Draft revised Recommendation ITU-T Y.3505 (formerly Y.3505-rev)

Cloud computing – Overview and functional requirements for data storage federation

Summary
This Recommendation provides overview and functional requirements of data storage federation. Data storage federation provides a single virtual volume from multiple data sources in heterogeneous storages. In this Recommendation, configuration for logical components, and ecosystem of data storage federation as well as cloud computing based data storage federation are introduced for data storage federation. Functional requirements are derived from use cases.

Keywords
cloud computing, data storage federation, functional requirement

Table of Contents

Page

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Cloud computing – Overview and functional requirements for data storage federation

1 Scope

This Recommendation provides overview and functional requirements of data storage federation including benefits, configuration for logical components, and ecosystem of data storage federation as well as cloud computing based data storage federation. The functional requirements provided in this Recommendation are derived from use cases.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.3500] Recommendation ITU-T Y.3500 (2014), *Information technology – Cloud computing – Overview and vocabulary.*

[ITU-T Y.3502] Recommendation ITU-T Y.3502 (2014), *Information technology — Cloud computing - Reference architecture.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 activity [ITU-T Y.3502]: A specified pursuit or set of tasks.

3.1.2 cloud computing [ITU-T Y.3500]: Paradigm for enabling network access to a scalable and elastic pool of shareable physical or virtual resources with self-service provisioning and administration on-demand.

NOTE – Examples of resources include servers, operating systems, networks, software, applications, and storage equipment.

3.1.3 cloud service customer [ITU-T Y.3500]: Party which is in a business relationship for the purpose of using cloud services.

NOTE - A business relationship does not necessarily imply financial agreements.

3.1.4 cloud service provider [ITU-T Y.3500]: Party which makes cloud services available.

3.1.5 metadata [b-ISO/IEC 2382]: Data about data or data elements, possibly including their data descriptions, and data about data ownership, access paths, access rights and data volatility.

3.1.6 role [ITU-T Y.3502]: A set of activities that serves a common purpose.

3.1.7 sub-role [ITU-T Y.3502]: A subset of the activities of a given role.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 data storage federation: A processing to provide a single virtual volume from the multiple heterogeneous data storages using storage virtualization.

NOTE – In this Recommendation, heterogeneous storage refers to DSF local storage.

3.2.2 DSF local storage: A physical storage to be integrated.

NOTE – DSF local storage includes on-premise storage (e.g., main memory, non-volatile memory express, solid-state disk, hard disk drive, serial attached SCSI, internet SCSI storage and network-attached storage, object-based storage device, intelligent storage device, etc.), and cloud storage with different management units such as block, object, and file.

3.2.3 single virtual volume: A virtual storage unit provided in forms of a block device, file, or object-based storage.

NOTE – Customer of single virtual volume includes an end-user, server, operating system, and application.

3.2.4 storage virtualization: An abstraction of storage resource to provide logical storage.

NOTE – The abstraction includes consolidating the different type of storages into virtual storage pool as well as dividing virtual storage pool into a single virtual volume.

3.2.5 virtual storage pool: A logical storage by integration of DSF local storage.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

API	Application Programming Interface
CCRA	Cloud Computing Reference Architecture
CSC	Cloud Service Customer
CSM	Cloud Service Manger
CSP	Cloud Service Provider
DMP	Data Manipulation Provider
DSF	Data Storage Federation
FTP	File Transfer Protocol
iSCSI	Internet Small Computer System Interface
NFS	Network File System
NVMe	Non-Volatile Memory Express

PCIe	Peripheral Component Interconnect Express
RAM	Random Access Memory
SCSI	Small Computer System Interface
SFP	Storage Federation Provider
SFTP	Secure Fire Transfer Protocol
SMB	Server Message Block
SSD	Solid State Disk

5 Conventions

In this Recommendation:

The keywords "**is required to**" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

The keywords "**is recommended**" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

6 Overview of data storage federation

6.1 Introduction to data storage federation

Increasing data services in many industries, which use big volume of data with various data types, the storage capacity is tremendously growing. A storage user has difficulties to utilize various storages due to the different access mechanisms of each storage, and the different storage capabilities. In order to resolve these difficulties, data storage federation (DSF) supports customers to utilize their data storages efficiently by the federation of heterogeneous storages including cloud storage and on-premise storage.

