardware to organize and fasten cables.

The Top Exit Cabling option can be used for routing power cables and IO cables out the top of the machine.

Without the Top Exit Cabling feature, power and cables still can be run out the top of the rack through two adjustable openings at the top rear of the rack, as shown on the left side of Figure 11-6 on page 469.

The Bottom Exit Cabling feature provides tailgate hardware for routing power cables or IO cables out the bottom of the machine.

For more information, see *IBM 8561 Installation Manual for Physical Planning*, GC28-7015, and 11.4, “Physical planning” on page 468.

11.4.4 Bottom Exit cabling feature

The Bottom Exit cabling feature (FC 7899) is required for raised floor environments, where I/O cabling or power cords must exit from the bottom of the frame. This feature includes the hardware to allow bottom exit, and other components for cable management and filler plates to preserve the recommended air circulation, as shown in Figure 11-7.

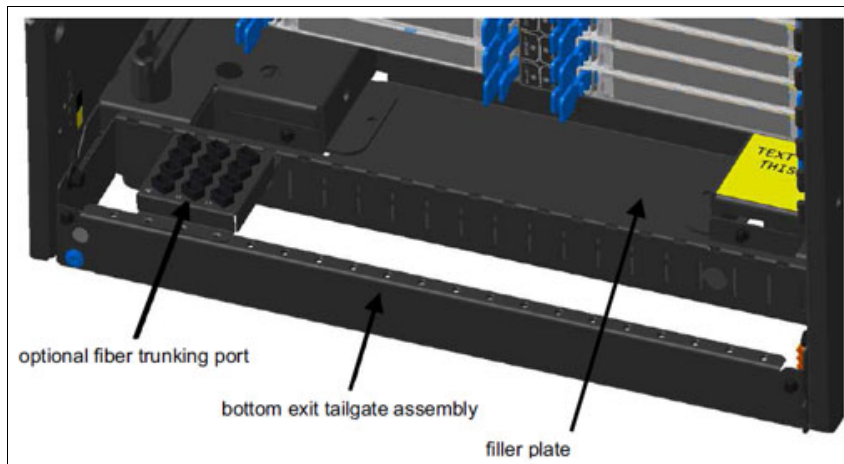


Figure 11-7 Bottom exit cabling feature

11.4.5 Frame Bolt-down kit

An Earthquake Kit, RF (FC 8014 and FC 8015) is available for the IBM z16. The kit provides hardware to enhance the ruggedness of the frame, the frame stiffener, and to tie down the frame to a concrete floor.

The frame tie-down kit can be used on a nonraised floor (FC 8015) where the frame is secured directly to a concrete floor, or on a raised floor (FC 8014) where the frame is secured to the concrete floor underneath the raised floor.

Raised floors 241.3 mm (9.5 inches) - 1270 mm (50 inches) are supported.

The kits help secure the frames and their contents from damage when they are exposed to shocks and vibrations, such as in a seismic event. The frame tie-downs are intended for securing a frame that weighs up to 1308 kg (2885 lbs).

For more information, see *IBM 3931 Installation Manual for Physical Planning*, GC28-7015.

11.4.6 Service clearance areas

IBM z16 servers require specific service clearance (see Figure 11-8) to ensure the fastest possible repair in the unlikely event that a part must be replaced. Failure to provide enough clearance to open the front and rear covers results in extended service times or outages.

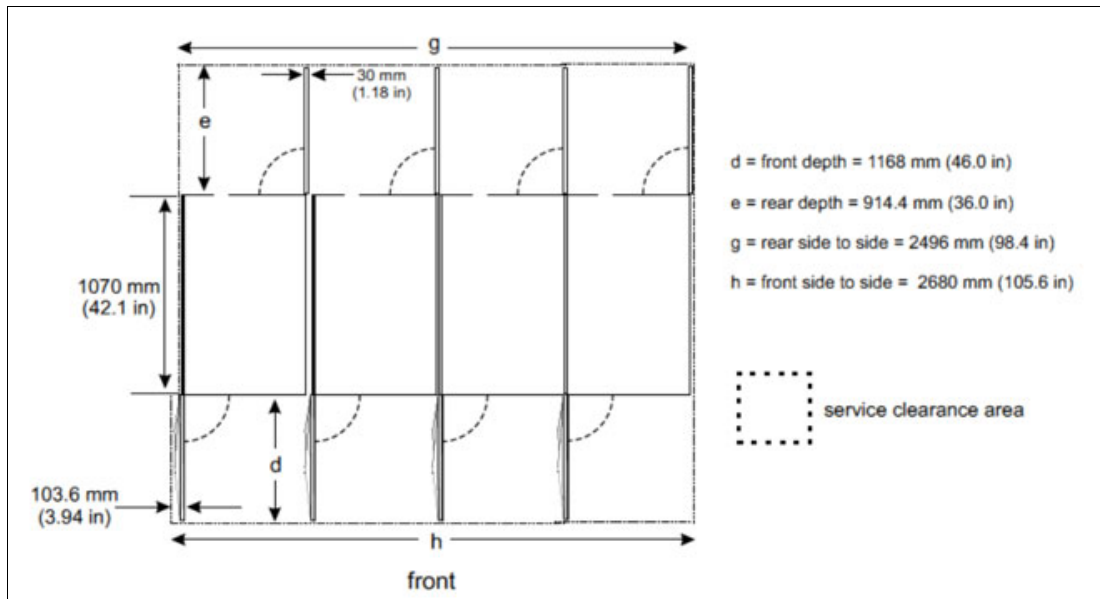


Figure 11-8 Maximum service clearance area (four frames)

For more information, see *IBM 3931 Installation Manual for Physical Planning*, GC28-7015.

11.5 Energy management

This section describes the elements of energy management to help you understand the requirements for power and cooling, monitoring and trending, and reducing power consumption.

The energy management structure for the server is shown in Figure 11-9.

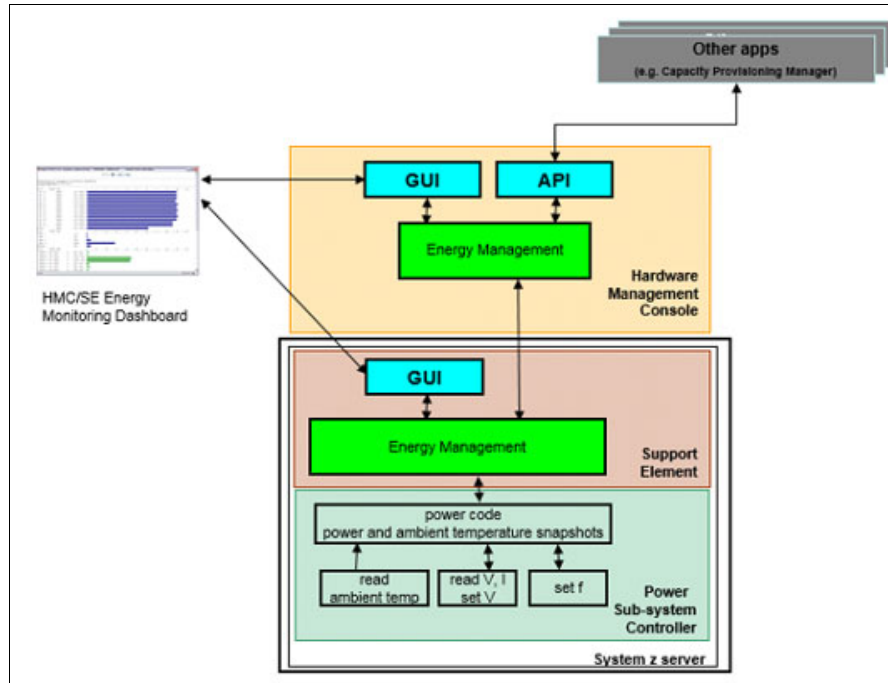


Figure 11-9 IBM z16 Energy Management

The hardware components in the IBM z16 are monitored and managed by the energy management component in the Support Element (SE) and HMC. The graphical user interfaces (GUIs) of the SE and HMC provide views, such as the Monitors Dashboard, Environmental Efficiency Statistics, and Energy Optimization Advisor.

The following tools are available to plan and monitor the energy consumption of IBM z16 servers:

- ▶ Power estimation tool on Resource Link
- ▶ Energy Optimization Advisor task for maximum potential power on HMC and SE
- ▶ Monitors Dashboard and Environmental Efficiency Statistics tasks on HMC and SE

11.5.1 Environmental monitoring

This section describes energy monitoring HMC and SE tasks.

Energy Optimization Advisor

This window is started from the HMC targeting the system and task under Energy Management. The window displays the following recommendations:

- ▶ Thermal Advice
- ▶ Processor Utilization Advice

Select the advice hyperlinks to provide specific recommendations for your system, as shown in Figure 11-10.

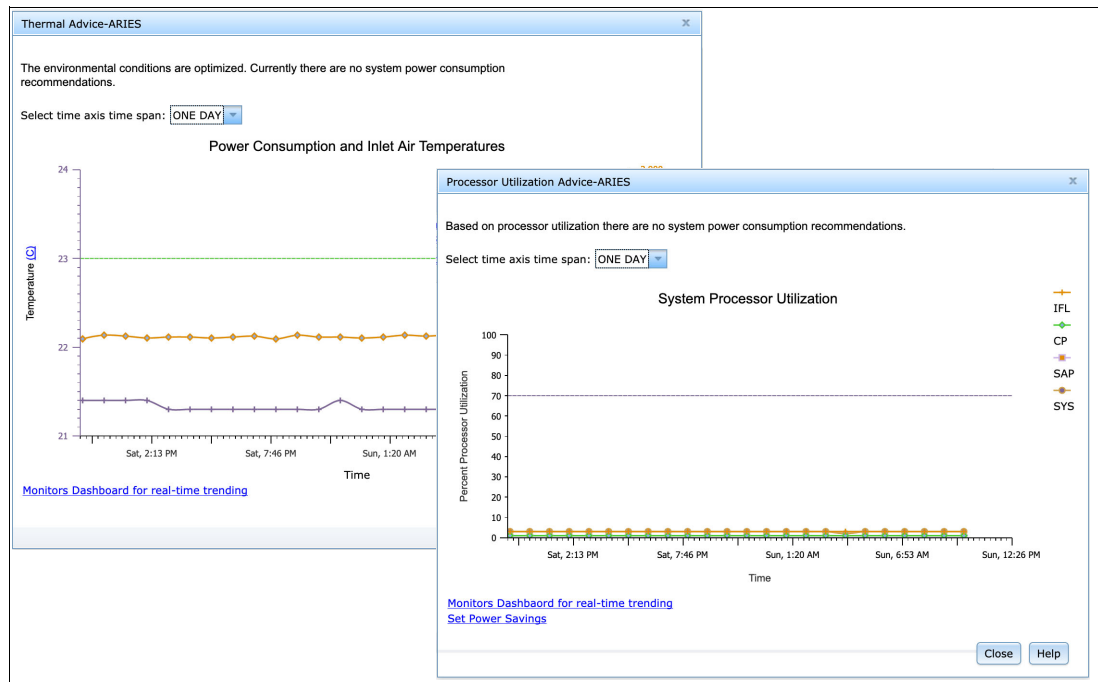


Figure 11-10 Energy Optimization Advisor

Monitors Dashboard task

In IBM z16 servers, the Monitors Dashboard task in the Monitor task group provides a tree-based view of resources. Multiple graphical views display data, including history charts. This task monitors processor and channel usage. It produces data that includes power monitoring information, power consumption, and the air input temperature for the server.

An example of the Monitors Dashboard task is shown in Figure .

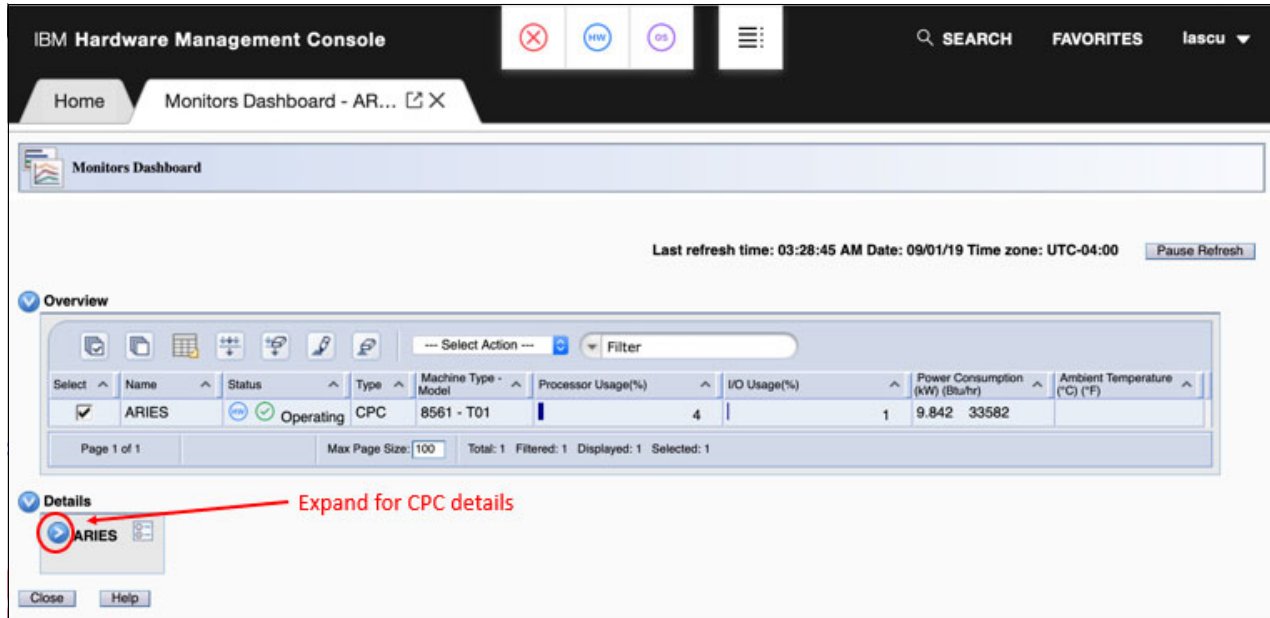


Figure 11-11 Monitors Dashboard task

Environmental Efficiency Statistics task

The Environmental Efficiency Statistics task (see Figure 11-12) is part of the Monitor task group. It provides historical power consumption and thermal information for the CPC.

The data is presented in table format and graphical “histogram” format. The data also can be exported to a .csv-formatted file so that the data can be imported into a spreadsheet. For this task, you must use a web browser to connect to an HMC.

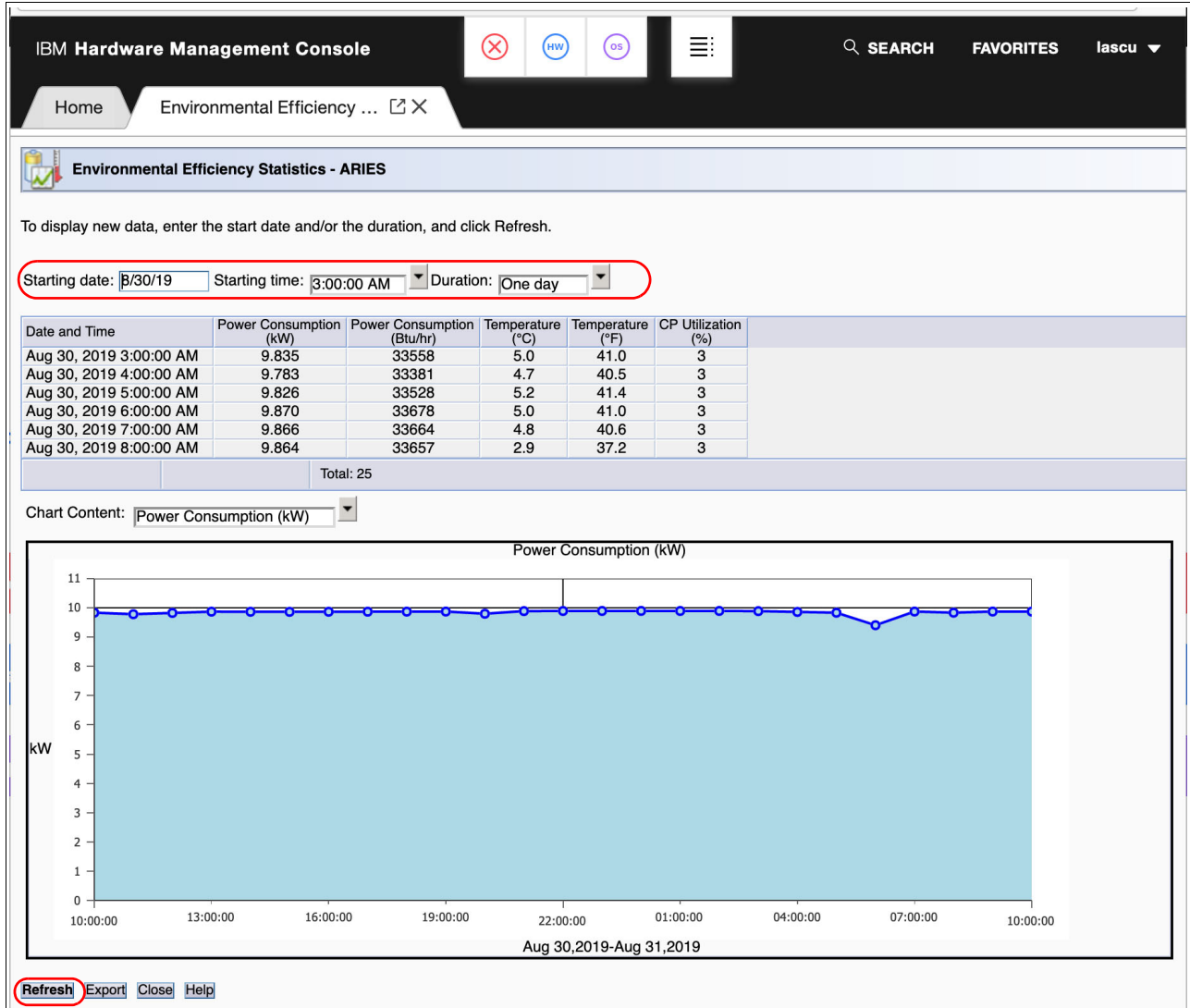


Figure 11-12 Environmental Efficiency Statistics task



Performance and capacity planning

This chapter describes the performance and capacity planning of IBM z16.

Note: Throughout this chapter, *IBM z16* refers to IBM z16 Model A01 (Machine Type 3931) unless otherwise specified.

This chapter includes the following topics:

- ▶ 12.1, “IBM z16 performance characteristics” on page 478
- ▶ 12.2, “IBM z16 Large System Performance Reference ratio” on page 480
- ▶ 12.3, “Fundamental components of workload performance” on page 481
- ▶ 12.4, “Relative Nest Intensity” on page 483
- ▶ 12.5, “LSPR workload categories based on L1MP and RNI” on page 485
- ▶ 12.6, “Relating production workloads to LSPR workloads” on page 485
- ▶ 12.7, “CPU MF counter data and LSPR workload type” on page 486
- ▶ 12.8, “Workload performance variation” on page 487
- ▶ 12.9 “Capacity planning considerations for IBM z16”, on page 487

12.1 IBM z16 performance characteristics

The IBM z16 Model A01 Feature Max200 (7K0) is designed to offer up to 17% more capacity compared to an IBM z15 Model T01 (7H0) system.

Uniprocessor performance also increased. On average, an IBM z16 model 701 offers performance improvements almost 10% over the IBM z15 Model 701. Figure 12-1 shows a system performance comparison of successive IBM Z servers.

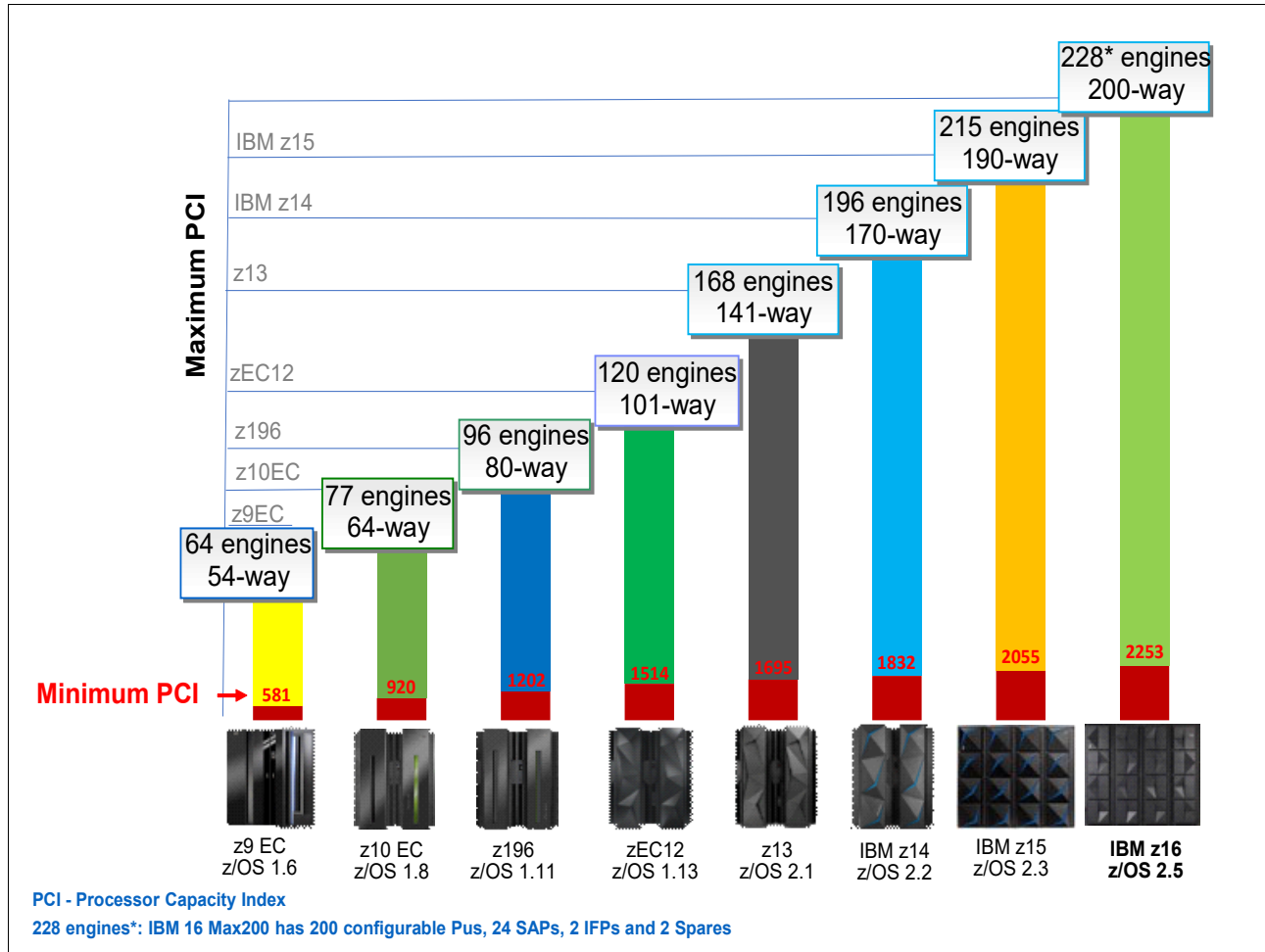


Figure 12-1 System performance comparison of successive IBM Z servers

12.1.1 IBM z16 single-thread capacity

Note: The acronym PCI stands for *Processor Capacity Index*.

Operating system support varies for the number of “engines” that are supported.

The IBM z16 processor chip runs at 5.2 GHz clock speed, which is the same as the IBM z15 processor chip, but the performance is increased. For N-way processors model, it increases 1.11x on average at equal N-way configuration.

These numbers differ depending on the workload type and LPAR configuration.

12.1.2 IBM z16 SMT capacity

From z13 to IBM z16, customers can choose to run two threads on IFL and zIIP cores by using SMT mode. SMT increases throughput by 10 - 40% (average 25%), depending on workload.

For zIIPs and IFLs, the performance improvement per SMT enabled core for z16 (3931) versus z15 (8561) is approximately 11%, which is the same improvement for zIIPs and IFLs in a single thread.

12.1.3 IBM Integrated Accelerator for zEnterprise Data Compression (zEDC)

Starting with z13, IBM introduced the zEnterprise Data Compression (zEDC) Express PCIe feature, which increases efficiency for data storing and data transfers.

The zEDC Express feature was adopted by enterprises because it helps with software costs for compression and decompression operations (by offloading these operations), and increases data encryption (compression before encryption) efficiency.

With IBM z15, the zEDC Express functions were moved off from the PCIe infrastructure into the processor chip. By moving the compression and decompression into the processor on-chip, IBM z15 processor provides a new level of performance for these tasks and eliminates the need for the zEDC Express feature virtualization. It also brings new use cases to the platform.

The IBM z16 continues to support IBM Integrated Accelerator for zEDC. For more information, see Appendix C, “IBM Integrated Accelerator for zEnterprise Data Compression” on page 511.

12.1.4 Primary performance improvement drivers with IBM z16

The attributes and design points of IBM z16 contribute to overall performance and throughput improvements as compared to the IBM z15. The following major items contribute to IBM z16 performance improvements:

- ▶ IBM z16 microprocessor architecture:
 - 7 nm technology
 - New Core-Nest Interface
 - Brand new branch prediction design that is implemented SRAM
 - Significant architecture changes: COBOL compiler and more
 - On chip Artificial Intelligence (AI): Deep learning focus for inference
 - Forth-generation SMT processing for zIIPs, IFLs, and SAPs
- ▶ Cache:
 - L2 Private cache (unified) increased to 32 MB
 - Virtual L3 cache up to $8 \times 32 = 256$ MB per CP chip
 - Virtual L4 cached up to $8 \times 32 \times 8 = 2048$ MB per drawer

- ▶ Software and hardware:
 - z/OS HiperDispatch Optimizations
 - PR/SM Algorithm Improvements (including LPAR Resource Placement)
 - Quantum safe Encryption
 - New System Recovery Boost functions

12.2 IBM z16 Large System Performance Reference ratio

The Large System Performance Reference (LSPR) provides capacity ratios among various processor families that are based on various measured workloads. It is a common practice to assign a capacity scaling value to processors as a high-level approximation of their capacities.

For z/OS studies, the capacity scaling factor that is commonly associated with the reference processor is set to a 2094-701 with a Processor Capacity Index (PCI) value of 593. This value is unchanged since z/OS V1R11 LSPR. The use of the same scaling factor across LSPR releases minimizes the changes in capacity results for an older study and provides more accurate capacity view for a new study.

Performance data for IBM z16 servers were obtained with z/OS V2R4 (running Db2 for z/OS V12, CICS TS V5R3, IMS V14, Enterprise COBOL V6R2, and WebSphere Application Server for z/OS V9.0.0.8). All IBM Z server generations are measured in the same environment with the same workloads at high usage.

Note: If your software configuration is different from what is described here, the performance results might vary.

On average, IBM z16 servers can deliver up to 17% more performance in a 200-way configuration than an IBM z15 190 -way. However, the observed performance increase varies depending on the workload type.

Consult the LSPR when you consider performance on the IBM z16. The range of performance ratings across the individual LSPR workloads is likely to include a large spread. Performance of the individual logical partitions (LPARs) varies depending on the fluctuating resource requirements of other partitions and the availability of processor units (PUs). Therefore, it is important to know which LSPR workload type suite your production environment. For more information, see 12.8, “Workload performance variation” on page 487.

For more information about performance, see [this web page](#) of the IBM Resource Link website.

For more information about millions of service units (MSU) ratings, see this [IBM Z resources](#) web page.

12.2.1 LSPR workload suite

Historically, LSPR capacity tables, including pure workloads and mixes, were identified with application names or a *software* characteristic; for example, CICS, IMS, OLTP-T,¹ CB-L,² LoIO-mix,³ and TI-mix.⁴ However, capacity performance is more closely associated with how a workload uses and interacts with a specific processor *hardware* design.

¹ Traditional online transaction processing workload (formerly known as IMS).

² Commercial batch with long-running jobs.

The CPU Measurement Facility (CPU MF) data that was introduced on the z10 provides insight into the interaction of workload and *hardware design* in production workloads. CPU MF data helps LSPR to adjust workload capacity curves that are based on the underlying hardware sensitivities; in particular, the processor access to caches and memory.

This processor access to caches and memory is called *Relative Nest Intensity* (for more information, see 12.4, “Relative Nest Intensity” on page 483). By using this data, LSPR introduces three workload capacity categories that replace all older primitives and mixes.

LSPR contains the internal throughput rate ratios (ITRRs) for the IBM z16 and the previous generation processor families. These ratios are based on measurements and projections that use standard IBM benchmarks in a controlled environment.

Note: The throughput that any user experiences can vary depending on the amount of multiprogramming in the user’s job stream, the I/O configuration, and the workload that is processed. Therefore, no assurance can be given that an individual user can achieve throughput improvements that are equivalent to the performance ratios that are stated.

12.3 Fundamental components of workload performance

Workload performance is sensitive to the following major factors:

- ▶ Instruction path length
- ▶ Instruction complexity
- ▶ Memory hierarchy and memory nest

These factors are described next.

12.3.1 Instruction path length

A *transaction* or *job* runs a set of instructions to complete its task. These instructions are composed of various paths through the operating system, subsystems, and application. The total count of instructions that are run across these software components is referred to as the *transaction* or *job path length*.

The path length varies for each transaction or job, and depends on the complexity of the tasks that must be run. For a specific transaction or job, the application path length tends to stay the same, assuming that the transaction or job is asked to run the same task each time.

However, the path length that is associated with the operating system or subsystem can vary based on the following factors:

- ▶ Competition with other tasks in the system for shared resources. As the total number of tasks grows, more instructions are needed to manage the resources.
- ▶ The number of logical processors (*n-way*) of the image or LPAR. As the number of logical processors grows, more instructions are needed to manage resources that are serialized by latches and locks.

³ Low I/O Content Mix Workload.

⁴ Transaction Intensive Mix Workload.

12.3.2 Instruction complexity

The type of instructions and the sequence in which they are run interacts with the design of a microprocessor to affect a performance component. This factor is defined as *instruction complexity*. The following design alternatives affect this component:

- ▶ Cycle time (GHz)
- ▶ Instruction architecture
- ▶ Pipeline
- ▶ Superscalar
- ▶ Out-of-order execution
- ▶ Branch prediction
- ▶ Translation Look-aside Buffer (TLB)
- ▶ Transactional Execution (TX)
- ▶ Single instruction multiple data instruction set (SIMD)
- ▶ Simultaneous multi-threading (SMT)⁵

As workloads are moved between microprocessors with various designs, performance varies. However, when on a processor, this component tends to be similar across all models of that processor.

12.3.3 Memory hierarchy and memory nest

The *memory hierarchy* of a processor generally refers to the caches, data buses, and memory arrays that stage the instructions and data that must be run on the microprocessor to complete a transaction or job.

The following design choices affect this component:

- ▶ Cache size
- ▶ Latencies (sensitive to distance from the microprocessor)
- ▶ Number of levels, the Modified, Exclusive, Shared, Invalid (MESI) protocol, controllers, switches, the number and bandwidth of data buses, and so on.

With IBM z16, physical L3/L4 caches no longer exist. L2 caches that are on each processor core are virtual L3/L4 caches on IBM z16. For more information, see Chapter 3, “Central processor complex design” on page 69.

⁵ Available for IFL, zIIP, and SAP processors only.

A memory nest in an IBM z16 CPC drawer is shown in Figure 12-2.

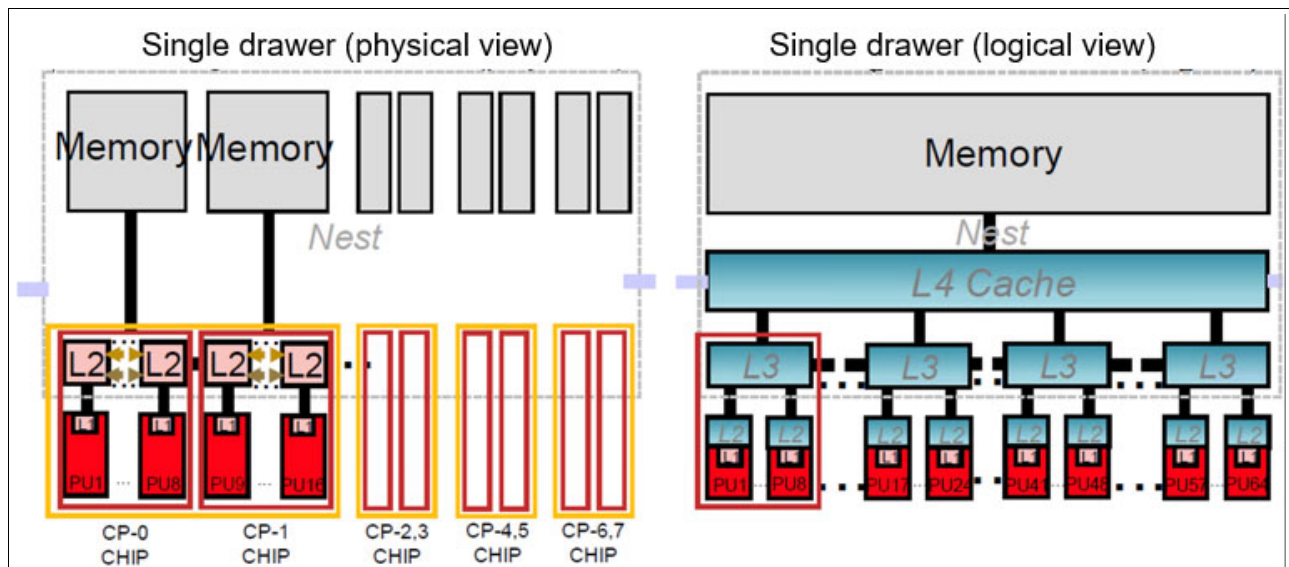


Figure 12-2 IBM z16 physical and virtual single drawer memory hierarchy

Workload performance is sensitive to how deep into the memory hierarchy the processor must go to retrieve the workload instructions and data for running. The best performance occurs when the instructions and data are in the caches that are nearest the processor because little time is spent waiting before running. If the instructions and data must be retrieved from farther out in the hierarchy, the processor spends more time waiting for their arrival.

As workloads are moved between processors with various memory hierarchy designs, performance varies because the average time to retrieve instructions and data from within the memory hierarchy varies. Also, when on a processor, this component continues to vary because the location of a workload's instructions and data within the memory hierarchy is affected by several factors that include, but are not limited to, the following factors:

- ▶ Locality of reference
- ▶ I/O rate
- ▶ Competition from other applications and LPARs

12.4 Relative Nest Intensity

The most performance-sensitive area of the memory hierarchy is the activity to the memory nest. This area is the distribution of activity to the shared caches and memory.

The term *Relative Nest Intensity* (RNI) indicates the level of activity to this part of the memory hierarchy. By using data from CPU MF, the RNI of the workload that is running in an LPAR can be calculated. The higher the RNI, the deeper into the memory hierarchy the processor must go to retrieve the instructions and data for that workload.

RNI reflects the distribution and latency of sourcing data from shared caches and memory, as shown in Figure 12-3.

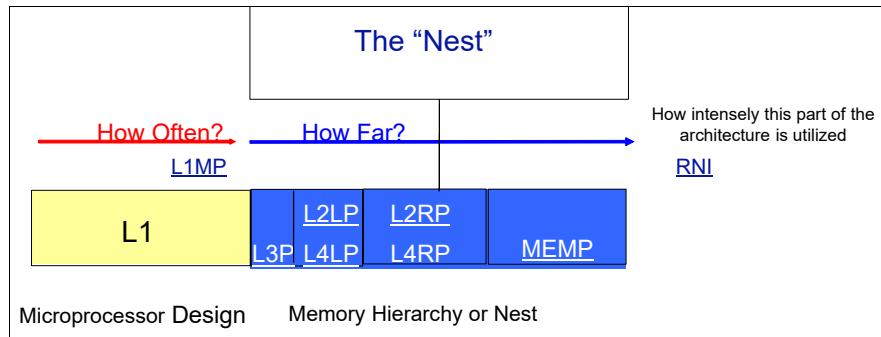


Figure 12-3 Relative Nest Intensity

Many factors influence the performance of a workload. However, these factors often are influencing the RNI of the workload. The interaction of all these factors results in a net RNI for the workload, which in turn directly relates to the performance of the workload.

These factors are tendencies, not absolutes. For example, a workload might have a low I/O rate, intensive processor use, and a high locality of reference, which all suggest a low RNI. However, it might be competing with many other applications within the same LPAR and many other LPARs on the processor, which tends to create a higher RNI. It is the net effect of the interaction of all these factors that determines the RNI.

The traditional factors that were used to categorize workloads in the past are shown with their RNI tendency in Figure 12-4.

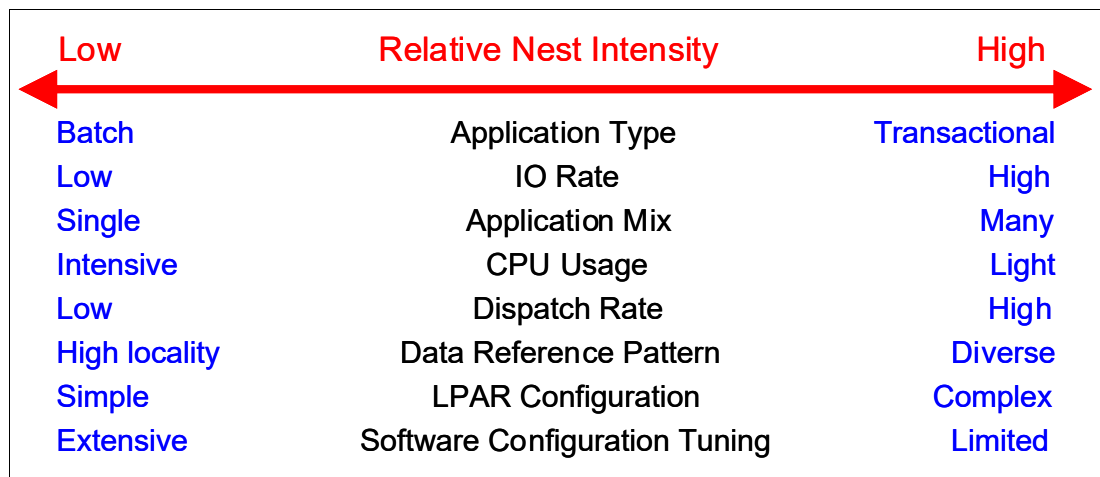


Figure 12-4 Traditional factors that were used to categorize workloads

Little can be done to affect most of these factors. An application type is whatever is necessary to do the job. The data reference pattern and processor usage tend to be inherent to the nature of the application. The LPAR configuration and application mix are mostly a function of what must be supported on a system. The I/O rate can be influenced somewhat through buffer pool tuning.

However, one factor, *software configuration tuning*, is often overlooked but can have a direct effect on RNI. This term refers to the number of address spaces (such as CICS application-owning regions [AORs] or batch initiators) that are needed to support a workload.

This factor always existed, but its sensitivity is higher with the current high frequency microprocessors. Spreading the same workload over more address spaces than necessary can raise a workload's RNI. This increase occurs because the working set of instructions and data from each address space increases the competition for the processor caches.

Tuning to reduce the number of simultaneously active address spaces to the optimum number that is needed to support a workload can reduce RNI and improve performance. In the LSPR, the number of address spaces for each processor type and *n-way* configuration is tuned to be consistent with what is needed to support the workload. Therefore, the LSPR workload capacity ratios reflect a presumed level of software configuration tuning. Retuning the software configuration of a production workload as it moves to a larger or faster processor might be needed to achieve the published LSPR ratios.

12.5 LSPR workload categories based on L1MP and RNI

A workload's L1MP (Level 1 Miss Per 100 instructions or percentage of data and instruction references that miss the L1 cache) and RNI are the most influential factors in determining workload performance. Other more traditional factors, such as application type or I/O rate, include RNI tendencies. However, it is the L1MP and the net RNI of the workload that is the underlying factor in determining the workload's performance.

The LSPR now runs various combinations of former workload primitives, such as CICS, Db2, IMS, OSAM, VSAM, WebSphere, COBOL, and utilities, to produce capacity curves that span the typical range of RNI.

The following workload categories are represented in the LSPR tables:

- ▶ **LOW** (relative nest intensity)
A workload category that represents light use of the memory hierarchy.
- ▶ **AVERAGE** (relative nest intensity)
A workload category that represents average use of the memory hierarchy. This category is expected to represent most production workloads.
- ▶ **HIGH** (relative nest intensity)
A workload category that represents a heavy use of the memory hierarchy.

These categories are based on the L1MP and the RNI. The RNI is influenced by many variables, such as application type, I/O rate, application mix, processor usage, data reference patterns, LPAR configuration, and the software configuration that is running. CPU MF data can be collected by z/OS System Measurement Facility on SMF 113 records or by z/VM Monitor starting with z/VM V5R4.

For more information about how z/VM Monitor captures CPU MF records visit the following link: <https://www.vm.ibm.com/perf/tips/cpumf.html>

12.6 Relating production workloads to LSPR workloads

Historically, the following techniques were used to match production workloads to LSPR workloads:

- ▶ Application name (a client that is running CICS can use the CICS LSPR workload)
- ▶ Application type (create a mix of the LSPR online and batch workloads)
- ▶ I/O rate (the low I/O rates that are used a mix of low I/O rate LSPR workloads)

The IBM z Processor Capacity Reference (IBM zPCR) tool supports the following workload categories:

- ▶ Low
- ▶ Low-Average
- ▶ Average
- ▶ Average-high
- ▶ High

For more information about the no-charge IBM zPCR tool (which reflects the latest IBM LSPR measurements), see the [Getting Started with IBM z Processor Capacity Reference](#).

As described in 12.5, “LSPR workload categories based on L1MP and RNI” on page 485, the underlying performance sensitive factor is how a workload interacts with the processor hardware.

12.7 CPU MF counter data and LSPR workload type

Beginning with the z10 processor, the hardware characteristics can be measured by using CPU MF (SMF 113) counters data. A production workload can be matched to an LSPR workload category through these hardware characteristics.

For more information about RNI, see 12.5, “LSPR workload categories based on L1MP and RNI” on page 485.

The AVERAGE RNI LSPR workload is intended to match most client workloads. When no other data is available, use the AVERAGE RNI LSPR workload for capacity analysis.

Low-Average and Average-High categories allow better granularity for workload characterization but these categories can apply on IBM zPCR only.

The CPU MF data can be used determine workload type. When available, this data allows the RNI for a production workload to be calculated.

By using the RNI and another factor from CPU MF, the L1MP (Level 1 Miss Per 100 instructions or percentage of data and instruction references that miss the L1 cache), a workload can be classified as LOW, AVERAGE, or HIGH RNI. This classification and resulting hit are automated in the IBM zPCR tool. It is preferable to use IBM zPCR for capacity sizing.

Refer to Table 12-1 for the LSPR Workload Decision Table, based in L1MP and RNI.

L1MP	RNI	LSPR Workload Match
< 3%	>= 0.75 < 0.75	AVERAGE LOW
3% to 6%	> 1.0 0.6 to 1.0 < 0.6	HIGH AVERAGE LOW
> 6%	>= 0.75 < 0.75	HIGH AVERAGE

Table 12-1 L1MP and RNI-based LSPR Workload Decision Table

Reminder:

- ▶ RNI is **not** a performance metric.
- ▶ RNI and L1MP allows one to match their workload to an LSPR workload
 - Any other use of RNI is not valid

Starting with z/OS V2R1 with APAR OA43366, zFS file is no longer required for CPU MF and Hardware Instrumentation Services (HIS). HIS is a z/OS function that collects hardware event data for processors in SMF records type 113, and a z/OS UNIX System Services output files.

Only SMF 113 record is required to know proper workload type by using CPU MF counter data. CPU overhead of CPUMF is minimal. Also, the amount of SMF 113 record is 1% of typical SMF 70 and 72 which RMF writes.

CPU MF and HIS can be used for deciding workload type and other purposes. For example, starting with z/OS V2R1, you can record Instruction Counts in SMF type 30 record when you activate CPU MF. Therefore, we strongly recommend that you *always* activate CPU MF.

For more information about getting CPUMF counter data, see [CPU MF - 2022 Update and WSC Experiences](#) at the IBM Techdoc Library website.

12.8 Workload performance variation

As the size of transistors approaches the size of atoms that stand as a fundamental physical barrier, a processor chip's performance can no longer double every two years (Moore's Law⁶ does not apply).

A holistic performance approach is required when the performance gains are reduced because of frequency. Therefore, hardware and software synergy becomes an absolute requirement.

Starting with z13, Instructions Per Cycle (IPC) improvements in core and cache became the driving factor for performance gains. As these microarchitectural features increase (which contributes to instruction parallelism), overall workload performance variability also increases because not all workloads react the same way to these enhancements.

Because of the nature of the IBM z16 multi-CPC drawer system and resource management across those drawers, performance variability from application to application is expected.

Also, the memory and cache designs affect various workloads in many ways. All workloads are improved, with cache-intensive loads benefiting the most. For example, having more PUs per CPC drawer, each with higher capacity than IBM z15, more workload can fit on an IBM z16 CPC drawer. This configuration can result in better performance. For example, IBM z15 two drawer system model T01 can populate maximum 71 PUs (Max71).

In contrast, IBM z16 two drawer system Max82 can populate maximum 82 PUs. Therefore, five and six more PUs can share caches and memories within the first and second drawers respectively, so the performance improvements is expected.

The workload variability for moving from IBM z14 and IBM z15 to IBM z16 is expected to be stable. Workloads that are migrating from z10 EC, z196, and zEC12 to IBM z16 can expect to see similar results with slightly less variability than the migration from IBM z14 and IBM z15.

⁶ For more information, see the [Moore's Law website](#).

Experience demonstrates that IBM Z servers can be run at up to sustained 100% utilization levels. However, most customers prefer to leave some room and run at 90% or slightly under.

12.9 Capacity planning considerations for IBM z16

In this section, we describe recommended ways to conduct capacity planning for IBM z16.

Do not use MIPS or MSUs for capacity planning: Do *not* use “one number” capacity comparisons, such as MIPS or MSUs. IBM does not officially announce the processor performance as “MIPS”. MSU is only a number for software license charge and it does *not* represent the processor’s performance.

12.9.1 Collect CPU MF counter data

It is important to recognize the LSPR workload type of your production system. As described in 12.7, “CPU MF counter data and LSPR workload type” on page 486, the capacity of the processor is different from the LSPR workload type. By collecting the CPU MF z/OS SMF 113 record, you can recognize the workload type in a specific IBM-provided capacity planning tool. Therefore, collecting CPU MF counter data is a first step to begin the capacity planning.

12.9.2 Creating EDF files with CP3KEXTR

An EDF file is an input file of the IBM Z capacity planning tools. You create this file for individual z/OS SYSIDs / LPARs by using the CP3KEXTR program. The CP3KEXTR program reads SMF records and extracts needed data as input to the IBM z Processor Capacity Reference (IBM zPCR) and IBM Z Batch Network Analyzer (IBM zBNA) tools.

Note: You should create an EDF file for each z/OS SYSID and load all the EDFs for the same CPC into IBM zPCR at the same time so to ensure that the correct LSPR Workload is assigned to each LPAR. IBM zPCR supports using drag-n-drop for multiple EDF files.

CP3KEXTR is offered as a no-charge application. It can also create the EDF files for IBMzCP3000. IBM zCP3000 is an IBM internal tool, but you can create the EDF files for it on your system.

For more information about CP3KEXTR, see the IBM Techdoc [z/OS Data Extraction Program \(CP3KEXTR\) for IBM zPCR and IBM zBNA](#).

Creating EDF file with CP3KVMXT (z/VM)

CP3KVMXT is the VM Extract Utility for IBM zCP3000 and IBM zPCR Capacity Planning Support Tools. CP3KVMXT reads CP Monitor data from a z/VM system, and generates an Enterprise Data File (EDF) of PR/SM, system image, and workload-related measurements for input into the IBM zCP3000 and IBM zPCR capacity planning tools. A CP3KVMXT-created EDF can be used to model interactive VM workloads or workloads under guest operating systems such as Linux and can be concurrently loaded with a CP3KEXTR-created z/OS EDF for the same data intervals.

Note: You should create an EDF file for each z/VM system and load all the EDFs for the same CPC into IBM zPCR at the same time so to ensure that the correct LSPR Workload is assigned to each LPAR. IBM zPCR supports using drag-n-drop for multiple EDF files.

For additional information, see [CP3KVMXT - VM Extract Utility for zCP3000 and zPCR Capacity Planning Support Tools](#).

12.9.3 Loading EDF files to the capacity planning tool

By loading EDF files to IBM capacity planning tool, you can see the LSPR workload type that is based on CPU MF counter data.

Figure 12-5 on page 490 shows a sample IBM zPCR window of a workload type. In this example, the workload type displays in the “Assigned Workload” column. The example shows only one partition, PX11, selected. Note that all active partitions can be selected on this panel. When you load the EDF file to IBM zPCR, it automatically sets your LPAR configuration. It also makes easy to define the LPAR configuration to the IBM zPCR.