DSF integrates the DSF local storage into a virtual storage pool and creates a single virtual volume in the virtual storage pool as shown in Figure 6-1.

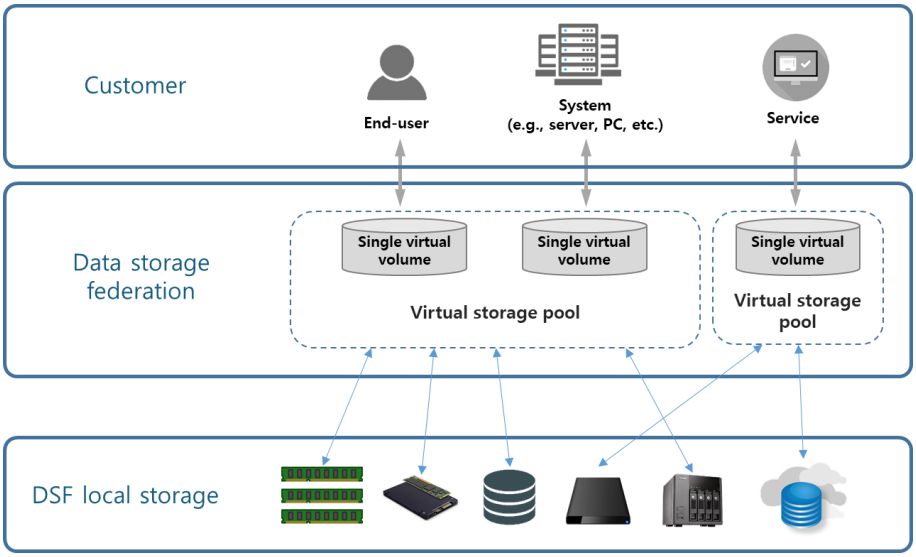


Figure 6-1 – Concept of data storage federation

DSF provides the single virtual volume for a customer with a single access point, and also provides storage access mechanisms to DSF local storage.

When a customer requests the single virtual volume with customer's requirements, DSF creates a single virtual volume in the virtual storage pool which meets customer's requirement by storage operations. According to customer requests to use the single virtual volume, storage operations are performed such as creating, deleting, and scaling storage (single virtual volume) by DSF.

Examples of basic storage operations are described in detail as follows:

- **creating**: connecting DSF local storage, creating virtual storage pool, and creating single virtual volume;
- **deleting**: deleting single virtual volume, deleting virtual storage pool, and disconnecting DSF local storage;
- **scaling**: extending single virtual volume, extending virtual storage pool, and attaching another DSF local storage.