Create LPAR Configuration from EDF

IBM zPCR Version 9.6.4

LPAR Configuration from EDF
z/OS SMF Data Set Name: LARGTEMP.BETTEN.HALK1123.SMFRMF.PX11
Extract Version: CP3KEXTR11/09/23
EDF File Name: C:\Work\John\zPCR\+Code for zPCR-V9.6.4\EDF Files\PX11.EDF
Interval #2: Date=2023-11-15 Time=08:15:00 Length=00:15:00
CPC ID: CPC94A88; GP Processor Model = 3931-729
z16 Host = 3931-A01(Max82)/700 with 55 CPs: GP=29 zIIP=10 IFL=9 ICF=7

Create LPAR Configuration
#1 Configuration #1
LPAR Host as specified above
Partition Configuration as specified below

Copy LP	LP is Active	LP from EDF	Partition Identification					Partition Configuration					HiperDispatch		CPU-MF		Method Used		
			No.	Type	Name	SCP	Assigned Workload	Mode	Total LCPs	Weight	Weight %	Capping INIT ABS	SMT Benefit	Is Active	Parked LCPs	RNI		Workload Assignment	
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	1	GP	PX11	z/OS-2.4	Average	SHR	29.0	999	91.7%				<input checked="" type="checkbox"/>	0.7	0.64	Average	CPU-MF
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		zIIP	PX11	z/OS-2.4	Average	SHR	8.0	450	62.5%				<input checked="" type="checkbox"/>	1.0	0.64	Average	
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		2	GP	PP01	z/OS-2.4	Average	SHR	2.0	20	1.8%								Default
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>			zIIP	PP01	z/OS-2.4	Average	SHR	2.0	50	6.9%								Default
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		3	GP	PX15	z/OS-2.4	Average	SHR	3.0	10	0.9%								Default
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>			zIIP	PX15	z/OS-2.4	Average	SHR	4.0	100	13.9%								Default
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		4	GP	TX41	z/OS-2.4	Average	SHR	2.0	50	4.6%								Default
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>			zIIP	TX41	z/OS-2.4	Average	SHR	2.0	80	11.1%								Default
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		5	GP	TX45	z/OS-2.4	Average	SHR	2.0	10	0.9%								Default
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>			zIIP	TX45	z/OS-2.4	Average	SHR	2.0	40	5.6%								Default
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		6	IFL	VMP1	z/VM-7.2	Average/LV	SHR	5.0	500	50.0%								Default
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		7	IFL	VMR1	z/VM-7.2	Average/LV	SHR	3.0	100	10.0%								Default
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		8	IFL	VMT1	z/VM-7.2	Average/LV	SHR	5.0	400	40.0%								Default
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		9	ICF	CFP1	CFCC	CFCC	DED	5.0	n/a									Default
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		10	ICF	CFS1	CFCC	CFCC	SHR	2.0	500	50.0%								Default
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		11	ICF	CFT1	CFCC	CFCC	SHR	2.0	500	50.0%								Default

Default SCP for GP Partitions: z/OS z/VM IFL Partitions: z/VM

Estimate parked LCPs where unknown for: GP partitions IFL partitions

Remove Parked LCPs from the LCP Count when copying partitions into zPCR

Note: One or more partitions have "Parked" LCPs. The LCP count for HiperDispatch partitions should be reduced by the number of "Parked" LCPs

Click on "Copy LP" checkbox to select partitions to be copied to the LPAR configuration

Figure 12-5 IBM zPCR LPAR Configuration from EDF window

12.9.4 IBM z16 Performance Best Practices

Understand and follow the IBM z16 best practices and use the following tips to get the most efficiency, best performance and best throughput of the IBM z16:

- ▶ Collect the CPU MF counters (z/OS SMF 113s) on all LPARs. (CPU MF runs on every IBM z16 supported Operating Systems OS), see: <http://www.ibm.com/support/techdocs/atsmastr.nsf/WebIndex/TC000066>
 - For z/OS, capture correlator SMF 98 subtype 1.
 - Provides supervisor information in five seconds intervals and helps perform performance problem analysis. Check the following White paper: <https://www.ibm.com/support/pages/node/6437547>
- ▶ z/VM CPU MF is collected in Monitor records. (there is no SMF). For more information, refer to: <https://www.vm.ibm.com/perf/tips/cpumf.html>

- ▶ Set your weights and Logicals for all your partitions to match your business needs.
- ▶ Set the efficient number of logicals to support the engines by weight
 - Assign one or two more logicals than engines by weight.
 - For instance, a 20 GCP LPAR processors with a 50% weight, set your logicals to one or two 2 more than 10. Assign the weights and logicals also applies to specialty engines.
- ▶ Assign a suitable number of logical CPs. If you assign too many logical CPs to the LPAR, PR/SM may place them at further distances, reducing efficiency and increasing unnecessary LPAR management. This issue reduces the efficiency of the cache. For more information about the number of Logical CPs defined for an LPAR, please refer to this document: [Number of Logical CPs Defined for an LPAR](#).
- ▶ The server capacity declines relative to the LCP:RCP ratio (sum of logical CPs that is defined in all LPARs: the number of physical CPs on your configuration). Therefore, assigning the correct number of logical CPs to an LPAR is important.
- ▶ Utilize IBM zPCR to size IBM Processors. (Don't use MIPS tables to do capacity sizing).
- ▶ Design your LPARs to "fit" in a single drawer with room to grow.
 - When the number of logicals exceeds the drawer boundary all physics come into play, slowing down, and that CPU time is clocked to your applications and to your bill.
- ▶ For the larger partitions, start the strategy to split them into smaller partitions.
 - Use IBM zPCR to show potential capacity savings for "more smaller" LPARs.
- ▶ Utilize HiperDispatch in every z/OS and z/VM LPAR. HiperDispatch optimizes processor cache usage by creating an affinity between a PU and the workload.

12.9.5 IBM zPCR HiperDispatch Report

IBM zPCR HiperDispatch report supports the ability to show how many Vertical High, Medium, and Low CPs will be assigned to each partition, based on current weights and LCPs. Figure 12-6 on page 492 shows how to select the HiperDispatch Assignment Report from the Partition Detail Report.

For additional information refer to: "HiperDispatch" on page 119.

Partition Detail Report
Based on LSPR Data for IBM Z Processors
Study ID: Sample Study for Advanced zPCR Use
#3 Planned z16 3931-A01
Description: XYZ Production
z16 Host = 3931-A01(Max39)/700 with 13 CPs: GP=7 zIIP=1 IFL=4 ICF=1
9 Active Partitions: GP=3 zIIP=2 IFL=3 ICF=1
Capacity base: 2094-701 @ 593.00 MPS for a shared single-partition configuration
Capacity for z/OS on z10 and later processors is represented with HiperDispatch turned ON

Partition Identification										Partition Configuration			
Include	No.	Type	Name	SCP	Assigned Workload	Mode	Logical CPs	Weight	Weight Percent	Capping	SMT	HTM	CSV
<input checked="" type="checkbox"/>	1	GP	LP-01	z/OS-2.4	Average	SHR	6	700	53.85%	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	2	GP	LP-02	z/OS-2.4	Average	SHR	4	400	30.77%	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	3	GP	LP-03	z/OS-2.4	Avg-High	SHR	3	200	15.38%	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	4	IPL	LP-04	z/VM-7.1	Average/LV	SHR	4	400	64.00%	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	5	IPL	LP-05	Linux	Average/L	SHR	2	200	32.00%	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	6	IPL	LP-06	Linux	Low-Avg/L	SHR	1	25	4.00%	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	7	ICF	LP-07	CFCC	CFCC	DED	1	n/a		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

HiperDispatch
Graph
HiperDispatch Assignment for Shared Partitions
Study ID: Sample Study for Advanced zPCR Use
#3 Planned z16 3931-A01
Description: XYZ Production
z16 Host = 3931-A01(Max39)/700 with 13 CPs: GP=7 zIIP=1 IFL=4 ICF=1
9 Active Partitions: GP=3 zIIP=2 IFL=3 ICF=1

Partition Identification										HiperDispatch Configuration					
Include	No.	Type	Name	SCP	Assigned Workload	Mode	LCPs	Weight Percent	Engines by Weight	VHs	VMs	VM %	VLs	Nvr Pk	VL Nvr Pk %
<input checked="" type="checkbox"/>	1	GP	LP-01	z/OS-2.4	Average	SHR	6	53.85%	3.77	3	1	77%	2	0	0%
<input checked="" type="checkbox"/>	2	GP	LP-02	z/OS-2.4	Average	SHR	4	30.77%	2.15	1	2	58%	1	0	0%
<input checked="" type="checkbox"/>	3	GP	LP-03	z/OS-2.4	Avg-High	SHR	3	15.38%	1.08	0	2	54%	1	0	0%
<input checked="" type="checkbox"/>	2	zIIP	LP-02	z/OS-2.4	Average	SHR	1	66.67%	0.67	0	1	67%	0	0	0%
<input checked="" type="checkbox"/>	3	zIIP	LP-03	z/OS-2.4	Avg-High	SHR	1	33.33%	0.33	0	1	33%	0	0	0%
<input checked="" type="checkbox"/>	4	IPL	LP-04	z/VM-7.1	Average/LV	SHR	4	64.00%	2.56	2	1	56%	1	0	0%
<input checked="" type="checkbox"/>	5	IPL	LP-05	Linux	Average/L	SHR	2	32.00%	1.28	n/a	2	64%	n/a	n/a	n/a
<input checked="" type="checkbox"/>	6	IPL	LP-06	Linux	Low-Avg/L	SHR	1	4.00%	0.16	n/a	1	16%	n/a	n/a	n/a
<input checked="" type="checkbox"/>	7	ICF	LP-07	CFCC	CFCC	DED	1		1.00						

Table View Controls
Display zAAP/zIIP/IFL/ICF Associated Partitions
 With Parent GP Separate by Pool
Show: GP Pool Specialty Pools
 All Partitions zAAP zIIP ICF
 Includes Only IPL ICF

Capacity Summary by Pool

CP Pool	Real CPs	LCPs	DED LCPs	SHR LCPs	LCP:RCP	Sum of Weight
GP	7	3	13	1,857	700	
zIIP	1	2	2	2,000	600	
IFL	4	3	7	1,700	625	
ICF	1	1	1			
Totals	13	9	1	22		

Host Summary SMT Benefit LCP Alternatives zAAP/zIIP/IFL/ICF HiperDispatch

Note: SCP doesn't support HiperDispatch. For shared LCPs, VMs column represents number of LCPs, which have an equal share as shown in VM %.

Figure 12-6 Selecting HiperDispatch Assignment for Shared Partitions from the Partition Detail Report

Both windows shown in Figure 12-6 will remain visible. Changes to the Partition Detail Report will reflect in the HiperDispatch window.

HiperDispatch
Graph
HiperDispatch Assignment for Shared Partitions
Study ID: Sample Study for Advanced zPCR Use
#3 Planned z16 3931-A01
Description: XYZ Production
z16 Host = 3931-A01(Max39)/700 with 13 CPs: GP=7 zIIP=1 IFL=4 ICF=1
9 Active Partitions: GP=3 zIIP=2 IFL=3 ICF=1

Partition Identification										HiperDispatch Configuration					
Include	No.	Type	Name	SCP	Assigned Workload	Mode	LCPs	Weight Percent	Engines by Weight	VHs	VMs	VM %	VLs	Nvr Pk	VL Nvr Pk %
<input checked="" type="checkbox"/>	1	GP	LP-01	z/OS-2.4	Average	SHR	6	53.85%	3.77	3	1	77%	2	0	0%
<input checked="" type="checkbox"/>	2	GP	LP-02	z/OS-2.4	Average	SHR	4	30.77%	2.15	1	2	58%	1	0	0%
<input checked="" type="checkbox"/>	3	GP	LP-03	z/OS-2.4	Avg-High	SHR	3	15.38%	1.08	0	2	54%	1	0	0%
<input checked="" type="checkbox"/>	2	zIIP	LP-02	z/OS-2.4	Average	SHR	1	66.67%	0.67	0	1	67%	0	0	0%
<input checked="" type="checkbox"/>	3	zIIP	LP-03	z/OS-2.4	Avg-High	SHR	1	33.33%	0.33	0	1	33%	0	0	0%
<input checked="" type="checkbox"/>	4	IPL	LP-04	z/VM-7.1	Average/LV	SHR	4	64.00%	2.56	2	1	56%	1	0	0%
<input checked="" type="checkbox"/>	5	IPL	LP-05	Linux	Average/L	SHR	2	32.00%	1.28	n/a	2	64%	n/a	n/a	n/a
<input checked="" type="checkbox"/>	6	IPL	LP-06	Linux	Low-Avg/L	SHR	1	4.00%	0.16	n/a	1	16%	n/a	n/a	n/a
<input checked="" type="checkbox"/>	7	ICF	LP-07	CFCC	CFCC	DED	1		1.00						

Note: SCP doesn't support HiperDispatch. For shared LCPs, VMs column represents number of LCPs, which have an equal share as shown in VM %.

Figure 12-7 HiperDispatch Assignment for Shared Partitions Report Example

Figure 12-7 on page 492 shows all defined partitions and how HiperDispatch is expected to manage their logical CPs.

HiperDispatch supports logical CPs running z/OS v1.7 and later and z/VM v6.3 and later. For z/OS partitions zIIPs and shared CPs are affected similarly. For z/VM partitions IFLs and associated logical CPs are also affected similarly.

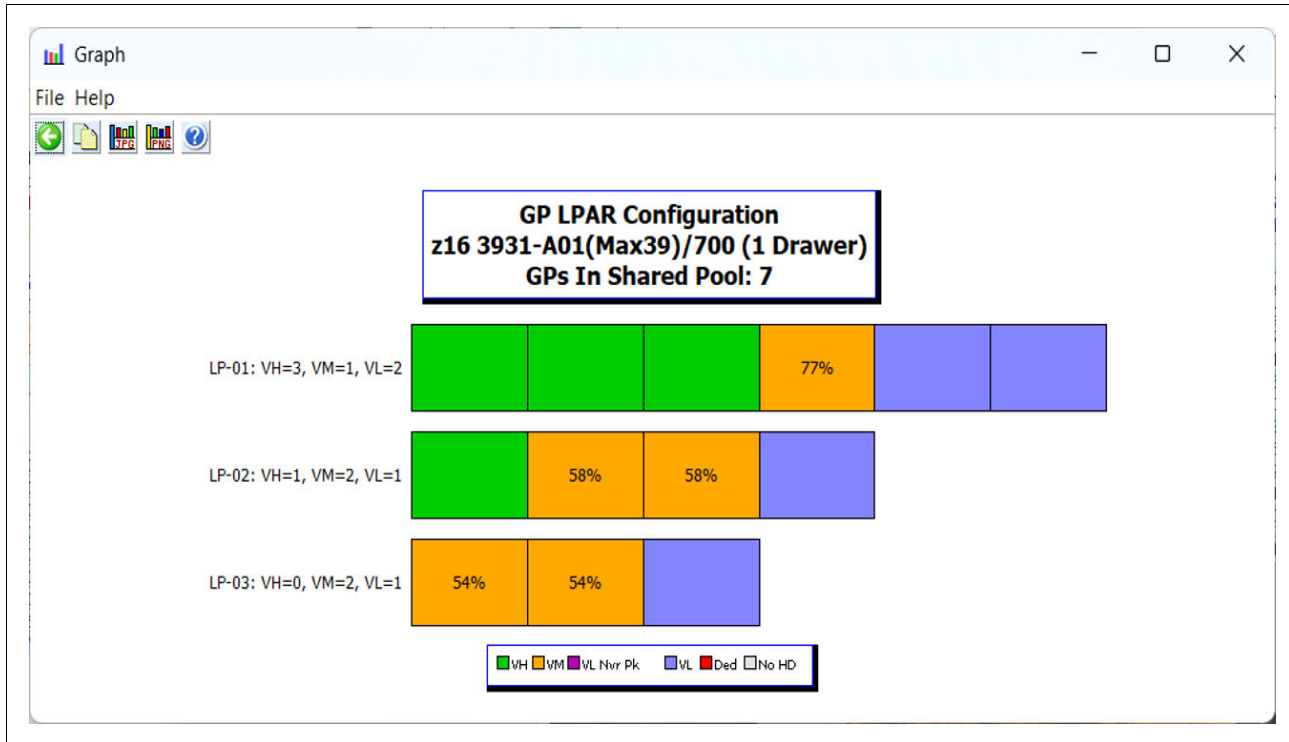


Figure 12-8 HiperDispatch Graph for the GP LCP HD Assignments Processor Topology Support

The HiperDispatch window shown in Figure 12-7 on page 492, contains most of the information from the Partition Detail Report, plus:

- ▶ Engines by Weight: Partition Weight % times the number of real CPs in the pool
- ▶ VHs: Number of LCPs categorized as Vertical High
- ▶ VMs: Number of LCPs categorized as Vertical Medium.
- ▶ VM %: Percent of time the partition's Vertical Medium LCPs are committed
- ▶ VLs: Number of LCPs categorized as Vertical Low
- ▶ VL Nvr Pk: Number of LCPs categorized as Vertical Low Never Parked
- ▶ VL Nvr Pk%: Percent of time the partition's Vertical Low Never Parked LCPs are committed.

When input fields are modified on the Partition Detail Report window, results on the HiperDispatch window will also be updated. Note that when exiting the HiperDispatch window, any changes made to the Partition Detail Report window are not automatically reset.

Note: For GP or IFL partitions where HiperDispatch is not supported, only the VMs and VM% columns apply. For ICF partitions, none of the HiperDispatch columns apply.

12.9.6 IBM zPCR Topology Report

Starting with the z16, a new Topology Report window is available. In order to view it, the z16 configuration must have been generated via EDF for a configuration where CPU MF was enabled. The Topology window portrays how the partition's logical CPs and their classification are distributed:

- ▶ Across the installed drawers (maximum of 4)
- ▶ Across the 4 Dual Chip Modules (DCMs) on each drawer
- ▶ Across the 2 chips on each DCM

See Figure 12-10 on page 495.

Figure 12-9 Selecting Topology Report from the Partition Detail

The IBM zPCR topology report is shown in Figure 12-10 on page 495, where:

- ▶ LPARs are identified by row
- ▶ z16 Drawer/DCM/CHIP appears at the top lines
- ▶ Topology report displays warning messages
- ▶ LPARs Totals by Pool table is displayed at the bottom **with support to filter by partition**
- ▶ Report is accessed from the Partition Detail Window
- ▶ Latest versions of extract are required:
 - available here: [IBM Support page](#).

Note: The Topology report in Figure 12-10 on page 495 is showing all active partitions. Information about a specific partition can be obtained by clicking on the “Remove all” button to the left of the Partition Totals by Pool table at the bottom right and then clicking on the “View” check-box for a specific partition.

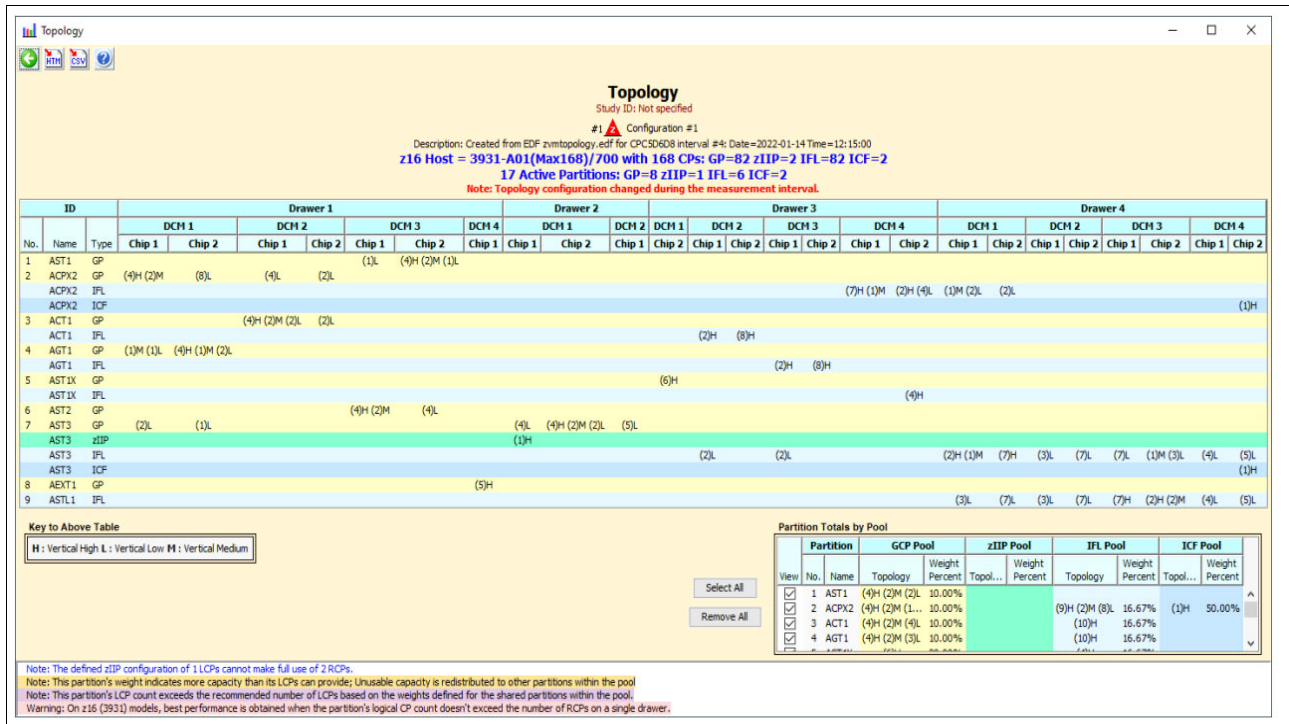


Figure 12-10 IBM zPCR Topology report example

IBM zPCR Topology Report is based in the z/OS new Data Gatherer functionality delivered with APAR A62064, PTF available for z/OS 2.5 and z/OS 2.4. z/OS data is in the SMF 70.1 record.

z/VM support is provided in the 7.3 version and APARs are available for z/VM 7.1 and 7.2.

Additionally, consider collecting the z/OS SMF 99 Subtype 14 records for all LPARs in the IBM z16. Record has a single LPAR scope, so need all LPARs to get the total picture.

z/OS SMF 99 Subtype 14 contains HiperDispatch Topology data including:

- ▶ Logical Processor characteristics: Polarity (VH, VM, VL) and Afinity Node
- ▶ Physical topology information: Drawer/ DCM/ Chip location data for each logical CP.
- ▶ z/OS SMF 99 Subtype 14 is written every 5 minutes or when a Topology change occurs
 - Topology changes:
 - Configuration Change or weight change
 - Driven by IRD weight management
 - Record provides a Topology Change indicator to show when the topology changed
- ▶ LPAR topology may have a very significant impact on processor CPU efficiency. Remote cache accesses may take hundreds of machine cycles. SMF 99.14 records are produced every 5 minutes and capture drawer/DCM/chip location data for each logical CP.

In the Topology Reports, IBM zPCR reports “measured” data and it shows the “what-is” and not the “what-if” topology scenarios.

12.9.7 IBM z16 HMC - View Partition Resource Assignments

Note: To access HMC *Partition Resource Assignments*, you must use the “Service” logon id or any other user id with the same authority.

At the HMC “Home” screen click Systems Management, under the task bar and then select your listed target system.

Under “Tasks” at the bottom right click the Configuration (+) sign. Next, click “View Partition Resource Assignments”. The panel shown in Figure 12-11 will display:

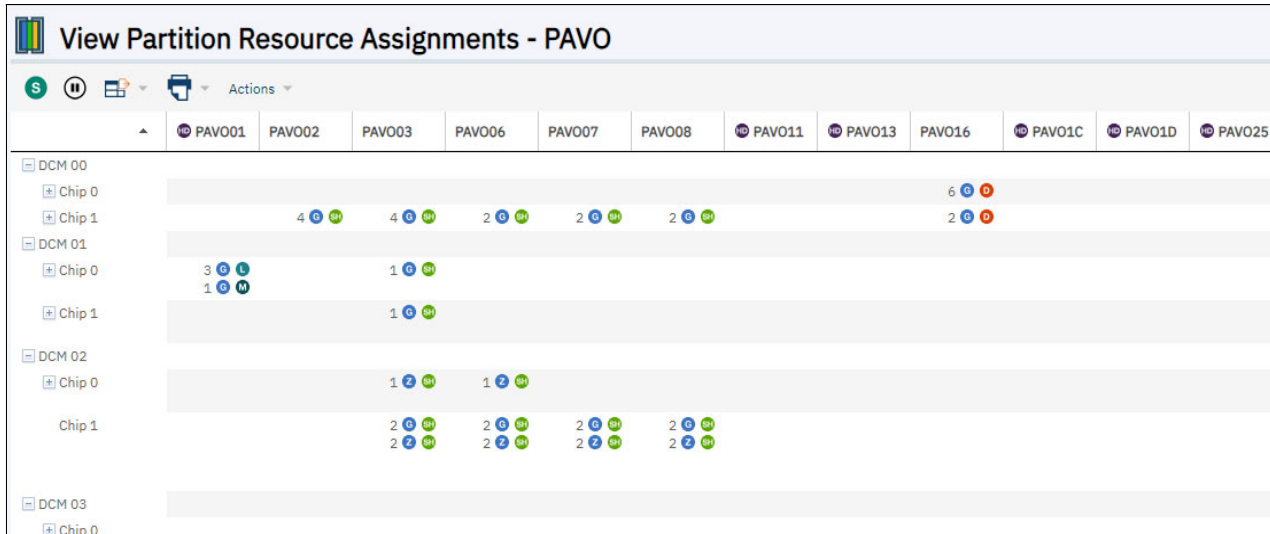


Figure 12-11 HMC - View Partition Resource Assignments for the IBM z16⁷

Use the Partition Resource Assignments to view processor allocations to partitions in your system. The active logical partitions are identified at the top of the table. The Node and Chip numbers associated with each active logical partition are identified on the left. You can view the Node and Chips assignments using the **Expand All** and **Collapse All** options under the “Actions” pull down view or hide sections.

To view the resource assignments for partitions:

- ▶ Logical partition name:
 - Displays the active logical partition and if HiperDispatch (image icon of the logical partition name entry) is enabled.
- ▶ Node:
 - Displays the processor Node number in your system.
- ▶ Chip:
 - Displays the processor Chip number associated with the Node and lists the processor types associated with each active logical partitions. The Chip Collapse All icon displays a summary view. The following physical processor types are:
 - General processors: (G)
 - Coupling facility processors: (C)
 - Integrated Facilities for Linux® IFLs): (I)
 - z Integrated Information Processors (zIIPs): (Z)
 - Integrated Firmware Processor (IFPs): (F)

The physical processor types may have some of the following conditions:

- ▶ Indicates the physical processor types are shared: (SH)
- ▶ Indicates the physical processor is dedicated: (D)

⁷ The image has been reduced from its original size horizontally, due to the number of active partitions, and vertically due to the number of installed drawers.

⁹ NUMA, Non-Uniform Memory Access is a multiprocessor design where memory access time depends on the memory location relative to the processor.

- Indicates the vertical polarity for the physical processor types (H / M / L)

12.9.8 IBM zPCR Large Partition Support

IBM zPCR version 9.6.4⁸ implemented an important change to the LPAR Configuration Capacity Planning function. For the IBM z16, 3931 (Max200/700) a change was made to match the way RCPs per drawer are assigned when the total number RCPs in the configuration is up to 191. This change compensates for the way the RCP count per drawer actually occurs.

This change was needed since it turns out that not all IBM z16 Max200's have 51 configurable PU drawers. Some Max200's have 48 PU drawers when there are 191 or less PU's in the configuration.

IBM zPCR shows the distribution of PUs per drawer according to the Table 12-2, and there are very useful graphs called **Estimated Distribution of RCPs Across Drawers** that are available as an option from the Partition Detail Report, which identifies the number of PUs on each drawer.

See Figure 12-13 on page 499 and Figure 12-15 on page 501 for details about the new available graphs.

Table 12-2 below shows the PUs distribution per drawer for an IBM z16 Max200 according to the number of available configurable PUs.

Table 12-2 Configurable PUs available per drawer

Number of available PUs in the configuration	1st Drawer configurable PUs	2nd Drawer configurable PUs	3rd Drawer configurable PUs	4th Drawer configurable PUs
up to 191 PUs	48	48	47	48
192 or more PUs	51	51	47	51

Figure 12-12 on page 498 shows a Partition Detail Report of an IBM z16, 3931-A01 (Max 200)/700 with 196 CPs (60 GPs, 60 zIIPs, 60 IFLs and 16 ICFs), and four active partitions (1 GP, 1 zIIP, 1 IFL and 1 ICF). Resources are allocated as shown in the Partition Identification and Partition Configuration fields.

As this IBM z16 has 196 CPs, (Figure 12-12 on page 498), the PU resources are distributed according to the Table 12-2, and are shown in the *Estimated Distribution of RCPs Across Drawers* graph in Figure 12-13 on page 499.

Important:

Please pay special attention to the colors assigned to the Logical CPs column and relate them to the “warnings” and “notes” at the bottom of the report. See “Partition Detail Report warnings” on page 498.

⁸ Your currently installed version of IBM zPCR must be uninstalled before installing IBM zPCR 9.6.4. This step is necessary to facilitate conversion to the latest IBM Java 17 Semeru 64-bit runtime environment that is included with IBM zPCR.

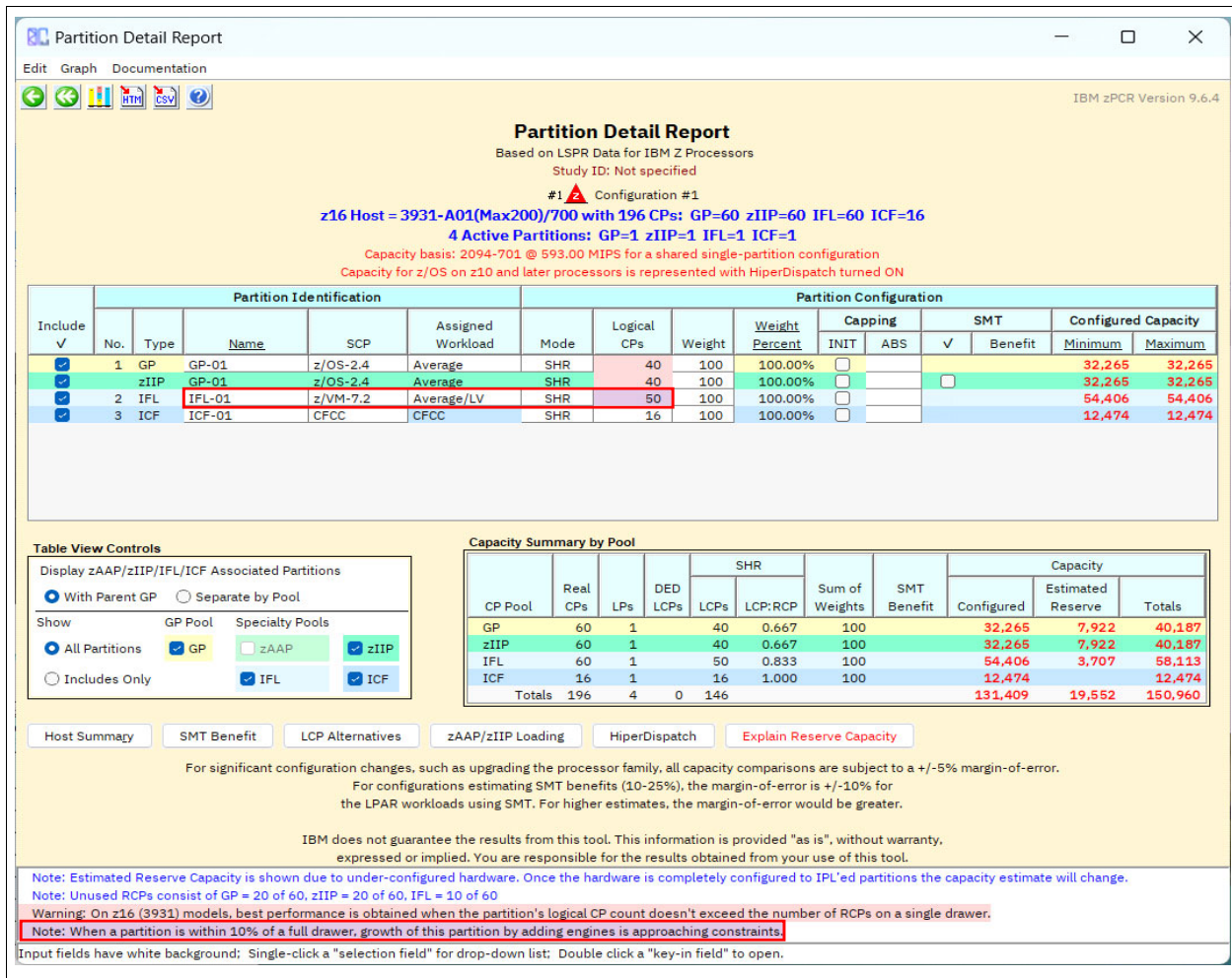


Figure 12-12 Partition Detail Report example (Max200)/700 with 196 CPs

Partition Detail Report warnings

IBM zPCR implemented a warning indicating that on IBM z13 and later, the best performance is achieved when the partition's logical CP count does not exceed the number of RCPs in a single drawer.

Additionally, IBM zPCR version 9.6.4 implemented a new notice for partitions approaching, within 10%, the maximum drawer size. This critical notice indicates that one or more partitions partition are getting close to a drawer boundary. When that happens, capacity growth by adding LCPs is very limited.

The new notice appears as a "Note" message in the Partition Detail Report. The "Note" and the partition LCPs are shaded with the same **violet** color, as shown for partition IFL-01 in Figure 12-12 above and for partition GP-02 in Figure 12-14 on page 500.

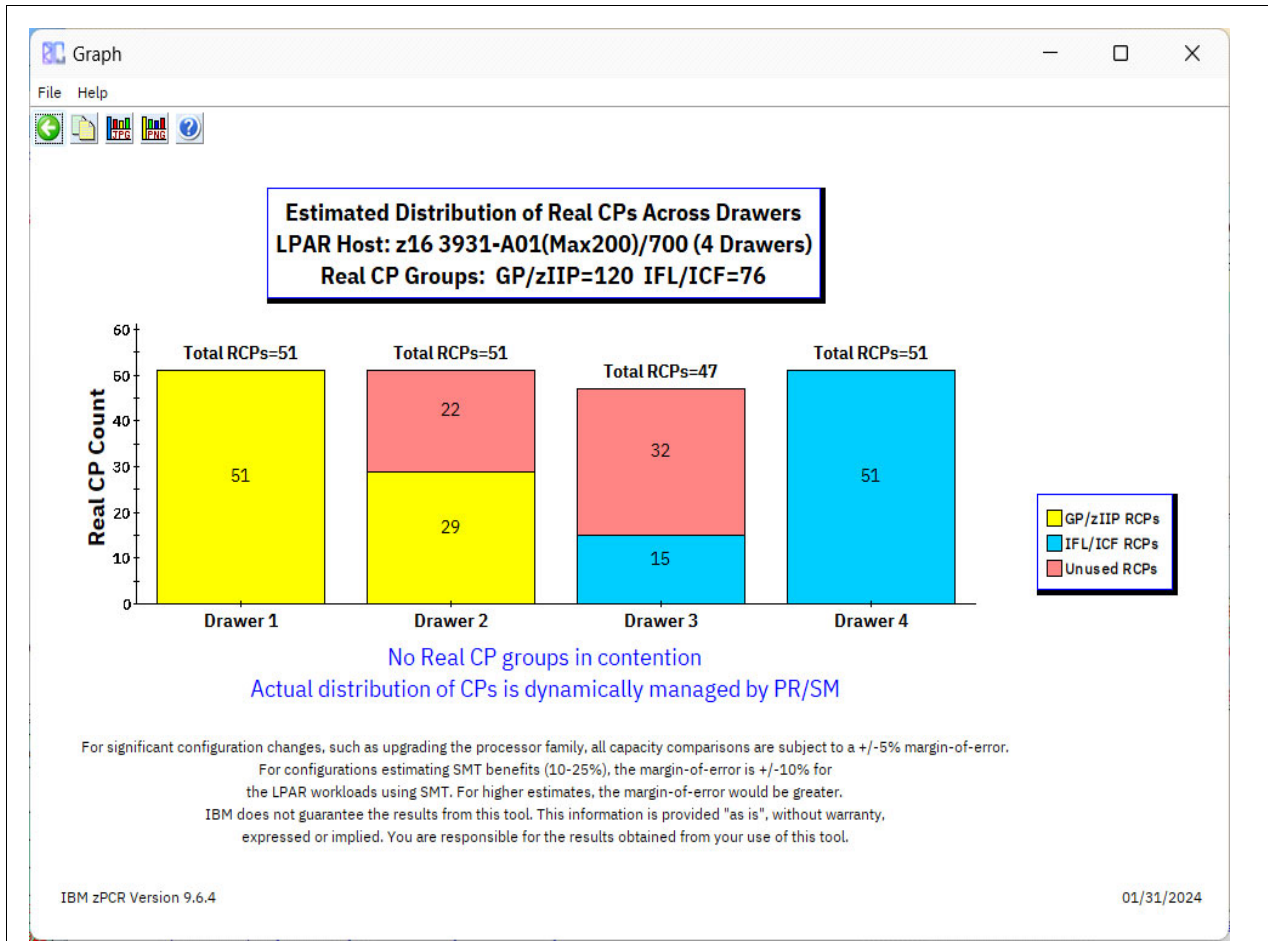


Figure 12-13 Estimated distribution of real CPs across drawers report

Figure 12-14 on page 500 shows another example of a Partition Detail Report this time for an IBM z16, 3931-A01, (Max200)/700 with 165 CPS (45 GPs, 44 zIIPs, 60 IFLs and 16 ICFs), and six active partitions (2 GP, 2 zIIP, 1 IFL and 1 ICF). Resources are allocated as shown in the Partition Identification and Partition Configuration fields.

As the IBM z16 (Figure 12-14 on page 500) has 165 CPs, the PU resources are distributed according to the Table 12-2 on page 497, and are shown in the *Estimated Distribution of RCPs Across Drawers* graph in Figure 12-15 on page 501.

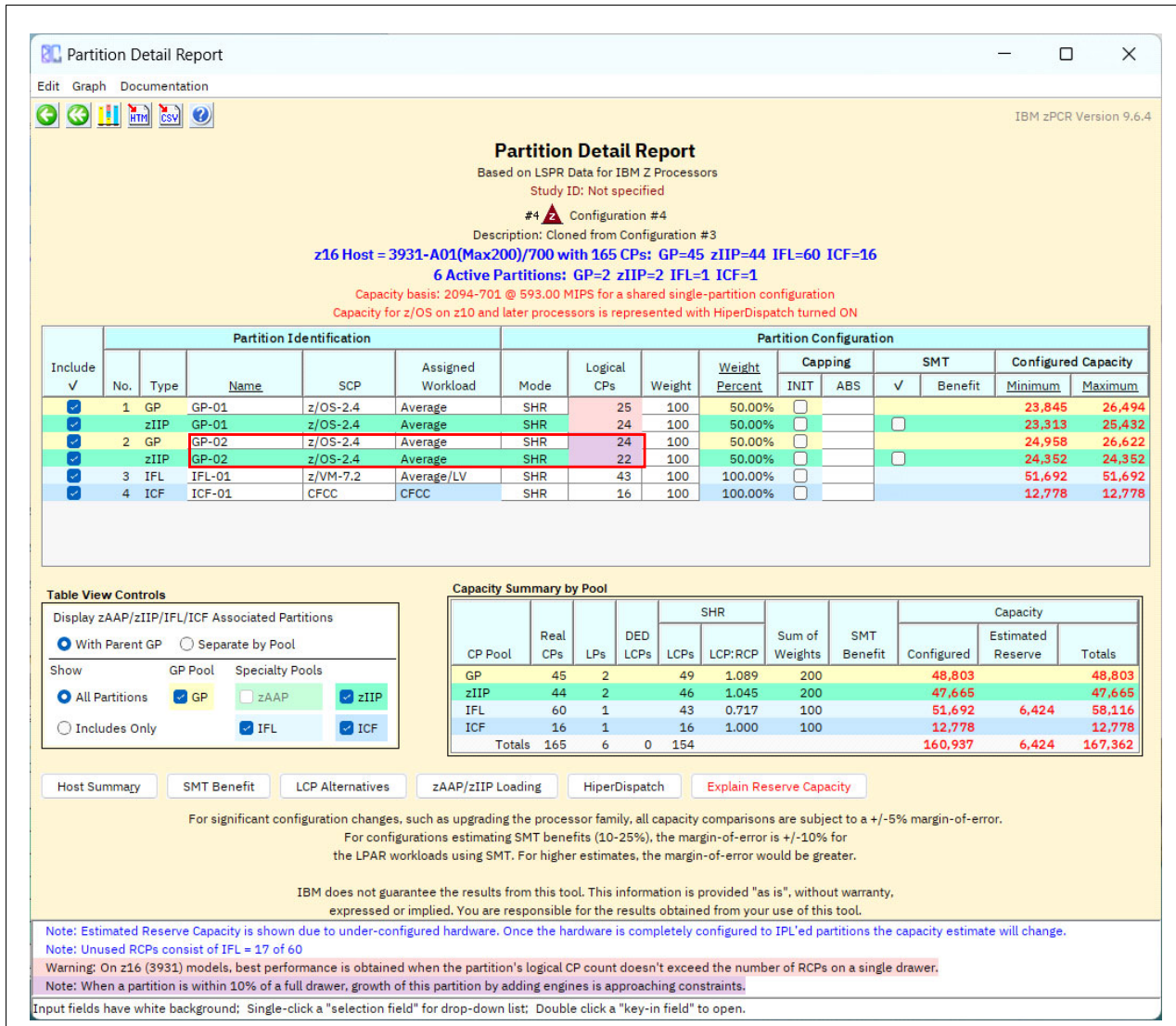


Figure 12-14 Partition Detail Report example (Max200)/700 with 165 CPs

The Partition Detail Report in Figure 12-14 above highlights the partition GP-02 to indicate it is within 10% of the maximum drawer size in the number of CPs. The GP-02 partition and the “Note” at the bottom are shaded with the same violet color.

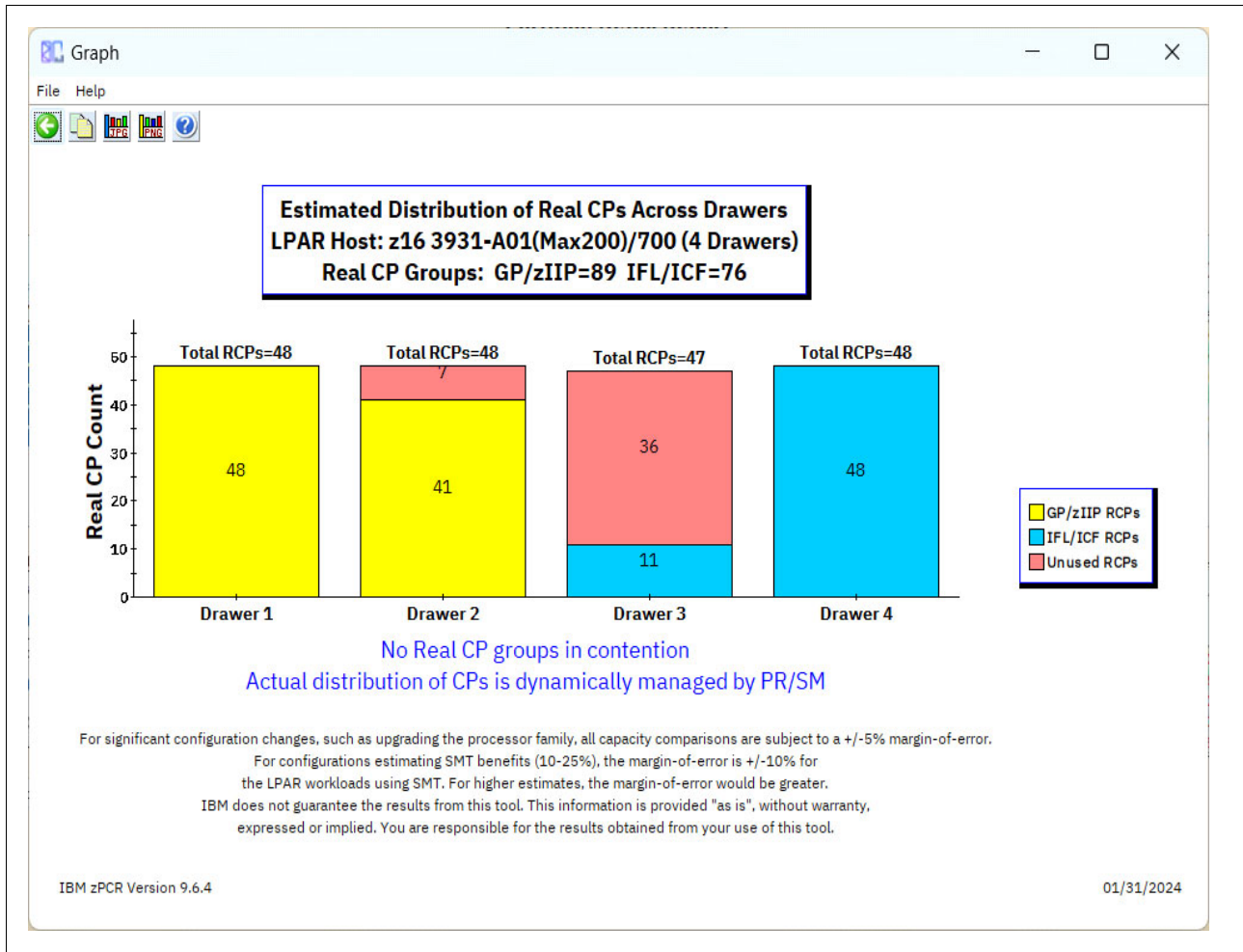


Figure 12-15 Estimated distribution of real CPs across drawers report

IBM z16 continues the IBM z14 and IBM z15 NUMA⁹ design. IBM z16 has two clusters and four DCMs per drawer (refer to Table 12-2 on page 497 for the number of Configurable PUs per drawer). In the case where a single partition spans from one drawer into a second, the cross-drawer penalty has increased on IBM z16. However, this is offset by more cores per drawer and higher capacity than IBM z15, which allows more work to “fit” on a single drawer.

As discussed in 3.5.9, “Processor unit assignment” on page 112, and under “Memory allocation” on page 115, PR/SM memory and logical processor allocation goal is to place all logical partition resources on a single CPC drawer, if possible. There can be negative impacts on a logical partition’s performance when CPs are allocated in different drawers.

IBM zPCR implements a warning notice when logical partition’s number of Logical CPs defined is larger than the number of Real CPs in a single drawer. When that scenario occurs, it is advisable to contact IBM to review your configuration. See Figure 12-16 on page 502.

z16 Host = 3931-A01(Max168)/700 with 64 CPS: GP=50 zIIP=10 IFL=3 ICF = 1
4 Active Partitions: GP=1 zIIP=1 ICF = 1

Include	Partition Identification					Partition Configuration			Capping		
	No.	Type	Name	SCP	Workload	Mode	LCPs	Weight	Weight %	✓	ABS
<input type="checkbox"/>		GP	LPAR1	z/OS-2.4*	Average	SHR	50	800		<input type="checkbox"/>	
<input type="checkbox"/>		zIIP	LPAR1	z/OS-2.4*	Average	SHR	6	800		<input type="checkbox"/>	
<input checked="" type="checkbox"/>	1	GP	LPAR2	z/OS-2.4*	Average	SHR	2	200	100.00%	<input type="checkbox"/>	
<input checked="" type="checkbox"/>		zIIP	LPAR2	z/OS-2.4*	Average	SHR	2	200	100.00%	<input type="checkbox"/>	

IBM zPCR - Notice ×

Large Partitions Exceeding a Drawer Boundary

On IBM z16 (3931) models, the best practice is a partition's logical CP count should not exceed the number of RCPs in the largest drawer.

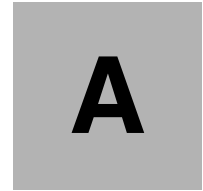
Partitions which exceed a drawer boundary have special capacity considerations.

This partition is likely to exceed a drawer boundary.

Immediately contact IBM to review your configuration: zPCR@us.ibm.com

Check to allow inclusion of this partition

Figure 12-16 Large Partition Exceeding a Drawer Boundary warning Message



Channel options

This appendix describes all channel attributes, required cable types, maximum unrepeated distance, and bit rate for IBM z16. The features that are hosted in the PCIe drawer for Cryptography also are listed.

For all optical links, the connector type is LC Duplex (except for the zHyperLink) and the ICA SR connections, which are established with multi-fiber push-on (MPO) connectors.

The MPO connector of the zHyperLink and the ICA connection feature two rows of 12 fibers and are interchangeable.

The electrical Ethernet cable for the Open Systems Adapter (OSA) connectivity is connected through an RJ45 jack.

The attributes of the channel options that are supported on IBM z16 are listed in Table A-1.