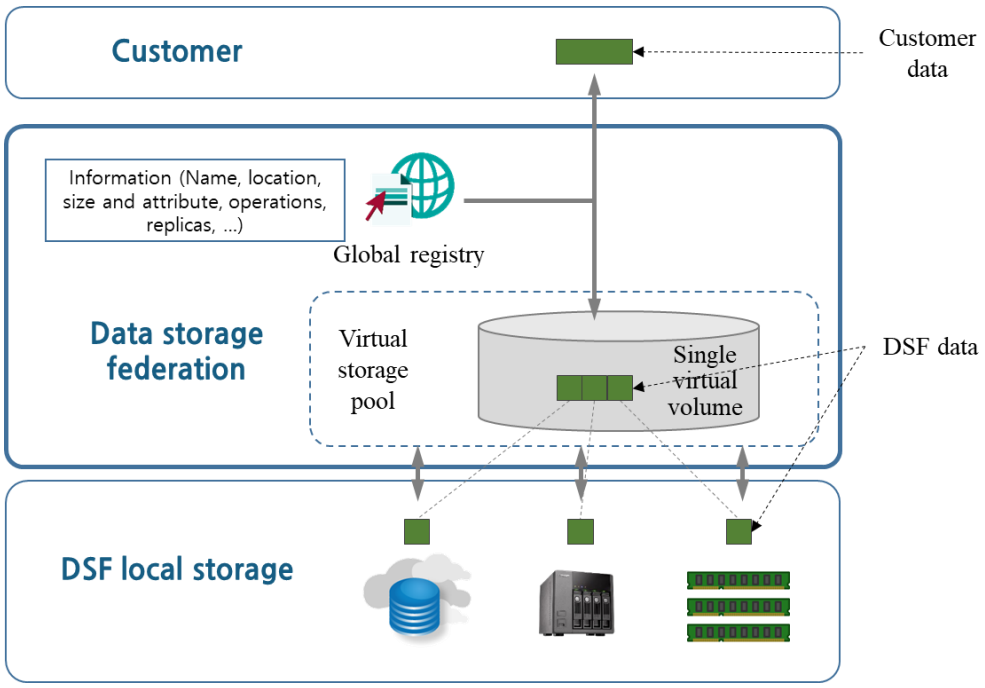


Figure 6-2 – Example of customer data manipulation in DSF

Figure 6-2 shows an example flow of data manipulation in DSF. When a customer stores customer data in a single virtual volume, DSF manipulates the customer data by data operations. By the execution of data operation, the customer data is fragmented to DSF data and which is stored to DSF local storage. Name and location of the customer data is registered to global registry. The global registry is a data set for the information of customer data.

NOTE 1 – DSF data is a manipulated customer data in DSF, and is permanently stored on DSF local storage. It includes fragmented, encrypted, de-duplicated and compressed customer data.

NOTE 2 – The information of customer data includes the location, size and attributes, and etc. This information is taken from data operation metadata and storage management metadata.

According to customer requests to use data in a single virtual volume, the data operations are performed such as creating, reading, updating, deleting, searching, and sharing data by DSF.

Example of basic data operations in DSF are described as follows:

- **creating**: fragmenting customer data, storing them to DSF local storage, and registering data name and locations to global registry;
- **reading**: searching data name and location in global registry, loading fragmented data from the DSF local storage and combining the fragmented data;
- **updating**: searching data name and location in global registry, updating customer data to DSF local storage, updating changes to global registry;
- **deleting**: searching data location in global registry, removing data location from global registry; and deleting fragmented data in the DSF local storage;
- **searching**: searching data name in global registry;
- **sharing**: searching data name, and change attribute in global registry to share.

6.2 Benefits of the data storage federation

DSF provides the beneficial features with customer perspectives such as cost, technical function, service enhancement, and resource utilization as follows:

- **Easy storage management:** the simple management by using a single user interface and centralized monitoring;
- **Cost-effectiveness:** the reduction of storage usage cost by archiving customer data to a cheaper DSF local storage;
- **Performance enhancement:** the improvement of data access performance by storing data to high-speed storages such as main memory, RAM, NVMe and etc.;
- **Data availability:** the increase of availability by replicating the data and storing to another DSF local storage;
- **Storage scalability:** the easy scaling storage resources by supporting on-demand storage capacity;
- **Storage utilization improvement:** the improvement of storage utilization by combining two or more DSF local storage to store a large data;
- **Data security:** storing secure data by splitting an important file into multiple fragments to different DSF local storage;
- **Data management transparency:** the convenience of data management for data discovery, use of data without knowledge of data location, storage type, data format.

6.3 Configuration of logical components for data storage federation

Figure 6-3 shows the general configuration - for logical components of DSF. The logical components consist of customer, storage connection, data manipulation, data distribution and storing, DSF local storage management, provision and policy management, and DSF local storage including cloud and on-premise storage.