Table A-1 IBM z16 channel feature support

Channel feature	Feature codes	Bit rate ^a in Gbps (or stated)	Cable type	Maximum unrepeated distance ^b	Ordering information
zHyperLink and Fiber Connection (FICON)					
zHyperlink Express1.1	0451	8 GBps	OM4, OM3	See Table A-2 on page 505	New build, Carry forward
zHyperlink Express	0431				Carry forward
FICON Express32S LX	0461	8, 16, or 32	SM 9 μm	5 km @ 32 Gbps ^c (3.1 miles) 10 km @ 16 or 8 Gbps (6.2 miles)	New build
FICON Express32S SX	0462	8, 16, or 32	OM1, OM2, OM3, or OM4	See Table A-3 on page 506.	New build
FICON Express16SA LX	0436	8, or 16	SM 9 μm	10 km (6.2 miles)	Carry forward

Channel feature	Feature codes	Bit rate ^a in Gbps (or stated)	Cable type	Maximum unrepeated distance ^b	Ordering information
FICON Express16SA SX	0437	8, or 16	OM1, OM2, OM3, OM4	See Table A-3 on page 506.	Carry forward
FICON Express16S+ LX	0427	4, 8, or 16	SM 9 µm	10 km (6.2 miles)	Carry forward
FICON Express16S+ SX	0428	4, 8, or 16	OM1, OM2, OM3, OM4	See Table A-3 on page 506.	Carry forward
FICON Express16S LX	0418	4, 8, or 16	SM 9 µm	10 km (6.2 miles)	Carry forward
Open Systems Adapter (OSA) and Remote Direct Memory over Converged Ethernet (RoCE)					
OSA-Express7S 1.2 25GbE LR	0460	25	SM 9 µm	10 km (6.2 miles)	New build
OSA-Express7S 1.2 25GbE SR	0459	25	MM 50 µm	70 m (2000) 100 m (4700)	New build
OSA-Express7S 1.2 10GbE LR	0456	10	SM 9 µm	10 km (6.2 miles)	New build
OSA-Express7S 1.2 10GbE SR	0457	10	MM 62.5 µm MM 50 µm	33 m (200) 82 m (500) 300 m (2000)	New build
OSA-Express7S 1.2 GbE LX	0454	1.25	SM 9 µm	10 km (6.2 miles)	New build
OSA-Express7S 1.2 GbE SX	0455	1.25	MM 62.5 µm MM 50 µm	275 m (200) 550 m (500)	New build
OSA-Express7S 1.2 1000BASE-T	0458	1000Mbps	Cat 5, Cat 6 unshielded twisted pair (UTP)	100 m	New build
OSA-Express7S 25GbE SR1.1	0449	25	MM 50 µm	70 m (2000) 100 m (4700)	Carry forward
OSA-Express7S 25GbE SR	0429				
OSA-Express7S 10GbE LR	0444	10	SM 9 µm	10 km (6.2 miles)	Carry forward
OSA-Express6S 10GbE LR	0424				
OSA-Express7S 10GbE SR	0445	10	MM 62.5 µm MM 50 µm	33 m (200) 82 m (500) 300 m (2000)	Carry forward
OSA-Express6S 10GbE SR	0425				
OSA-Express7S GbE LX	0442	1.25	SM 9 µm	5 km (3.1 miles)	Carry forward
OSA-Express6S GbE LX	0422				
OSA-Express7S GbE SX	0443	1.25	MM 62.5 µm MM 50 µm	275 m (200) 550 m (500)	Carry forward
OSA-Express6S GbE SX	0423				
OSA-Express7S 1000BASE-T	0446	1000 Mbps	Cat 5, Cat 6 unshielded twisted pair (UTP)	100 m	Carry forward
OSA-Express6S 1000BASE-T	0426	100 or 1000 Mbps			
25GbE RoCE Express3 LR	0453	25	SM 9 µm		New build
25GbE RoCE Express3 SR	0452	25	OM3, OM4		New build

Channel feature	Feature codes	Bit rate ^a in Gbps (or stated)	Cable type	Maximum unrepeated distance ^b	Ordering information
10GbE RoCE Express3 LR	0441	10	SM 9 μm		New build
10GbE RoCE Express3 SR	0440	10	OM2, OM3 OM4	33 m (200) 82 m (500) 300m (2000) ^d	New build
25GbE RoCE Express2.1	0450	25	OM3, OM4	70 m (2000) 100 m (4700)	Carry forward
25GbE RoCE Express2	0430				
10GbE RoCE Express2.1	0432	10	OM2, OM3 OM4	33 m (200) 82 m (500) 300m (2000) ^d	Carry forward
10GbE RoCE Express2	0412				
Parallel Sysplex					
CE2 LR	0434	10 Gbps	SM 9 μm	10 km (6.2 miles)	New build
ICA SR1.1	0176	8 Gbps	OM4 OM3	150 m 100 m	New build, Carry forward
ICA SR	0172				Carry forward

- The link data rate does not represent the performance of the link. The performance depends on many factors, including latency through the adapters, cable lengths, and the type of workload.
- Where applicable, the minimum fiber bandwidth distance in MHz-km for multi-mode fiber optic links is included in parentheses.
- For 32 Gbps links, point to point (to another switch, director, DWDM equipment or another FICON Express3sS) distance is limited to 5 km (3.1 miles).
- A 600 meters (1958.5 feet) maximum when sharing the switch across two RoCE Express features.

The unrepeated distances for different multimode (MM) fiber optic types for zHyperLink Express are listed in Table A-2.

Table A-2 Unrepeated distances

Cable type (modal bandwidth)	8 Gbps
OM3 (50 μm at 2000 MHz·km)	100 meters
	328 feet
OM4 (50 μm at 4700 MHz·km)	150 meters
	492 feet

The maximum unrepeated distances for FICON SX features are listed in Table A-3.

Table A-3 Maximum unrepeated distance for FICON SX features

Cable type/bit rate	8 Gbps	16 Gbps	32 Gbps
OM1 (62.5 µm at 200 MHz·km)	21 meters	15 meters	N/A
	69 feet	49 feet	N/A
OM2 (50 µm at 500 MHz·km)	50 meters	35 meters	20 meters
	164 feet	115 feet	65 feet
OM3 (50 µm at 2000 MHz·km)	150 meters	100 meters	70 meters
	492 feet	328 feet	229 meters
OM4 ^a (50 µm at 4700 MHz·km)	190 meters	125 meters	100 meters
	693 feet	410 feet	328 feet

a. Fibre Channel Standard (not certified for Ethernet)



IBM Z Integrated Accelerator for AI

This appendix provides a short overview of the new IBM Z Integrated Accelerator for Artificial Intelligence that is implemented in the IBM z16 processor (Telum).

Overview

Each generation of the IBM Z processing chip was enhanced with new on-chip functions, such as compression, sort, cryptography, and vector processing. The purpose-built accelerators that provide these functions mean lower latency and higher throughput for specialized operations. These accelerators work together with advanced chip design features such as data prefetch, high capacity L1 and L2 caches, branch prediction, and other innovations.

The on-chip accelerators provide support for and enable compliance with security policies because the data is not leaving the platform to be processed. The hardware, firmware, and software are vertically integrated to seamlessly deliver this function to the applications.

In August 2021, [IBM announced a new generation](#) of IBM Z processor, Telum with new Artificial Intelligence (AI) accelerator (see Figure B-1). This innovation brings incredible value to the applications and workloads that are running on IBM Z.

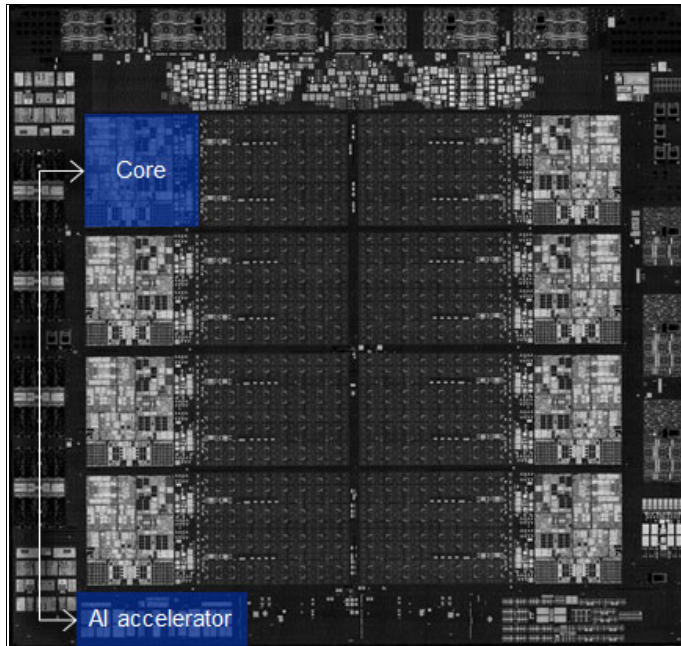


Figure B-1 IBM z16 Processor chip: AIU location

With the new IBM Z Integrated Accelerator for AI, customers can benefit from the acceleration of AI operations, such as fraud detection, customer behavior predictions, and streamlining of supply chain operations, all in real time. Customers can derive the valuable insights from their data instantly.

AI accelerator delivers AI inference in real time, at large scale and rate, with no transaction left behind without the need to offload data off the IBM Z for performing AI inference.

The AI capability is applied directly into the running transaction, shifting the traditional paradigm of applying AI to the transactions that were completed. This innovative technology can be used for intelligent IT workloads placement algorithms, which contributes to the better overall system performance. The co-processor is driven by the new Neural Networks Processing Assist (NNPA) instruction.

NNPA and IBM z16 Hardware

NNPA is a new nonprivileged Complex Instruction Set Computer (CISC) memory-to-memory instruction that operates on tensor objects that are in user programs' memory. AI functions and macros are abstracted by NNPA.

Figure B-2 shows the AI accelerator and its components: the data movers that surround the compute arrays are composed of the Processor Tiles (PT), Processing Elements (PE), and Special Function Processors (SFP).

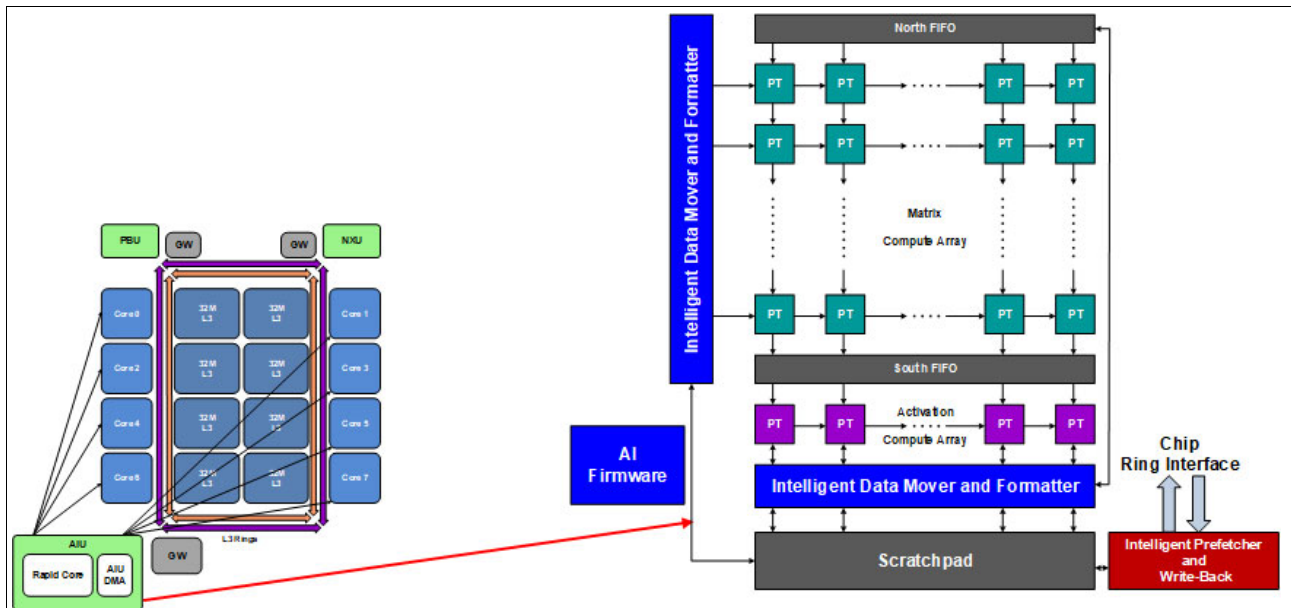


Figure B-2 AIU logical diagram

Intelligent data movers and prefetchers are connected to the chip by way of a ring interface for high-speed, low-latency, read/write cache operations (200+ GBps read/store bandwidth, and 600+GBps bandwidth between engines).

Compute Arrays consist of 128 processor tiles with 8-way FP-16 FMA SIMD, which are optimized for matrix multiplication and convolution, and 32 processor tiles with 8-way FP-16/FP-32 SIMD, which is optimized for activation functions and complex functions.

The integrated AI accelerator delivers more than 6 TFLOPs per chip and over 200 TFLOPs in the 32 chip system (a fully configured IBM z16 with four CPC drawers).

The AI accelerator is shared by all cores on the chip. The firmware, which is running on the cores and accelerator, orchestrates and synchronizes the execution on the accelerator.

How to use IBM Z Integrated AI Accelerator in your enterprise

This chart that is shown in Figure B-3 shows the high level of seamless integration of AI accelerator into enterprise AI/ML solution stack. Great flexibility and interoperability are realized for training and building models.

Acknowledging the diverse AI training frameworks, customers can train their models on platforms of their choice, including IBM Z (on-premises and in hybrid cloud) and then, deploy it efficiently on IBM Z in colocation with the transactional workloads. No other development effort is needed to enable this strategy.

To allow this flexible “Train anywhere, Deploy on IBM Z” approach, IBM invests in [Open Neural Network Exchange \(ONNX\)](#) technology (see Figure B-3).

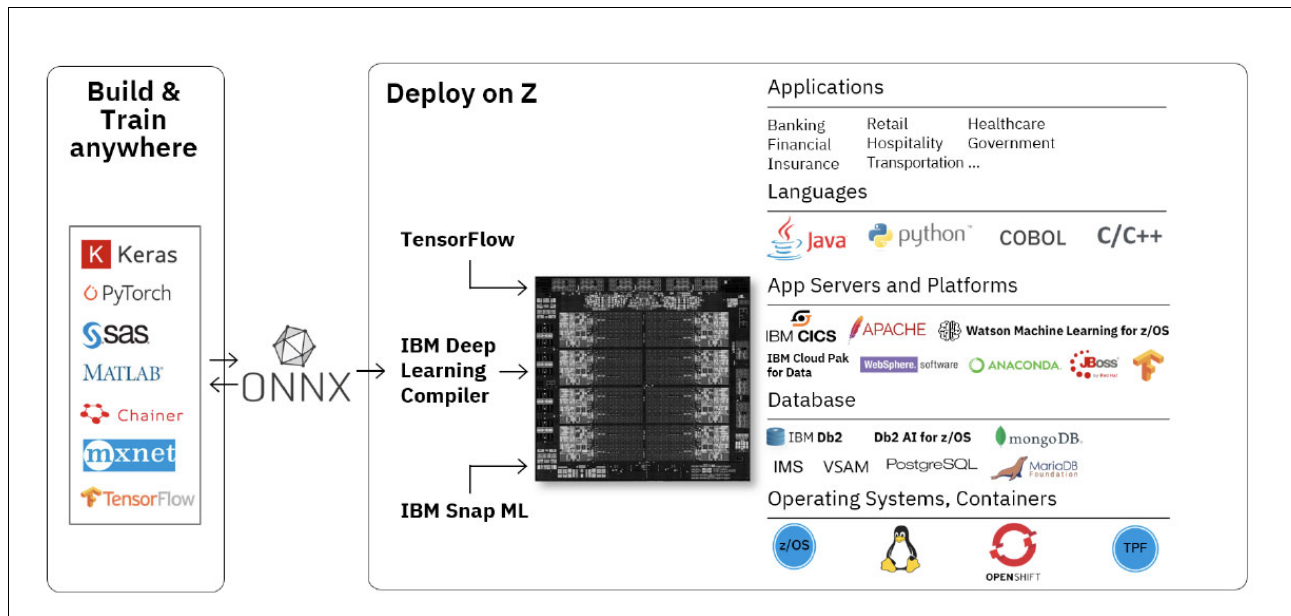


Figure B-3 ONNX ecosystem

This standard format represents AI models, with which a data scientist can build and train a model in the framework of choice without worrying about the downstream inference implications. To enable deployment of ONNX models, IBM provides an ONNX model compiler that is optimized for IBM Z. In addition, IBM is optimizing key open source frameworks, such as TensorFlow (and TensorFlow Serving) for use on IBM Z.

IBM’s open source [hzDNN library](#) provides common APIs for the functions that enable conversions from the Tensor format to the accelerator required format. Customers can run zDNN under z/OS¹ and Linux on IBM Z. A Deep Learning Compiler (DLC) for z/OS and Linux also is available that provide the AI functions to the applications.

¹ zDNN is zCX eligible, which it runs on zIIPs under z/OS



IBM Integrated Accelerator for zEnterprise Data Compression

This appendix describes the new IBM Integrated Accelerator for zEnterprise Data Compression (zEDC) that is implemented in IBM Z hardware.

The appendix includes the following topics:

- ▶ “Client value of IBM Z compression” on page 512
- ▶ “IBM z16 IBM Integrated Accelerator for zEDC” on page 513
- ▶ “IBM z16 migration considerations” on page 514
- ▶ “Software support” on page 515
- ▶ “Compression acceleration and Linux on IBM Z” on page 516

Client value of IBM Z compression

The amount of data that is captured, transferred, and stored continues to grow. Software-based compression algorithms can be costly in terms of processor resources, storage costs, and network bandwidth.

An optional PCIe feature that was available for IBM z14 servers, zEDC Express, addressed customer requirements by providing hardware-based acceleration for data compression and decompression. zEDC provided data compression with lower CPU consumption than compression technology that was available on the IBM Z server.

Customers deployed zEDC compression to deliver the following types of compression:

- ▶ Storage
- ▶ Data transfer
- ▶ Database
- ▶ In-application

Data compression delivers the following benefits:

- ▶ Disk space savings
- ▶ Improved elapse times
- ▶ Reduced CPU consumption
- ▶ Reduced network bandwidth requirements and transfer times

Many customers increased their zEDC footprint to 8 GBps with up to 16 features per IBM z14 system at 1 GBps throughput per feature (redundancy reduces total throughput to 8 GBps).

Although the zEDC PCIe feature provided CPU savings by offloading the select compression and decompression operations, it included the drawback of limited virtualization capabilities (one zEDC PCIe feature can be shared across a maximum of 15 LPARs) and limited bandwidth.

IBM z15 introduced an on-chip accelerator (implemented in the PU chip) for compression and decompression operations, which was tied directly into processor's L3 cache. As a result, it provided much higher bandwidth and removed the virtualization limitations of a PCIe feature.

The IBM z16 further addresses the growth of data compression requirements with the integrated on-chip compression unit (implemented in processor Nest, one per PU chip) that significantly increases compression throughput and speed compared to previous zEDC deployments.

IBM z16 IBM Integrated Accelerator for zEDC

IBM z16 on-chip compression provides value for existing and new compression users by bringing the compression facility into the PU chip, which is tied in L3¹ cache.

The IBM z16 Integrated Accelerator for zEDC delivers industry-leading throughput and replaces the zEDC Express PCIe adapter that is available on the IBM z14 and earlier servers.

IBM z16 compression and decompression are implemented in the Nest Accelerator Unit (NXU, see Figure 3-15 on page 93) on each processor chip and replaces the existing zEDC Express adapter in the PCIe+ I/O drawer.

One NXU is available per processor chip, which is shared by all cores on the chip and features the following benefits:

- ▶ New concept of sharing and operating an accelerator function in the nest
- ▶ Supports DEFLATE-compliant compression and decompression and GZIP CRC/ZLIB Adler
- ▶ Low latency
- ▶ High bandwidth
- ▶ Problem state execution
- ▶ Hardware and firmware interlocks to ensure system responsiveness
- ▶ Designed instruction
- ▶ Run in millicode

On-Chip Compression provides an up to 5% improvement in compression ratios for BSAM/VSAM data sets over zEDC while maintaining full compatibility.

Eliminating adapter sharing by using Nest Compression Accelerator

Sharing of zEDC cards is limited to 15 LPAR guests per adapter. The Nest Compression Accelerator removes this virtualization constraint because it is shared by all PUs on the processor chip and therefore is available to all LPARs and guests.

Moving the compression function from the (PCIe) I/O drawer to the processor chip means that compression can operate directly in L3 cache and data does not need to be passed by using I/O operations.

Compression modes

Compression is run in one of the following modes:

- ▶ Synchronous
Execution occurs in problem state where the user application starts the instruction in its virtual address space.
- ▶ Asynchronous
Execution is optimized for Large Operations under z/OS for authorized applications (for example, BSAM) and issues I/O by using EADMF for asynchronous execution.

¹ Virtual L3 (shared victim) cache for IBM z16. For more information, see Chapter 2, “Central processor complex hardware components” on page 15.

This type of execution maintains the current user experience and provides a transparent implementation for authorized users of zEDC.

Note: The zEDC Express feature does *not* carry forward to IBM z16.

IBM z16 migration considerations

The IBM Integrated Accelerator for zEDC is fully compatible with zEDC. Data that is compressed by zEDC can be read by IBM z16 (the on-chip) NXU and vice versa.

All z/OS configurations stay the same

No changes are required when moving from earlier systems by using zEDC to IBM z16.

The IFAPRDxx feature is still required for authorized services. For problem state services, such as zlib use of Java, it is not required.

Consider fail-over and disaster recovery sizing

The order of magnitude throughput increase on IBM z16 means that the throughput requirements need to be considered whether failing over to earlier systems with zEDC.

Performance metrics

On-chip compression introduces the following system reporting changes:

- ▶ No RMF PCIe reporting for zEDC
- ▶ Synchronous executions are not recorded (just an instruction invocation)
- ▶ Asynchronous executions are recorded:
 - SMF30 information is captured for asynchronous usage
 - RMF EADM reporting is enhanced (RMF 74.10)
 - SAP use is updated to include the time that is spent compressing and decompressing

zEDC to IBM z16 zlib Program Flow for z/OS

The z/OS-provided zlib library is statically linked into many IBM and ISV products and remains functional. However, to realize the best optimization for IBM z16, some minor changes are made to zlib.

The current zlib and the new zlib function are available for IBM z14 and earlier servers and IBM z16 hardware. It functions with or without the IBM z16 z/OS PTFs on IBM z14 and earlier servers.

Software support

On-Chip Compression function is compatible with zEDC support and is available in z/OS V2R2 and later for data compression and decompression. Although support for data recovery (decompression) if zEDC or On-Chip Compression not available, it is provided through software in z/OS V2R2 with the appropriate program temporary fixes (PTFs).

Software decompression is slow and can involve considerable processor resources. Therefore, it is not recommended for production environments.

A specific fix category that is named `IBM.Function.zEDC` identifies the fixes that enable or use the zEDC and On-Chip Compression function.

z/OS guests that run under z/VM V7.R1 with PTFs and later can use the zEDC Express feature and IBM z16 On-Chip Compression.

IBM 31-bit and 64-bit SDK for z/OS Java Technology Edition, Version 7 Release 1 (5655-W43 and 5655-W44) and IBM SDK 7 for z/OS Java provides the use of the zEDC Express feature and Shared Memory Communications-Remote Direct Memory Access (SMC-R), which is used by the 10 GbE RoCE Express feature.

For more information about how to implement and use the IBM Z compression features, see *Reduce Storage Occupancy and Increase Operations Efficiency with IBM zEnterprise Data Compression*, [SG24-8259](#).

IBM Z Batch Network Analyzer

IBM Z Batch Network Analyzer (zBNA) is a no-charge, “as-is” tool. It is available to customers, IBM Business Partners, and IBM employees.

zBNA is based on Microsoft Windows. It provides graphical and text reports, including Gantt charts, and support for alternative processors.

zBNA can be used to analyze client-provided System Management Facilities (SMF) records to identify jobs and data sets that are candidates for zEDC and IBM z16 On-Chip Compression across a specified time window (often a batch window).

zBNA can generate lists of data sets by the following jobs:

- ▶ Jobs that perform hardware compression and might be candidates for On-Chip Compression.
- ▶ Jobs that might be On-Chip Compression candidates, but are not in extended format.

Therefore, zBNA can help you estimate the use of On-Chip Compression features and help identify savings.

The following resources are available:

- ▶ IBM Employees can obtain zBNA and other CPS tools at the IBM Z Batch Network Analyzer (zBNA) Tool page of the IBM Techdoc website. For more information, contact your IBM Representative.
- ▶ IBM Business Partners can obtain zBNA and other CPS tools at the [IBM PartnerWorld website](#) (log in required).
- ▶ IBM customers can obtain zBNA and other CPS tools at the [IBM Z Batch Network Analyzer \(zBNA\) Tool web page](#) of the IBM Techdoc Library website.

Compression acceleration and Linux on IBM Z

The zEDC I/O adapter use is limited in many Linux on IBM Z environments because SR-IOV does not provide a high degree of virtualization; therefore, the user must pick and choose which guests are granted access to the accelerator.

The IBM z16 On-Chip Compression accelerator solves these virtualization limitations because the function is no longer an I/O device and is available as a problem state instruction to all Linux on IBM Z guests without constraints.

This feature enables pervasive usage in highly virtualized environments.

IBM z16 On-Chip Compression is available to open source applications by way of zlib.



Tailored Fit Pricing and IBM Z Flexible Capacity for Cyber Resiliency

This appendix describes IBM Z Tailored Fit Pricing and IBM Z Flexible Capacity for Cyber Resiliency.

Although they are two different offerings, Tailored Fit Pricing for Software is prerequisite requirement of Flexible Capacity for Cyber Resiliency (or short 'Flexible Capacity').

This appendix includes the following topics:

- ▶ “Tailored Fit Pricing” on page 518
- ▶ “Software Consumption Model” on page 519
- ▶ “Hardware Consumption Model” on page 520
- ▶ “Conclusion” on page 523
- ▶ “IBM Z Flexible Capacity for Cyber Resiliency” on page 524
- ▶ “Use cases of IBM Flexible Capacity for Cyber Resiliency” on page 524
- ▶ “How does IBM Flexible Capacity for Cyber Resiliency work?” on page 525
- ▶ “Tailored fit pricing for hardware and IBM Z Flexible Capacity for Cyber Resiliency” on page 529
- ▶ “Ordering and installing IBM Z Flexible Capacity for Cyber Resiliency” on page 530
- ▶ “Terms and conditions of IBM Z Flexible Capacity for Cyber Resiliency” on page 531
- ▶ “IBM Z Flexible Capacity for Cyber Resiliency versus Capacity Back Up” on page 532

Tailored Fit Pricing

Note: For more information about Tailored Fit Pricing, see this IBM Z Resources [web page](#).

The information that is included in this section about TFP is taken in part from the IBM publication *Tailored Fit Pricing - A sensible pricing model*, 75034875USEN-01.