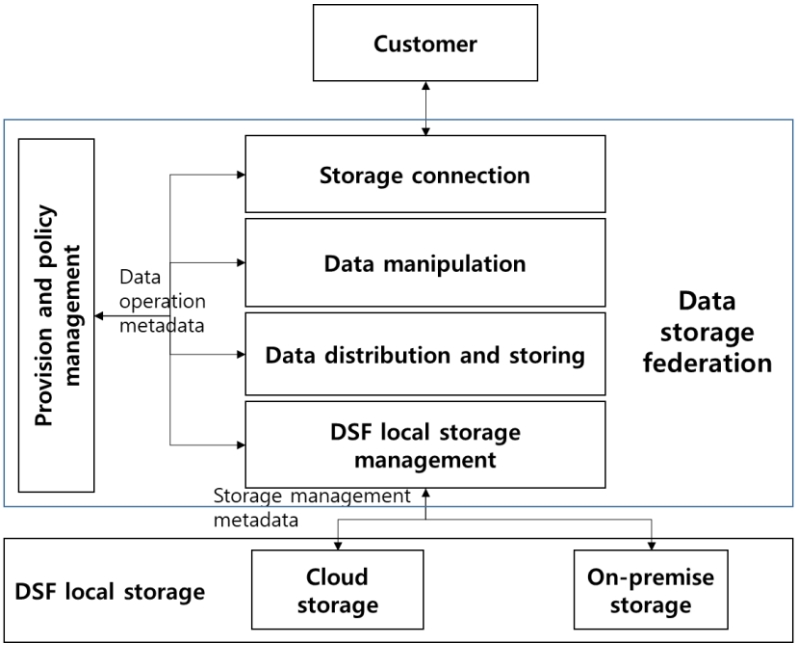


Figure 6-3 – General configuration for DSF

Storage connection component provides:

- interface of single virtual volume for customer;
- customer access mechanism to connect single virtual volume;

  NOTE 1 - customer access mechanism includes the different types of protocols according to the storage type (e.g., internet Small Computer System Interface (iSCSI) for block device storage, SMB, NFS, SFTP, FTP for file-based storage, and the Restful API for object-based storage and etc.).
- corresponding protocols or I/O interfaces of single virtual volume;
- acceleration of protocols for performance enhancement.

Data manipulation component provides:

- virtual storage pool;
- configuration for virtual storage pool without considering the actual - location of the data;
- the write buffer or read cache - for customer data;
- enhancement of the read and write response time using high-speed storages for buffer and cache;

  NOTE 2 – The high-speed storage includes main memory, non-volatile memory express (NVMe), SSD, and PCIe flash cards.
- data management for snapshots, fast replication, and distributed transaction logs.

Data distribution and storing component provides:

- the optimization of writing data to DSF local storage to minimize writing and accessing time;
- data fragmentation to distribute and store in DSF local storage;

  NOTE 3 – Data fragmentation is a method to distribute and store customer data in other storages.
- the encryption/decryption and compression/decompression of data fragments.

  NOTE 4 – The encryption and compression are taken into account by customer's demands.

DSF local storage management component provides:

- connections to DSF local storage;
- storage tiering of data according to the storage performance, time of data usage and data access frequency.

  NOTE 5 – Storage tiering is the action to distribute and collocate data across multiple storage tiers in hierarchical manner.

  NOTE 6 – This component automatically moves data between the various storage tiers according to the characteristics of the data.

  NOTE 7 – When data is initially created, it is stored in high-speed storage. When data access frequency is low, it is moved to a lower-speed storage.

Provisioning and policy management component provides:

- the configurations and controls of logical components;
- the policy management of data storage and data manipulation;

  NOTE 8 – Policy for data storage includes back-up, snapshot, scaling, recovery, data caching, thin-provisioning, tiering, storage type (file, block, object), and etc.