IBM Z platform users were used to paying for IBM Z software and hardware for peak capacity and managing their software costs by capping machine usage. Traditionally, they capped machine use by using the following methods:

- ▶ Running batch workloads during off-shift hours
- ▶ Reducing machine resources access to development and test
- ▶ Not introducing new workloads or applications onto the platform, even when it was the most logical technology for such workloads
- ▶ Investing in tools and resources to manage subcapacity capping

These approaches, while effective in predictable workload management, created a mind-set that stifles innovation and limits the ability for businesses to use the full value of Z technology, especially now as they adapt for digital transformation and the journey to hybrid cloud.

IBM introduced Tailored Fit Pricing (originally for IBM Z software) as a simpler pricing model to allow Z customers to better use their platform investments as their business demands, and in a more cost competitive way. Building on the success of this program, a variable IBM Z hardware model was introduced to extend the value of Tailored Fit Pricing for IBM Z.

With Tailored Fit Pricing models now available across hardware and software, customers can gain more flexibility and control with pricing solutions that can be tailored for business demands, which helps to balance costs while deriving even more value from hybrid cloud.

IBM's Tailored Fit Pricing model can address the following key concerns:

- ▶ Complexity of subcapacity pricing model that lead to IBM Z being managed as a cost center
- ▶ Difficulty in establishing the cost of new workload deployment and the effect on cost of existing workloads
- ▶ Investment in tools and resources to manage subcapacity that can inflate costs
- ▶ Lack of development and test resources
- ▶ Purchasing hardware for peak capacity to handle short term spikes

The software and hardware pricing models provide customers an opportunity to grow and more fully use their IBM Z investment for new opportunities.

IBM originally introduced DevTest Solution and New Application Solution in 2017. These solutions further evolved when in May 2019, IBM announced two significant other solutions: Enterprise Consumption (since renamed to the Software Consumption Solution), and Enterprise Capacity Solution.

In May 2021, IBM announced a new hardware solution, called Hardware Consumption Solution. All of these options were gathered into a new family of IBM Z pricing called Tailored Fit Pricing (TFP).

The Software Consumption Solution and the Hardware Consumption Solution are discussed next.

Software Consumption Model

To meet the demands of modern workloads and provide a commercial confidence to match the technology confidence, the Consumption Solution was well received and adopted.

Customers typically transition onto TFP Consumption for the following reasons:

- ▶ It is a software pricing model that is better suited to today's workloads profiles (typically, where they are increasingly spiky). Also, it is a pricing model that is better suited to future uses; for example, inclusion in Hybrid Cloud architectures.
- ▶ A customer on TFP Consumption can confidently remove all forms of capping and expose all their workloads to *all* of the hardware infrastructure they own.
- ▶ Any form of growth (from a new workload to a 30-year-old COBOL application that is used more often) qualifies for a much-improved Price per MSU.

One key concept in a Software Consumption Model is the customer baseline. The IBM team works with the customer to review their previous 12 months production MSU consumption and billing to determine an effective price per MSU and establish a predictable price for all growth at discounted rate (see Figure D-1).

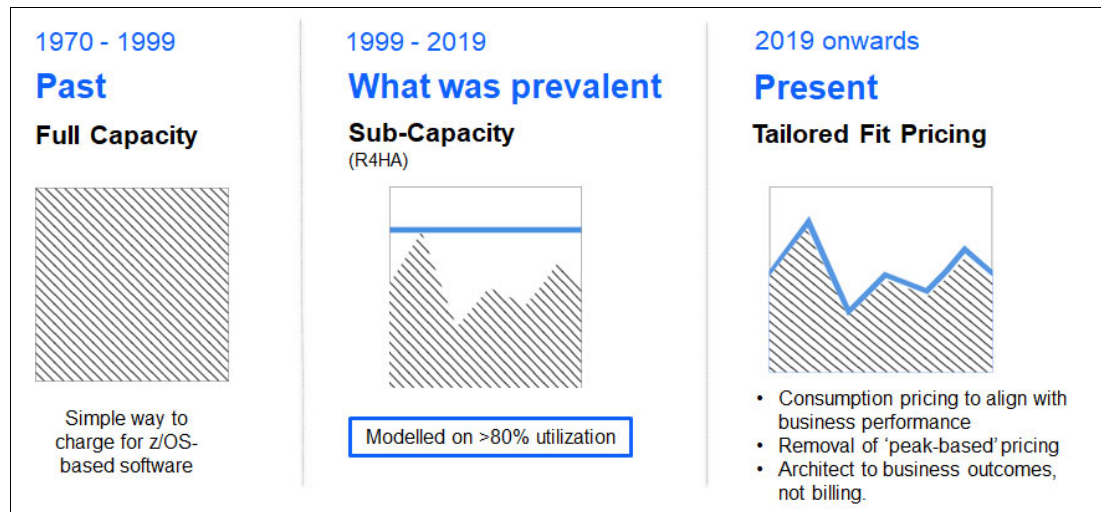


Figure D-1 Evolution of IBM Z Software pricing

With the Software Consumption model, no concept of peaks or white space is used that previously were integral to the sub-capacity-based model. Therefore, customers are free to remove capping and can use all of the owned capacity without worrying about penalties for peaking or spiking.

Although a customer does commit to an MSU baseline, if the MSUs for a specific year are not fully used, the customer can carry over any unused MSUs for use in the following year for the life of the contract. TFP consumption encourages and rewards growth; that is, MSUs that are processed above the baseline are charged at an aggressive Growth Price per MSU.

All workload processing can benefit by running with no capping and having all owned infrastructure available. Batch processing also can take advantage and reduce batch windows dramatically.

Without capping in place, customers can expect jobs to finish faster yet at the same cost. Online processing can process more transactions simultaneously, which improves response times. This result is a function of the new billing approach that is based on the amount of work that is done rather than peaks that are reached.

To provide improved economics for growth, TFP Consumption customers pay preferential pricing on the MSUs that are used above their baseline, regardless of whether that growth came from existing or new workloads. No other approval, qualification, or processing is required to use the growth pricing rate.

International Program License Agreement in the Software Consumption Model

IBM Z enterprise customers often have One Time Charge (OTC) IBM products that are running in the same environment as MLC products. With the Software Consumption Model, IBM offers two choices for the handling of OTC software: A Full Capacity licensing model, and the option to use their existing OTC software licensing in a consumption model with the flexibility to use the entitlement on a consumption basis across a year as business demands.

With coverage of both MLC and capacity-based IPLA products, the Software Consumption Model offers a single and comprehensive software solution to IBM Z customers.

Hardware Consumption Model

IBM introduced a hardware solution that provides added flexibility to the IBM Z IT infrastructure pricing and is a natural and valuable extension to the Tailored Fit Pricing models for IBM Z software.

To meet the demands of modern workloads, IBM Z hardware can now include, in addition to the base capacity, a subscription-based corridor of pay for use capacity. This always on corridor of consumption-priced capacity helps alleviate the effect of short unpredictable spikes in workload that are becoming more common in today's digital world.

The use charges feature a granularity of 1 hour and are based on MSUs that are used as measured by the subcapacity reporting Tool (SCRT), not full engine capacity.

Tailored Fit Pricing for IBM Z hardware enables customers to be ready for the unknown and unexpected. The presence of the always on capacity contributes to better efficiency, reduced overhead, and shorter response times. This offering is available for customers, starting with IBM z15, z/OS general-purpose CPs, and who are using Tailored Fit Pricing for IBM Z software.

Tailored Fit Pricing for IBM Z hardware in more detail

Tailored Fit Pricing (TFP)-Hardware pricing includes two aspects: a Subscription charge, and a Usage charge (see Figure D-2).

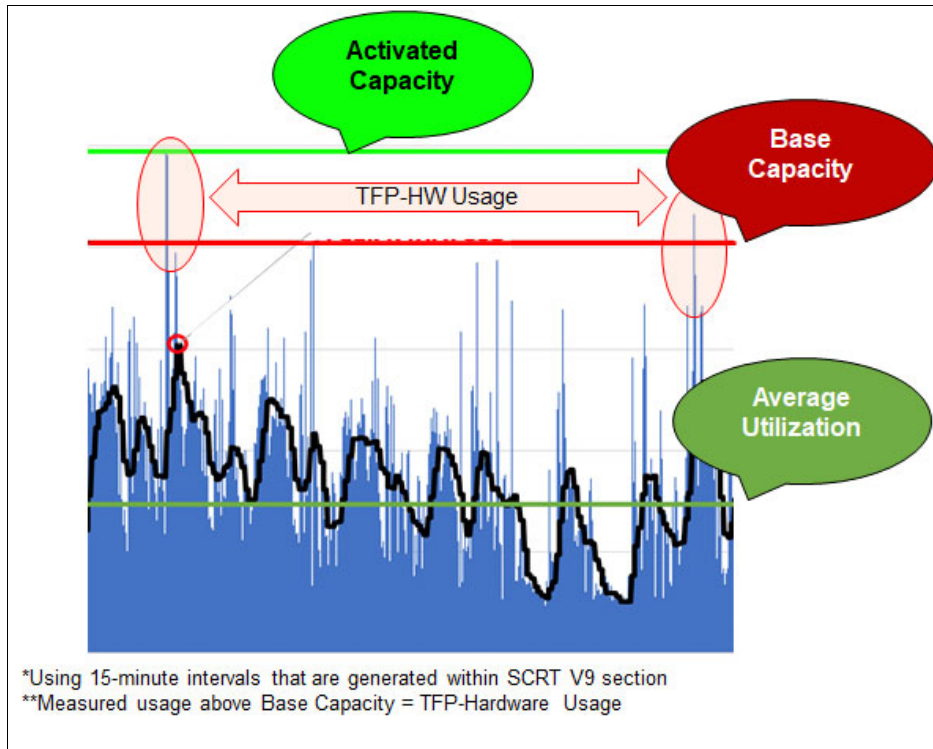


Figure D-2 TFP-Hardware use

One of the most important facts about TFP-Hardware is that a single system or central processing complex (CPC) always is considered. It is on this level that use is measured. The blue bars that are shown in Figure D-2 represent individual 15-minute intervals, and the use is measured in each one.

In Figure D-2, the dark green line shows the average use of the machine over the entire period that is measure (normally a month). The black line shows the Rolling 4 Hour Average (R4HA), and it is displayed for information purposes only because the R4HA is not used for TFP-Hardware calculations.

The red line is the customer owned capacity (or Base capacity). The light green line shows the activated capacity of the machine, as reported by Sub-Capacity Reporting Tool (SCRT).

As shown in Figure D-2, some of the blue bars reach above the red line, into the corridor between the red line and light green lines, which represents the TFP-Hardware capacity. Therefore, use over the customer's owned (Purchased) capacity is measured, so a Usage charge is incurred. If no use is measured over the customer's owned (Purchased) capacity, no Usage charge is incurred.

In addition to the Usage charge, which might not be relevant, a Subscription charge also can be assessed. The Subscription charge is a flat, per system, per month payment that is based on the amount of TFP-Hardware capacity that is provided on the system. The Subscription charge is invoiced prepaid for the contract term or postpaid monthly.

Because only entire engines can be activated, it is always full engine sizes that are based on IBM Large System Performance Reference (LSPR) capacity levels. The Subscription charge covers the value that the extra activated capacity brings, even if no measured usage exists (see Figure D-3).

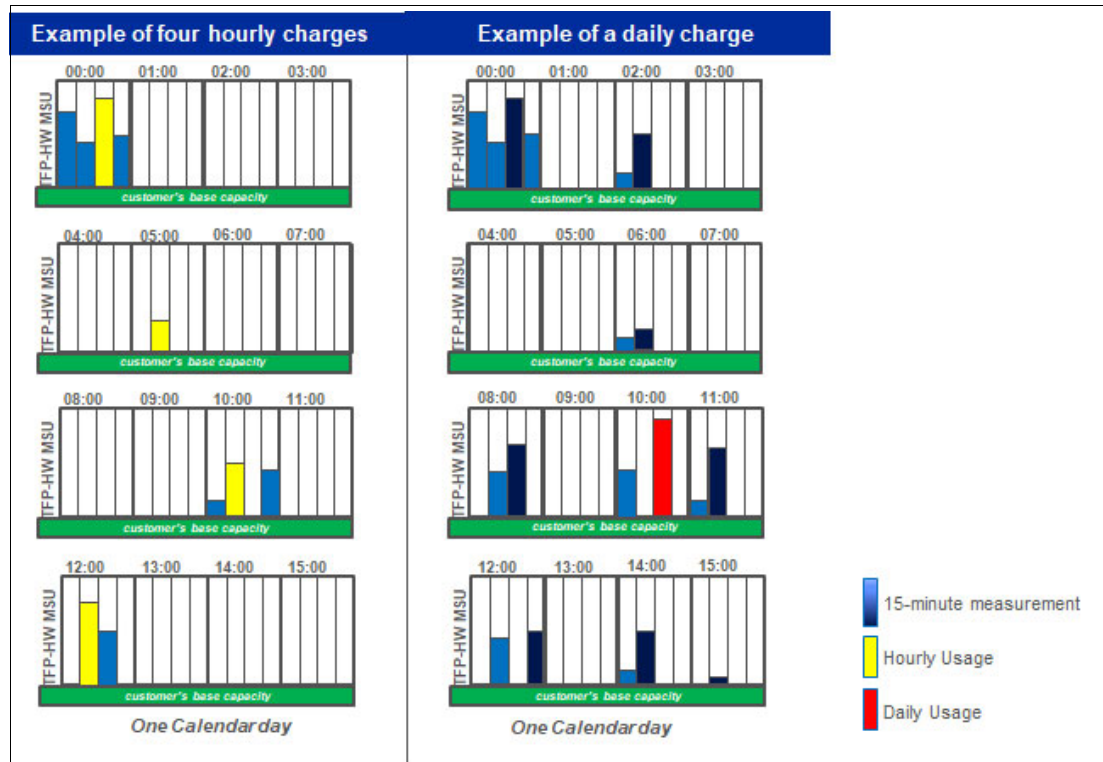


Figure D-3 Charge examples

The green bar in Figure D-3 represents the capacity that the customer owns (the so-called *Base capacity*). The transparent bars represent activated TFP-Hardware corridor.

The blue bars show the measured usage within the 15-minute intervals that are greater than the customer-owned capacity. The yellow bar is the highest measured TFP-Hardware use within the defined hour.

The red bar in Figure D-3 is the highest measured use during a calendar day and is only relevant if the customer has more than 4 hours of TFP-Hardware use within one calendar day.

The left column that represents one calendar day shows that 10 spikes above the Base capacity were measured. The spikes that are counted for invoicing are the yellow bars (the highest within each hour).

The yellow bars hold a measured million of service units (MSU) value. If the total MSU use of the yellow bars is 250 MSU, the customer receives an invoice of 250 times the hourly usage charge per MSU.

Also, the right column in Figure D-3 represents one calendar day, where 18 spikes above the Base capacity are measured. The spike that is counted for invoicing is the red bar (the highest within the calendar day). The red bar is considered because it was measured that the TFP-Hardware corridor was used for more than 4 hours during the calendar day.

The red bar also holds a measured MSU value for that calendar day. If the total MSU use of the red bar is 100 MSU, the customer receives an invoice of 100 times the daily usage charge per MSU.

Efficiency benefits of TFP-Hardware

Even if no use measured, the following benefits are realized resulting from having the extra capacity activated:

- ▶ Improved and more predictable response times with lower latency (especially when compared to a public cloud solution)
- ▶ Faster transaction processing, with shorter spikes of high use
- ▶ Higher number of active processor engines have a positive n-way effect (higher parallelization) and delivers more cache, less contention, and overhead
- ▶ Optimized workload handling under customer-defined use thresholds
- ▶ Improved insight for future capacity planning
- ▶ Improved balance between physical and logical Central Processor (CPs)
- ▶ Reduced Processor Resource/System Manager (PR/SM) logical partitions (LPAR) management, less overhead

Conclusion

The combination of TFP for the hardware and software is a powerful one for our customers to maximize their investment in IBM Z. For eligible customers, it allows them to use their hardware for their general capacity requirements with a consumption-based corridor on top.

When this TFP for hardware is combined with the TFP-SW solutions, it allows customers to unleash the full power of their IBM Z machine.

IBM Z Flexible Capacity for Cyber Resiliency

Resiliency continues to be a hot topic for clients and a key value driver for IBM Z, especially for the largest IBM Z clients in regulated industries.

IBM's answer was the introduction of zDR Cloud. This offering enables active MIPS flexibility between the production site and the DR site. It also offers greater flexibility over CBU tests for length of test execution and frequency.

However, the following disadvantages must be addressed:

- ▶ zDR Cloud requires an MES to run a site swap for test and CBU for unplanned site swap
- ▶ Onsite IBM intervention is required, which is not COVID-safe
- ▶ A 2-week lead time is required to implement, which induces delays
- ▶ it is applicable only to planned site swap scenarios; therefore, DR testing and real DR scenarios are not the same, which causes compliance issues
- ▶ A lack of standardization makes automation impossible

To overcome these issues, IBM developed the new IBM Z Flexible Capacity for Cyber Resiliency offering.

Flexible Capacity is designed to provide increased flexibility and control to shift production workloads between participating IBM z16 machines at different sites and stay for up to one year.

It helps organizations shift capacity between participating IBM z16 machines at different sites to improve Cyber Resiliency and offers increased flexibility to shift capacity on demand between participating IBM z16 machines at different sites.

By using IBM GDPS, scripts can be run to fully automate Flexible Capacity for Cyber Resiliency capacity shifts between participating IBM z16 machines at different sites.

It helps organizations to comply with evolving regulatory mandates by running a realistic failover scenario for production workloads that can also demonstrate business continuity.

Use cases of IBM Flexible Capacity for Cyber Resiliency

In this section, we present several IBM Flexibly Capacity use cases for Cyber Resiliency.

Disaster recovery and DR testing

Transfer the capacity that you need at your DR site to continue to run your business workloads for up to one year. Prove to regulators that the DR site that is used can run the customer's business also during peak times.

Frictionless compliance

Meet the ever-evolving stringent requirements of global regulators, which allows a highly automated and fast process to demonstrate a production site swap.

Facility maintenance

Run your production workload from your alternative site while you maintain your primary site with the capacity that you need.

Pro-active avoidance

Protect your critical business services from natural disasters. Avoid rolling power outages. Migrate your critical workloads to an alternative site before your business is affected and remain in that state for up to one year.

How does IBM Flexible Capacity for Cyber Resiliency work?

This section describes the high-level process for implementing IBM Flexible Capacity for Cyber Resiliency.

Set up process

Flexible Capacity for Cyber Resiliency is facilitated through a new type of Temporary Capacity record.

In the first step of the setup process (see Figure D-4), the active capacity of the participating IBM z16 machines is changed to a base machine plus the temporary entitlement record (TER) up to the High Water Mark (HWM) of the machine. The base capacity is defined by the customer. The machines' HWM remains unchanged.

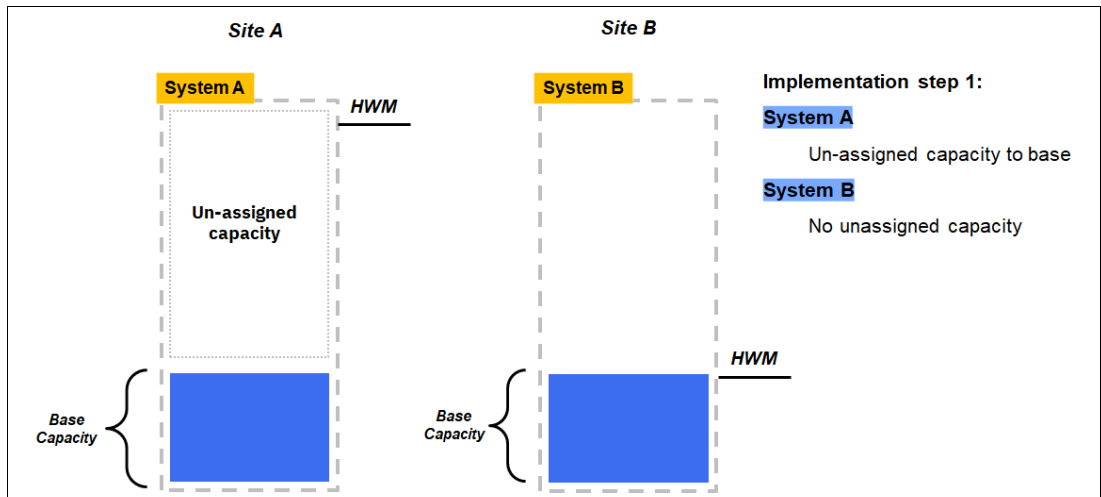


Figure D-4 Initial configuration

In the next step (see Figure D-5), the now unassigned capacity is restored with a new Flexible Capacity record. Another Flexible Capacity record is installed on System B to increase the capacity to the amount of MIPS that the customer licensed.

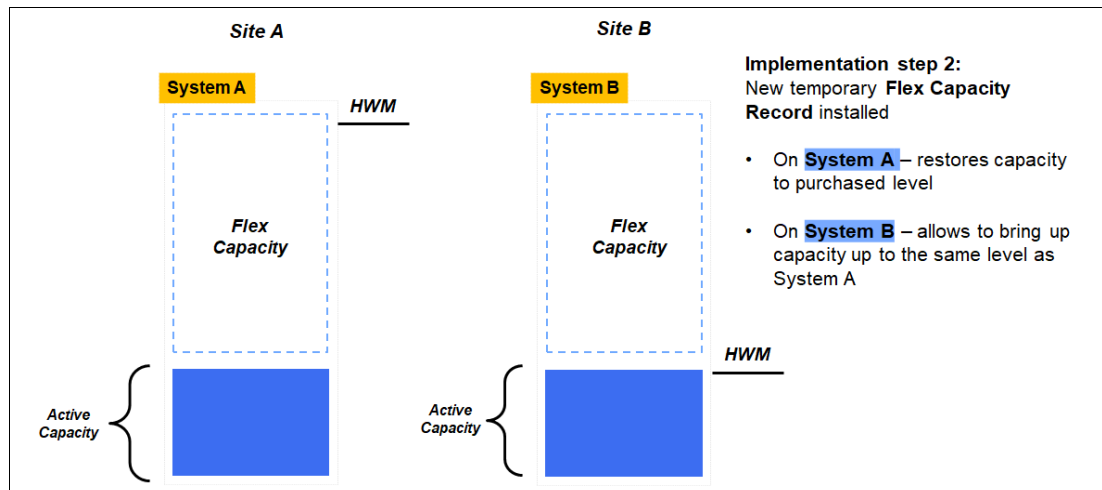


Figure D-5 Flexible Capacity Installed record

The IBM Flex Capacity record on System A then is activated until the machine’s HWM. On System B, the Flexible Capacity record is installed, but not activated. The setup process is now complete (see Figure D-6).

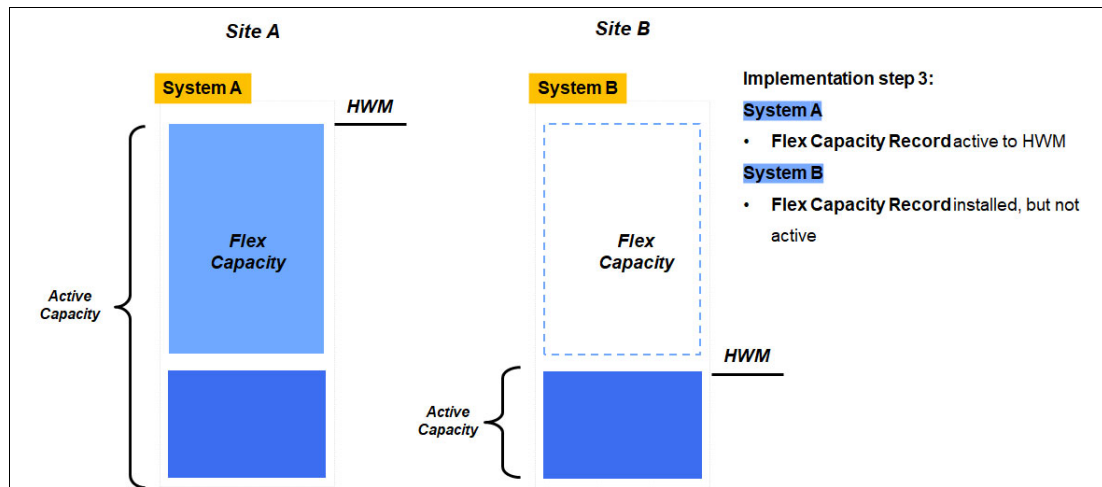


Figure D-6 Flexible Capacity activated record

Transferring capacity

After the set up is complete, it is possible to transfer capacity and workload from Site A to Site B. This process can be automated by using GDPS technology.

GCP (general-purpose processor) capacity is transferred by using licensed MIPS. However, you cannot activate half a CP. Therefore, it is the customer’s responsibility to stay under the licensed amount of MIPS; otherwise, extra charges are incurred for the use that is greater than the licensed MIPS.

After the Flexible Capacity record is active on both sites, a time limit of 24 hours begins in which workloads can be transferred from Site A to Site B without leading to more charges.