  NOTE 9 – Policy of data manipulation includes sharing support, read/write, replication, data migration, fragmentation, encryption, compression, de-duplication and etc.
- the provision of single virtual volume in virtual storage pool.

Two kinds of metadata are shown in figure 6-3 as follows:

- Data operation metadata is a description required to perform data operation. It includes the attribute of virtual storage pool and single virtual volume. It includes transaction log, and DSF data attribute of read/write caching, snapshot, replication, fragmentation, and etc.
- Storage operation metadata is a description required to perform storage operation. It includes the location of DSF local storage, interface, API for customer data operation, read/write speed, storage capacity, and etc.

6.4 Ecosystem of data storage federation

This clause identifies roles and sub-roles of the DSF ecosystem. In addition, relationships among roles and sub-roles are specified.

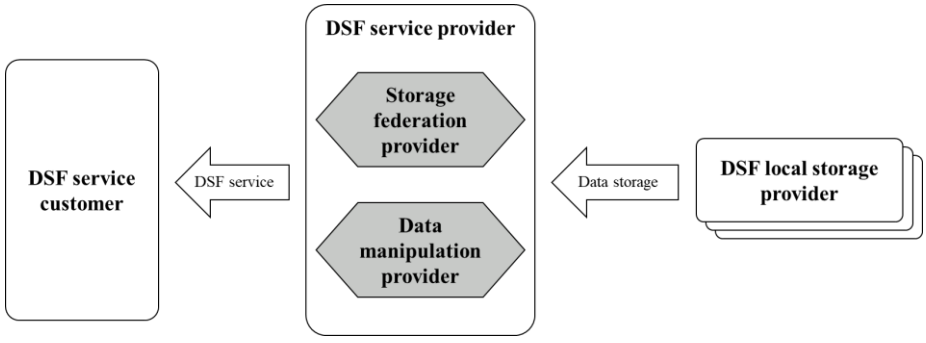


Figure 6-4 – **Data storage federation ecosystem**

DSF service is a service to provide single virtual volume and policies, and it is offered by DSF service provider.

The DSF ecosystem includes the following roles as shown in Figure 6-4:

- DSF service customer;
- DSF service provider;
- DSF local storage provider.

6.4.1 DSF service customer

The DSF service customer uses DSF service including a single virtual volume and policies from DSF service provider. DSF service customer's activity includes:

- Use DSF service.

6.4.2 DSF service provider

The DSF service provider federates DSF local storage and provides DSF service with an access mechanism.

The DSF service provider role consists of two sub-roles:

- Storage federation provider;
- Data manipulation provider.

6.4.2.1 Storage federation provider

The storage federation provider provides a single virtual volume by federation of DSF local storage. Storage federation provider's activities include:

- providing virtual storage pool;
- providing single virtual volume;
- managing storage management metadata;
- managing data storage policy.

6.4.2.2 Data manipulation provider

The data manipulation provider provides DSF data by manipulation, and manages data operation metadata and data manipulation policy (see clause 6.3). Data manipulation provider's activities include:

- manipulating DSF data;
- managing data operation metadata;
- managing data manipulation policy.

6.4.3 DSF local storage provider

The DSF local storage provider provides DSF local storage and interfaces to use it. DSF local storage provider's activity includes:

- provide DSF local storage.

7 Cloud computing based data storage federation system context

This clause describes how cloud computing can support the three main roles of the DSF ecosystem: DSF service customer, DSF service provider, and DSF local storage provider.

By using cloud computing roles, sub-roles and activities, cloud computing based DSF supports more extensible features by facilitating on-premise storage resources which connects personal and enterprise storage resources.

The cloud computing based DSF context is defined with new sub-roles and activities based on CCRA [ITU-T Y.3502]. For cloud computing based DSF, CSP:storage federation provider(CSP:SFP) for federation of DSF local storage and CSP:data manipulation provider(CSP:DMP) for management of DSF data and policies are defined to utilize DSF local storage as shown in Table 7-1.

Table 7-1 – Mapping roles and sub-roles between data storage federation ecosystem and cloud computing based DSF system context

Roles and sub-roles of DSF ecosystem	Sub-roles of cloud computing based DSF system context
DSF service customer	CSC:cloud service user(CSC:CSU)
DSF service provider:storage federation provider, DSF service provider:data manipulation provider	CSP:storage federation provider(CSP:SFP), CSP:data manipulation provider (CSP:DMP)
DSF local storage provider	CSP:cloud service manager(CSP:CSM)

Figure 7-1 illustrates the cloud computing sub-roles related to DSF. This figure also identifies activities for DSF and assigns them to cloud computing sub-roles, and illustrates how cloud computing supports DSF service from the perspective of CSP:SFP and CSP:DMP. The cloud computing based DSF utilizes other sub-roles of CSP.

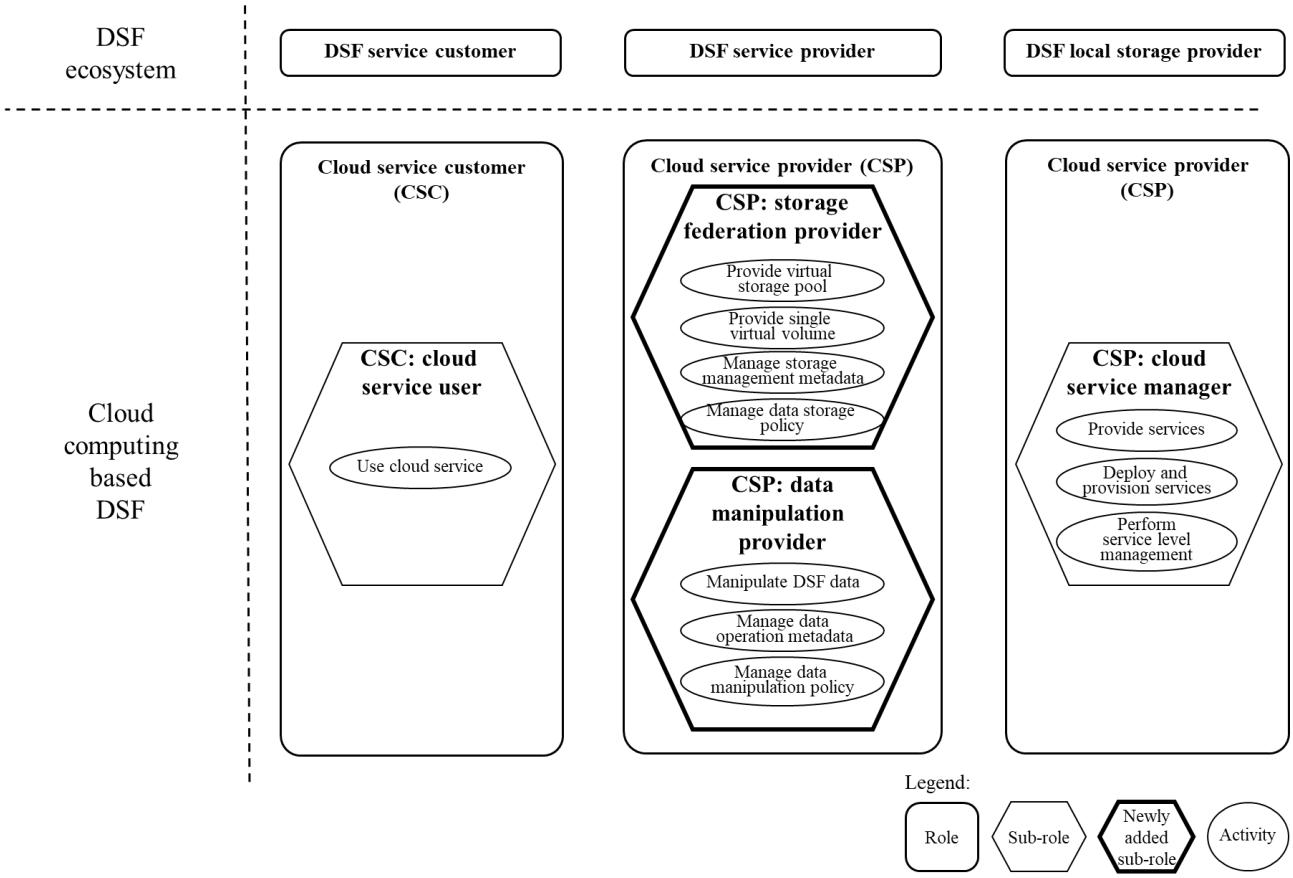


Figure 7-1 – Cloud computing based DSF context and its relationship with DSF ecosystem

7.1 CSP:storage federation provider (CSP:SFP)

CSP:storage federation provider (CSP:SFP) is responsible for the federation of DSF local storage. CSP:SFP's activities include:

- providing virtual storage pool;
- providing single virtual volume;
- managing storage management metadata;
- managing data storage policy.

7.1.1 Provide virtual storage pool

This activity involves integrating and managing DSF local storage to make a logical storage.

This activity involves:

- performing storage operation (see clause 6.1);
- managing virtual storage pool;
- delegating customer credentials of DSF local storage.

7.1.2 Provide single virtual volume

This activity involves providing and processing a way to use a single virtual volume for a CSC:CSU.

This activity involves:

- managing single virtual volume;
- providing a user access mechanism for CSC:CSUs;
- performing storage operation (see clause 6.1).

7.1.3 Manage storage management metadata

This activity involves creating, updating, and deleting metadata (see clause 6.3) for virtual storage pool and single virtual volume.

This activity involves:

- creating storage management metadata of DSF data;
- updating storage management metadata on changes;
- deleting storage management metadata.

7.1.4 Manage data storage policy