During this time window, Flexible Capacity can remain active on both sites, as shown in Figure D-7

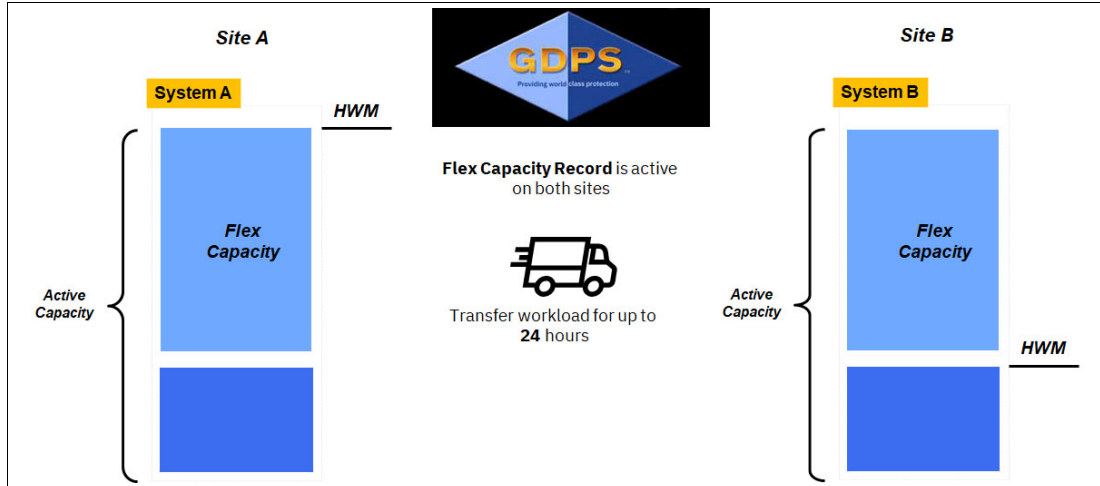


Figure D-7 Transfer window

After 24 hours, the Flexible Capacity in Site A is removed and System A is reduced to base capacity (see Figure D-8).

Flexible Capacity on System B can stay running for up to one year.



Figure D-8 Stay in DR for up to one year

Multi-system environment

A two-site, two-system environment is only the base infrastructure. Flexible Capacity for Cyber Resiliency also is suited for complex multi-system environments.

Flexible Capacity from several systems can be transferred to single systems in Site B or vice-versa (see Figure D-9).

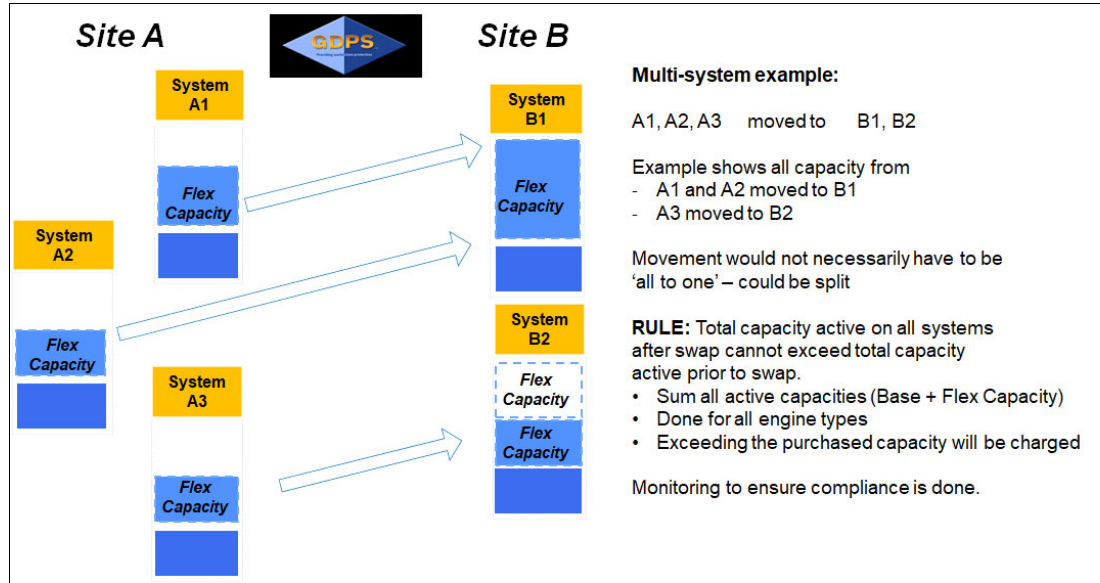


Figure D-9 Multi-system Flex Capacity example

Movement of capacity does not need to be “all to one”: the capacity also can be split.

However, the total capacity that is active on all systems after the swap cannot exceed the total capacity that is active before the swap.

Flexibly Capacity is available on all engine types; exceeding the purchased capacity incurs charged. Monitoring to ensure compliance is done by way of Call Home data that IBM receives periodically.

Tailored fit pricing for hardware and IBM Z Flexible Capacity for Cyber Resiliency

IBM Z Flexible Capacity for Cyber Resiliency can be used with TFP-Hardware. The Flexible Capacity limit is always based on the Base capacity. The presence or activation of TFP-Hardware does not affect the amount of capacity that can be activated by a Flexible Capacity Transfer record.

The Flexible Capacity Transfer record always is considered to be the first record that was activated, regardless of the order in which temporary records or TFP-Hardware were activated.

The example that is shown in Figure D-10 shows an active Sysplex across Site A and Site B.

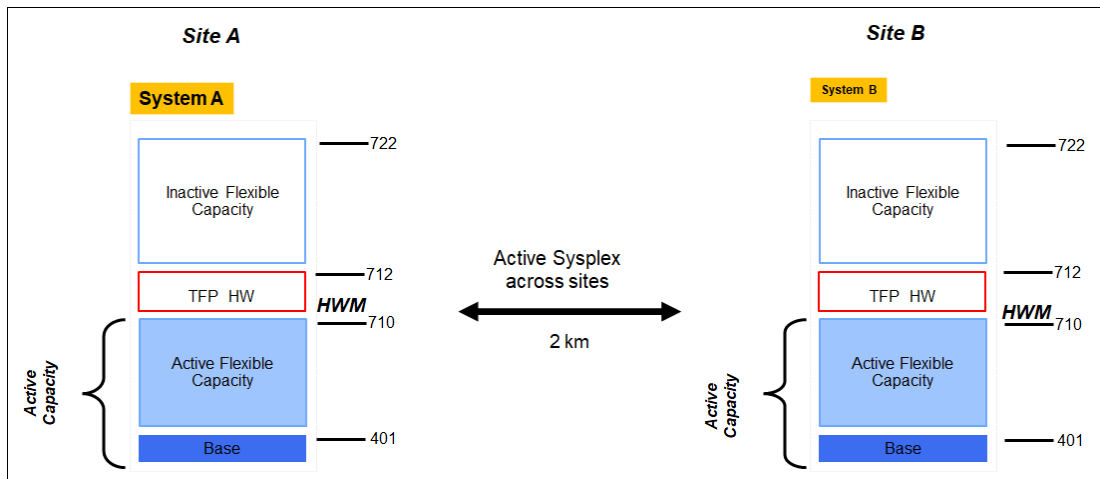


Figure D-10 Flexible Capacity: Two site sysplex

System A has a Base capacity of 401 and the Flexible Capacity Record is partially activated up to a 710. On top of the active Flexible Capacity sits a TFP-Hardware capacity of two extra CPs to a maximum of 712. The inactive part of the Flexible Capacity record floats on top of the TFP-Hardware capacity.

System A is in a Sysplex with System B that has the same configuration.

Now, the data-center operator decides to perform maintenance on System A and transfers its active Flexible Capacity to System B.

Figure D-11 shows the configuration of both machines after the transfer.

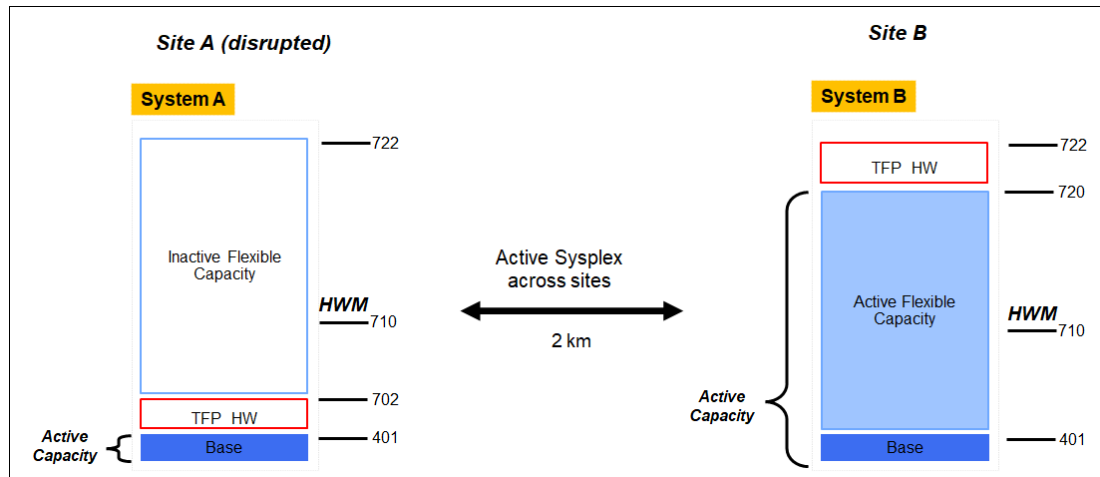


Figure D-11 Flexible Capacity with two site sysplex - transfer

System A transferred all of its Flexible Capacity to System B and is left with only the base capacity of 401. On top of the base capacity sits the TFP-Hardware capacity.

Now, System A can safely perform maintenance.

System B has now the entire Flexible Capacity record activated and shows an active capacity of 720. The TFP-Hardware capacity sits again on top of the active capacity and adds now another 2 CPs to the 720.

This shows that the presence or activation of TFP-Hardware does not impact the amount of capacity that can be activated by a Flexible Capacity Transfer record.

The TFP-Hardware capacity always “floats on top” of any other activated capacity for TFP-Hardware usage charging. Therefore, no double charging can occur.

Ordering and installing IBM Z Flexible Capacity for Cyber Resilience

To facilitate ordering Flex Capacity, the following Capacity on-Demand feature codes (FC) were introduced:

- ▶ Flexible Capacity Authorization (FC 9933)
- ▶ Flexible Capacity Transfer Record (FC 0376)
- ▶ Billing feature codes (Feature Codes 0317 - 0322, and 0378 - 0386)

FC 9933 and 0376 must be active on each machine that is participating in Flexible Capacity for Cyber Resiliency.

A new Capacity on-Demand contract attachment also must be signed by the customer.

Terms and conditions of IBM Z Flexible Capacity for Cyber Resiliency

The terms and conditions of IBM Z Flexible Capacity for Cyber Resiliency are listed in Table D-1.

Table D-1 Terms and conditions of IBM Flexible Capacity

Term or condition	Description
Cross site movement	Inter-site moves can be done, regardless of distance, mirroring, or coupling technology. Intra-site moves are <i>not</i> allowed (two machines in the same data center cannot move capacity back and forth).
Entitlement	The owner of the machine holds a title to the physical hardware. The capacity of that machine is enabled and controlled by way of the LIC of the machine, which is licensed, not sold
Overlap period	A 24-hour period in which the temporary record can be active on both systems.
Activation limit	12 activations or deactivations per record in a year (12 activations translates to 6 round trips).
Activation period	Keep the flexible capacity record active on your alternative site for up to one year.
License transfer	LIC is licensed to one specific serial numbered machine only. It cannot be transferred to another machine.
License expiration	The LIC license is expired 5 years past WFM. An invalid LIC license resumes if the IBM Z machine is upgraded or replaced with an IBM Z machine that is not older than N-2.
TFP for software	Offering requires TFP for software; CMP is grandfathered in.
Maintenance	Continue with same pricing scheme as for zDR Cloud 1.0 (price active capacity). Overlap time is determined by the customer.
Microcode only	IBM Z Flexible Capacity for Cyber Resiliency is Microcode only. More memory, I/O cards, drawers, and other infrastructure-related components must be prepared by the client.
Call home	Customer agrees to use Call Home data to monitor capacity usage.
Charges for capacity exceeding the temp record	Capacity that is used beyond the purchased capacity is charged at previously defined OOCOD prices.

IBM Z Flexible Capacity for Cyber Resilience versus Capacity Back Up

Flexible Capacity and Capacity Back Up (CBU) feature different purposes and limitations, as listed in Table D-2.

Table D-2 Differences between Flexible Capacity and CBU

	IBM Z Flexible Capacity for Cyber Resiliency	Capacity Back Up
Primary purpose and benefits	<p>All CBU benefits at an alternative site, plus:</p> <ul style="list-style-type: none"> ▶ Run mainframe workload in alternative site for up to 1 year ▶ Demonstrate ability to migrate entire mainframe workload to alternative site (for example, regulatory requirements) ▶ Run entire workload in alternative site for extended period (for example, facilities requirements) ▶ Proactively swap production to alternative out-of-region site before a (natural) disaster occurs 	<p>Run full mainframe workload if DR event is declared:</p> <ul style="list-style-type: none"> ▶ Ability to test DR readiness up to 10 days. ▶ Validate with nonproduction workload (up to 10 days per CBU test). ▶ Validate with production workload (up to 10 days per CBU test). Requires primary site capacity to be disabled.
Limitations	<ul style="list-style-type: none"> ▶ Alternative site can be used for maximum of 1 year ▶ Allows up to 24-hour overlap period, where full capacity is active on both sites for transferring workload ▶ Allows 12 swaps between sites per year (one direction) 	<p>Each CBU test is limited to a maximum of 10 days</p>
Contracts and features	<ul style="list-style-type: none"> ▶ LIC is licensed to only one specific serial-numbered machine, and its transfer to another machine is not permitted ▶ Offering requires TFP for software; CMP is grandfathered in. ▶ The LIC license expires 5 years past WFM. An invalid LIC license resumes if the IBM Z machine is upgraded or replaced with an IBM Z machine that is not older than N-2. 	<ul style="list-style-type: none"> ▶ Capacity Back Up Agreement ▶ CBU capacity provided in annual increments ▶ CBU tests provided in individual increments



Frame configurations Power Distribution Units and Bulk Power Assembly-based systems

This appendix describes the various frame configurations for Power Distribution Units (PDUs) and Bulk Power Assembly (BPA)-based systems. All of the figures that are included here are views from the rear of the system.

The common building blocks are displayed and range from 1 - 4 frames, with various numbers of CPC drawers and PCIe+ I/O drawers.

This chapter includes the following topics:

- ▶ “Power Distribution Unit configurations” on page 534
- ▶ “Bulk Power Assembly configurations” on page 537

Power Distribution Unit configurations

The various PDU-based system configurations are shown in Figure E-1 - Figure E-6 on page 536.

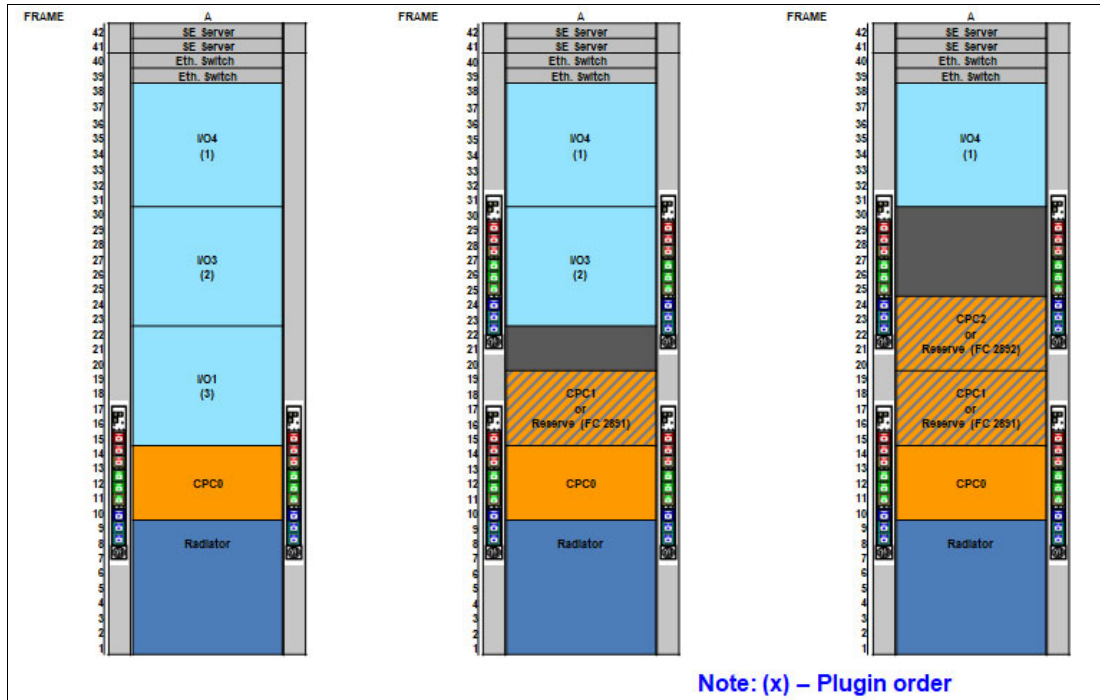


Figure E-1 Single frame

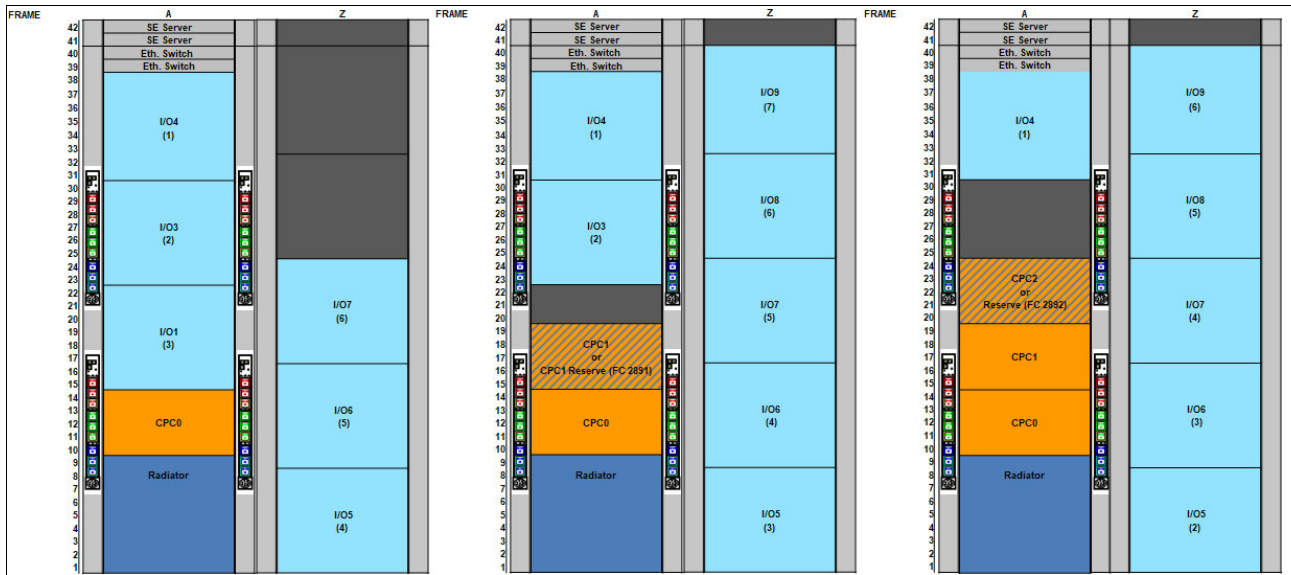


Figure E-2 Two frames AZ

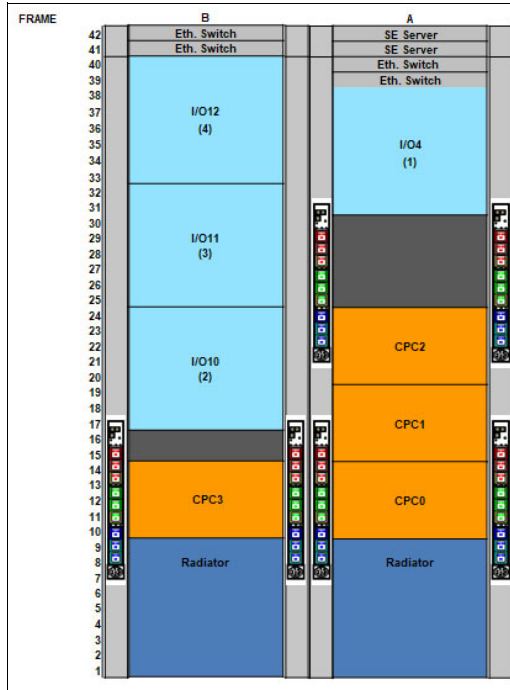


Figure E-3 Two frames AB

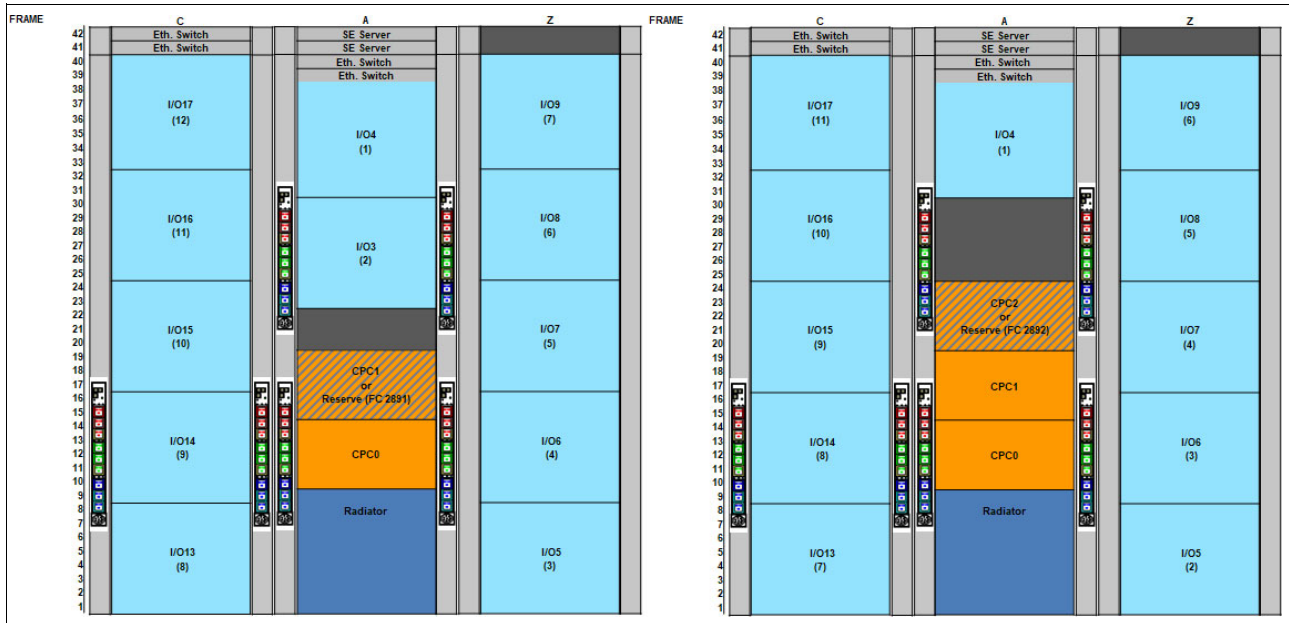


Figure E-4 Three frames ZAC

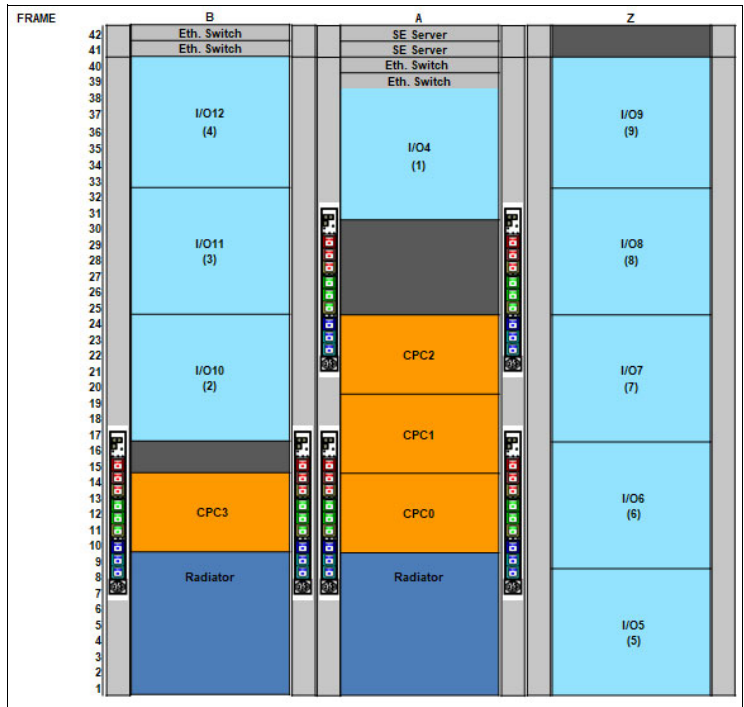


Figure E-5 Three frames ZAB

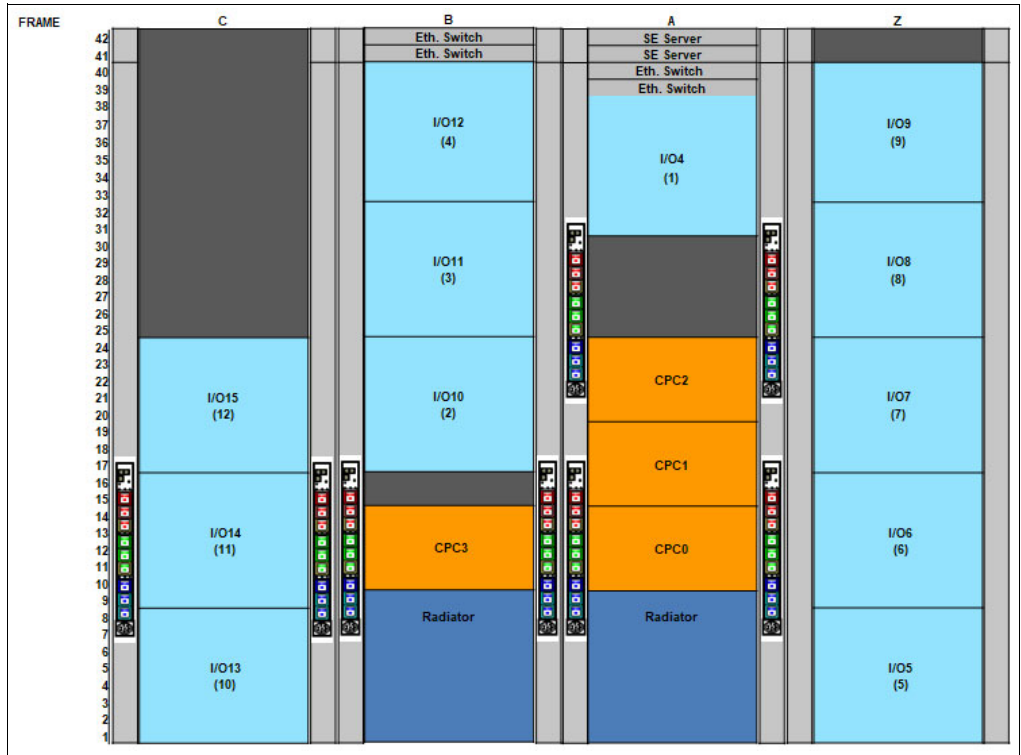


Figure E-6 Four frames ZABC, PDU

Bulk Power Assembly configurations

The BPA-based system configurations are shown in Figure E-7 - Figure E-17 on page 542.