This activity involves management of data storage policy.

This activity involves:

- creating data storage policy;
- triggering data storage policy;
- updating data storage policy;
- deleting data storage policy.

7.2 CSP:data manipulation provider (CSP:DMP)

CSP:data manipulation provider (CSP:DMP) is responsible for operation of DSF data and management of data manipulation policy. CSP:DMP's activities include:

- manipulating DSF data;
- managing data operation metadata;
- managing data manipulation policy.

7.2.1 Manipulate DSF data

This activity involves DSF data operation for CSC:CSU by data virtualization.

This activity involves:

- performing data operation (see clause 6.1).

NOTE 1 – Data virtualization is abstraction of multiple data resources into the logical data resource.

NOTE 2 – Multiple data resources include object storage, file storage, and block storage.

7.2.2 Manage data operation metadata

This activity involves creating, updating, and deleting metadata (see clause 6.3) for DSF data.

This activity involves:

- creating data operation metadata of DSF data;
- updating data operation metadata on changes;

- deleting data operation metadata.

7.2.3 Manage data manipulation policy

This activity involves management of data manipulation policy.

This activity involves:

- creating data manipulation policy;
- triggering data manipulation policy;
- updating data manipulation policy;
- deleting data manipulation policy.

8 Functional requirements for data storage federation

This clause describes the requirements for data storage federation.

8.1 Storage connection requirements

(1) It is required that CSP:SFP provide an interface to connect DSF local storage.

NOTE 1 – The interface to connect DSF local storage refers to the direct interfaces (i.e., object or block storage interface), or a proxy interface to configure several types of storages interface with software program.

NOTE 2 – The software program includes software agent, daemon, web worker and RESTful API for interface to DSF local storage.

NOTE 3 – The proxy interface connects DSF local storage by automatically detecting the interface with software program.

(2) It is required that CSP:SFP provide a user interface for CSC:CSU to use a single virtual volume.