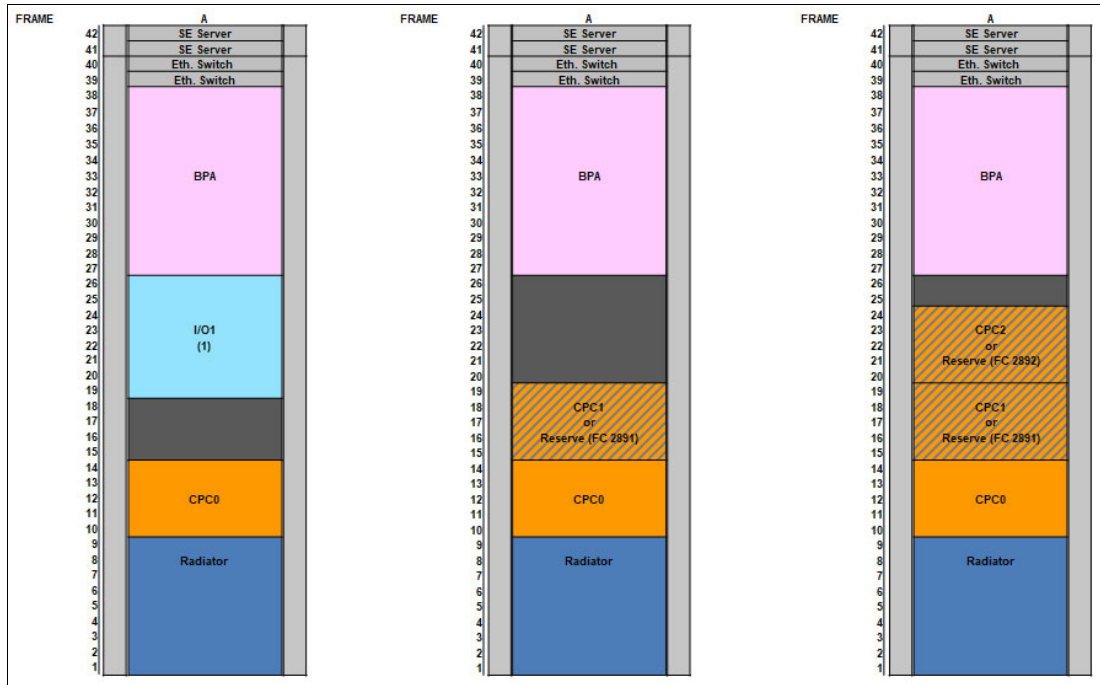


Figure E-7 Single frame

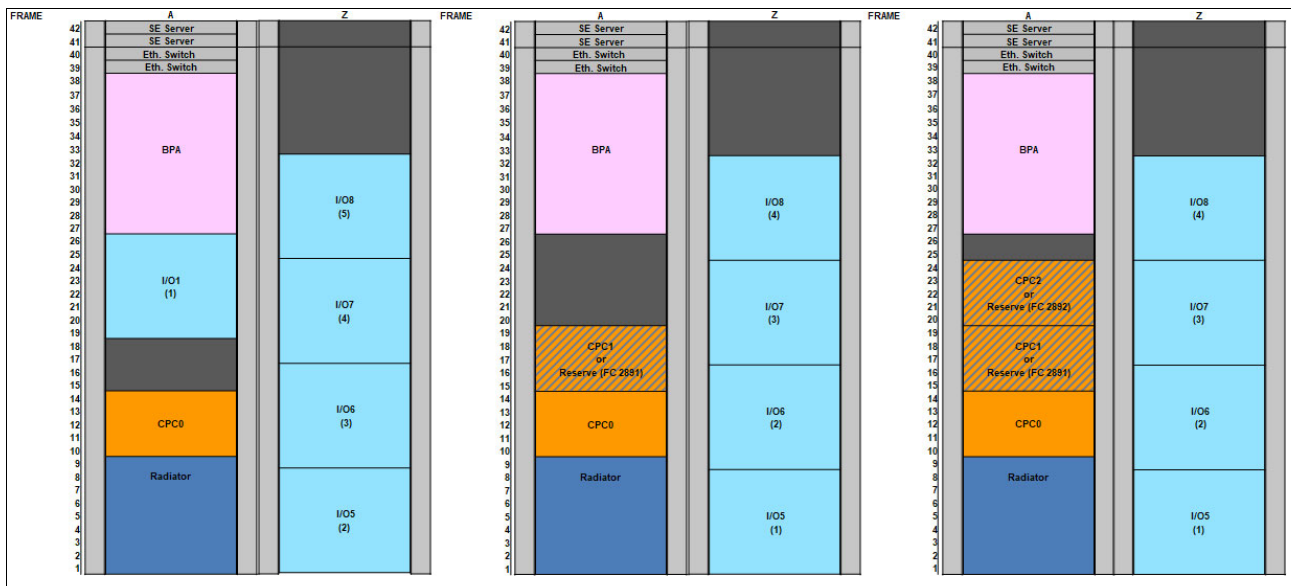


Figure E-8 Two frames AZ

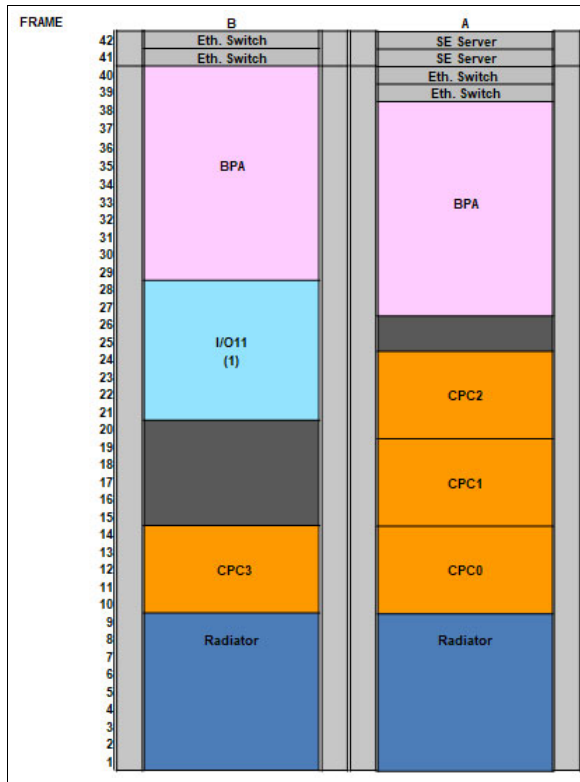


Figure E-9 Two frames AB, four CPCs

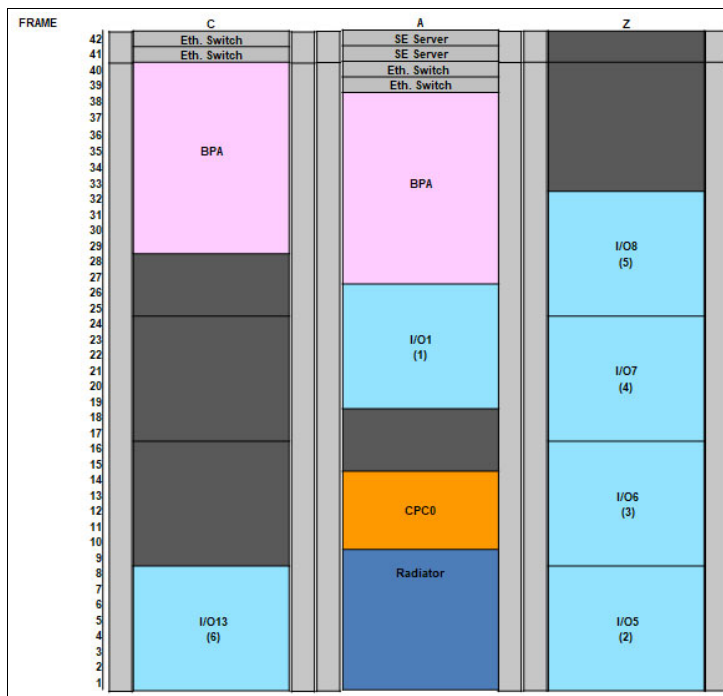


Figure E-10 Three frames ZAC one CPC

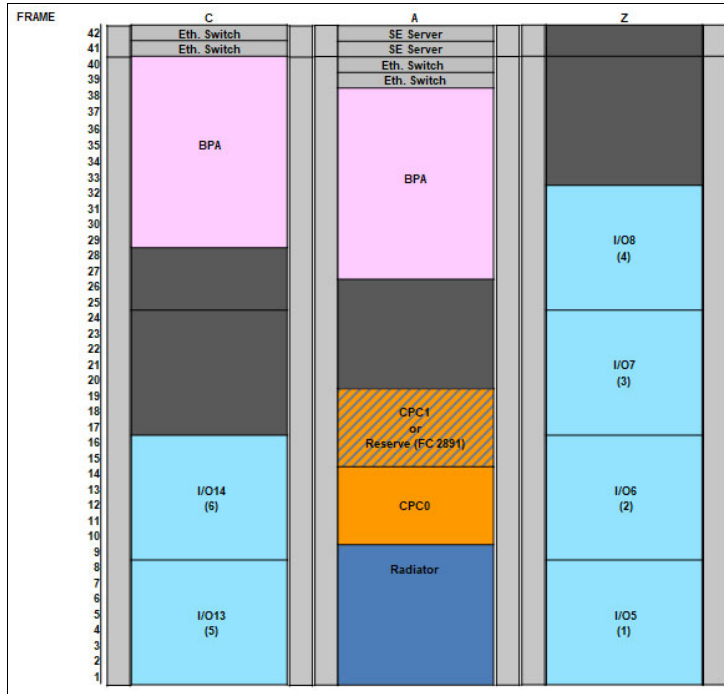


Figure E-11 Three frames ZAC, two CPC

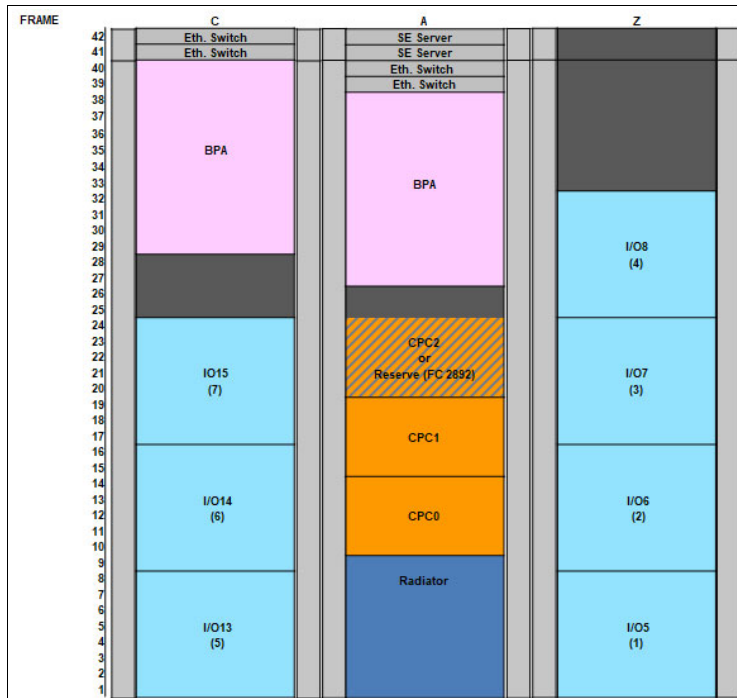


Figure E-12 Three frames ZAC, three CPC

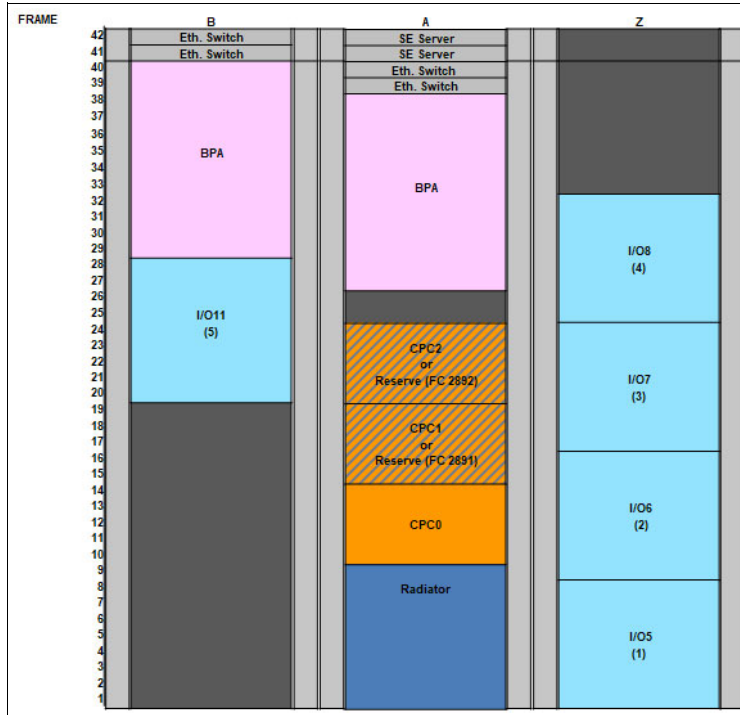


Figure E-13 Three frames ZAB

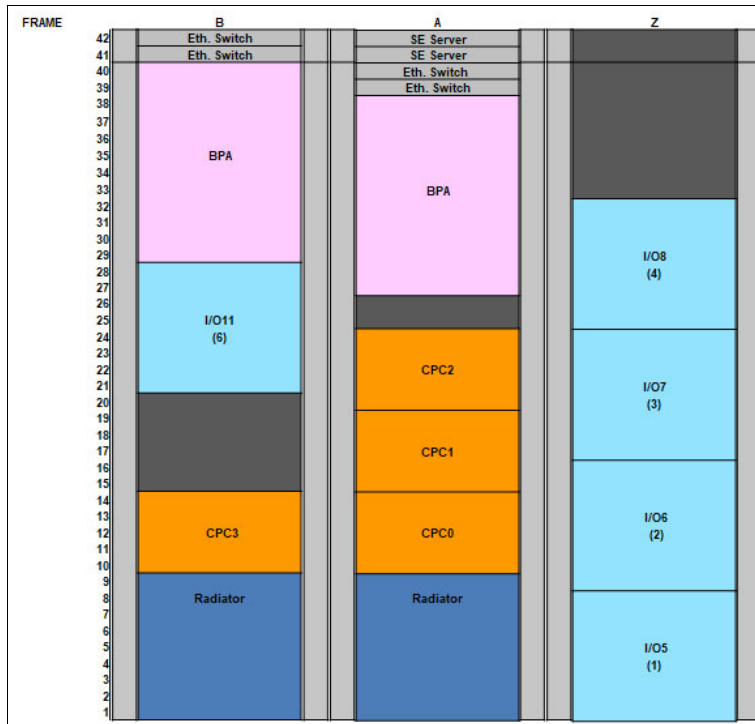


Figure E-14 Three frames ZAB, four CPC

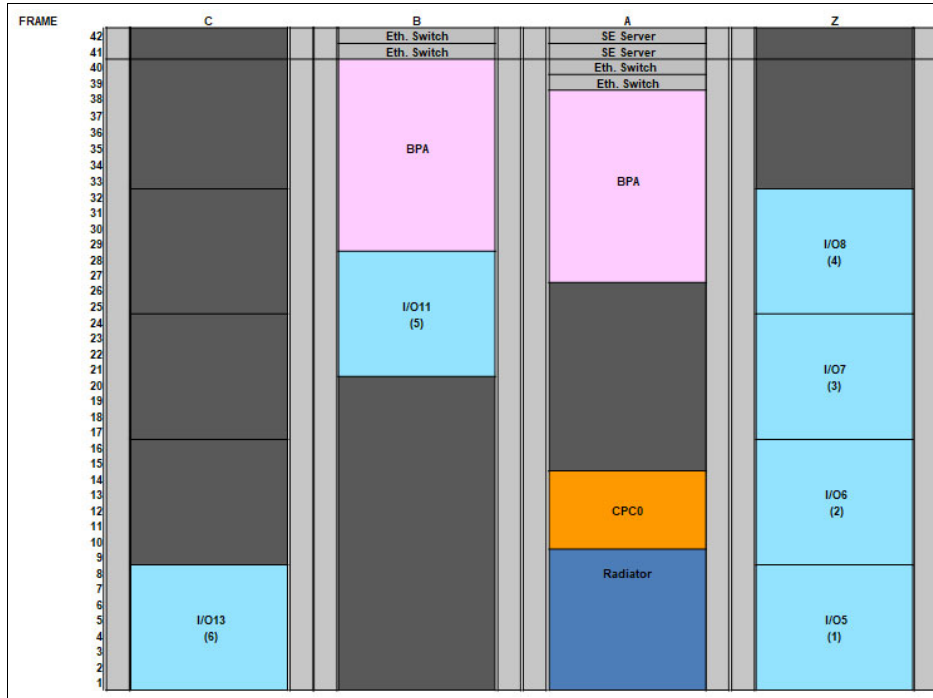


Figure E-15 Four frames ZABC, single CPC

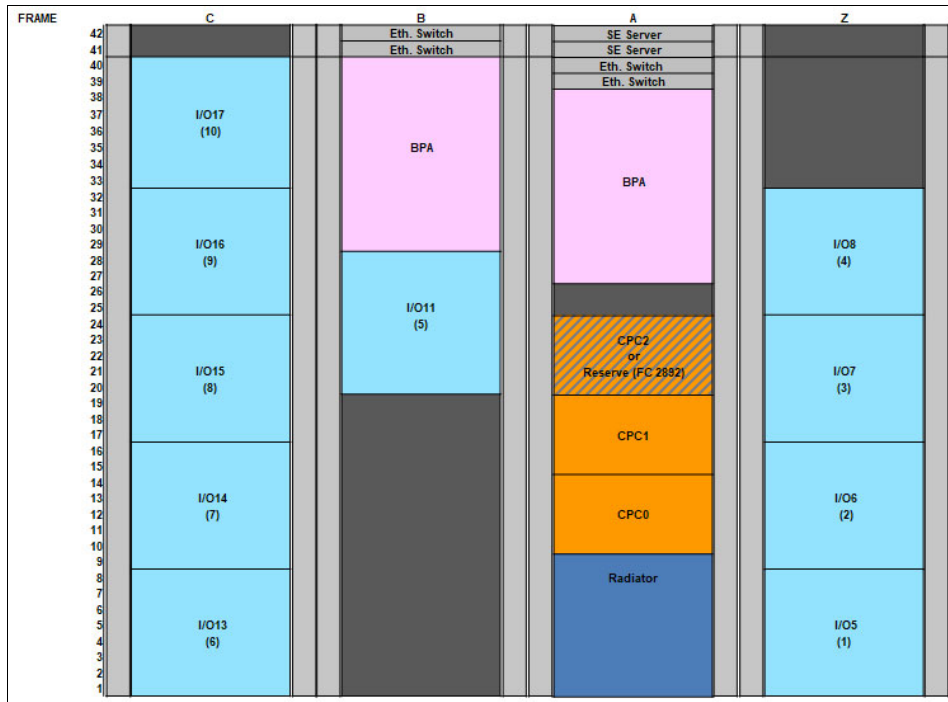


Figure E-16 Four frames ZABC, three CPCs

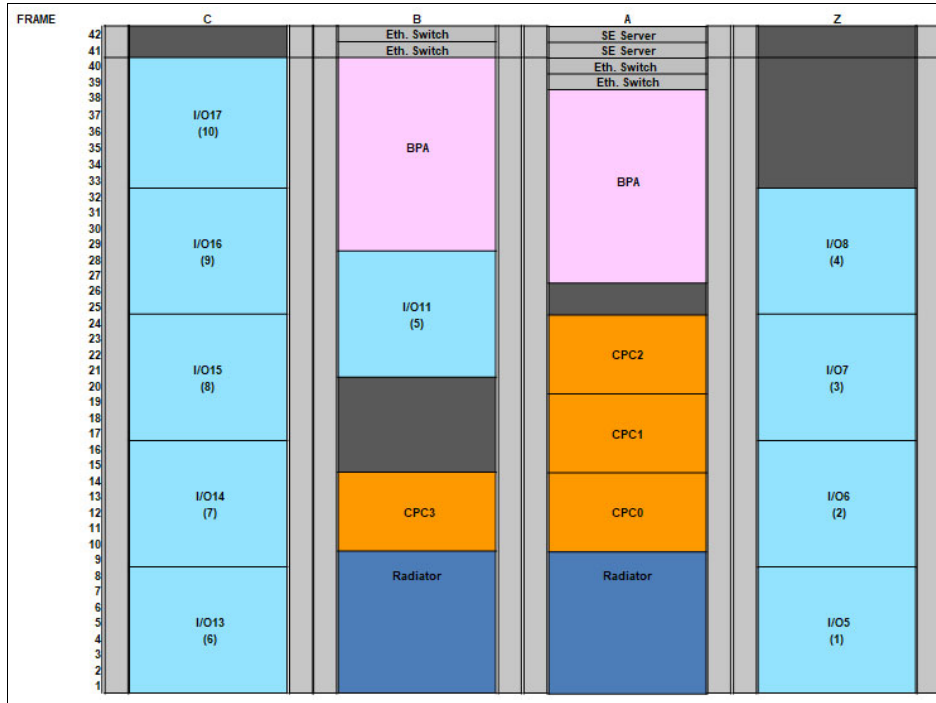


Figure E-17 Four frames ZABC, four CPC

Related publications

The publications that are listed in this section are considered particularly suitable for a more detailed discussion of the topics that are covered in this book.

IBM Redbooks

The following IBM Redbooks publications provide more information about the topic in this document. Note that some publications that are referenced in this list might be available in softcopy only:

- ▶ *IBM z16 Technical Introduction*, SG24-8950
- ▶ *IBM Z Connectivity Handbook*, SG24-5444
- ▶ *IBM z16 (3931) Configuration Setup*, SG24-8960

You can search for, view, download, or order these documents and other Redbooks, Redpapers, Web Docs, draft and additional materials, at the following website:

ibm.com/redbooks

Other publications

The publication *IBM Z 8561 Installation Manual for Physical Planning*, GC28-7002, also is relevant as another information source.

Online resources

The following online resources are available:

- ▶ The IBM Resource Link for documentation and tools website:
<http://www.ibm.com/servers/resourceLink>
- ▶ IBM Telum Processor: The next-gen microprocessor for IBM Z and IBM LinuxONE:
<https://www.ibm.com/blogs/systems/ibm-telum-processor-the-next-gen-microprocessor-for-ibm-z-and-ibm-linuxone/>
- ▶ Leveraging ONNX Models on IBM Z and LinuxONE:
<https://community.ibm.com/community/user/ibmz-and-linuxone/blogs/andrew-sica/2021/10/29/leveraging-onnx-models-on-ibm-z-and-linuxone>
- ▶ Jump starting your experience with AI on IBM Z:
<https://blog.share.org/Article/jump-starting-your-experience-with-ai-on-ibm-z>

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