NOTE 4 – User interface includes graphical user interface, web application, or the dedicated client for CSC:CSU to access a single virtual volume.

(3) It is recommended that CSP:SFP apply the changes of CSC:CSU's access mechanism according to the storage type of single virtual volume.

(4) It is required that CSP:DMP translate data operation to corresponding interface of DSF local storage.

NOTE 5 – Corresponding interface includes API, I/O interface, execution commands with driver and, etc.

NOTE 6 – Single virtual volume on virtual storage pool sends disk access command (read or write) through data distribution and storing to DSF local storage management to translate.

NOTE 7 – Translation between data operations includes checking target identification for which DSF local storage to use.

NOTE 8 – Target identification includes physical address, block ID and target API corresponding DSF local storage to use.

(5) It is recommended that CSP:SFP provide secure access mechanism to use single virtual volume for CSC:CSU.

(6) It is required that CSP:DMP provide the registration of the CSC:CSU's requirements.

NOTE 9 – The requirements of CSC:CSU include data storage capacity, access mechanism, storage types of single virtual volume, data safety, data mobility, performance information, polices and etc.

NOTE 10 – Performance information are read/write I/O bandwidth, network bandwidth, storage capacity, storage types, I/O latency, network latency and etc.

(7) It is required that CSP:SFP provide the seamless connection of DSF local storage interface to communicate with DSF local storage.

(8) It is required that CSP:SFP provide various storage types of virtual storage pool with interface to connect DSF local storage.

NOTE 11 – Storage types of virtual storage pools include main-memory, SSD or NVMe, HDD based storage pool, network-based storage pool, and etc.

NOTE 12 – Virtual storage pool has the logically mapped area of storage unified with one storage volume between different type of DSF local storages which has the combined direct interface (such as storage driver or direct I/O interfaces without buffer).

NOTE 13 – CSP provides an interface for creating and managing a virtual storage pool that connects various types of storages and CSP receive the request based on the performance information to use a single virtual volume on virtual storage pool that CSC creates.

(9) It is recommended that CSP:SFP provide single virtual volume according to CSC:CSU's requirements.

NOTE 14 – CSC:CSU selects single virtual volume which has the requirements for the lowest latency, the best bandwidth and huge capacity included in performance information.

8.2 Data manipulation requirements

(1) It is required that CSP:DMP provide the execution of CSC:CSU's CRUD data operation.

NOTE 1 – CRUD data operation includes creating, reading, updating, and deleting data.

(2) It is required that CSP:DMP provide the searching for data operation from CSC:CSU's data using query to global registry.

(3) It is recommended that CSP:DMP provide the sharing for data operation by updating of sharing status of DSF data in global registry after checking sharing status of DSF data.

NOTE 2 – Data sharing means that same DSF data is shared during data operation.

NOTE 3 – Sharing status of DSF data is an information about if DSF data is shared or not.

(4) It is recommended that CSP:DMP provide the capacity saving of data storage using de-duplication or compression of DSF data.

NOTE 4 – De-duplication removes the duplicated parts between data and files in virtual storage pool and DSF local storage using main memory, RAM, NVMe, and etc.

(5) It is recommended CSP:DMP provide DSF data encryption/decryption for data transfer to DSF local storage.

(6) It is required CSP:DMP provide data recovery of CSC:CSU from system failure.

NOTE 5 – Data recovery refers to restoring the most recently used CSC:CSU's data preventing data loss due to errors from the storage, and network connection failure.

(7) It is recommended that CSP:DMP provide DSF data migration to available DSF local storage for resilience and cost efficiency of the storage space.

NOTE 6 – The data migration for the resilience and cost efficiency of the data storage space is automatically performed without user intervention or recognition.

(8) It is required that the CSP:DMP provide the validation of DSF data on data operation to check the data integrity.

(9) It is required that CSP:DMP support CSC:CSU's data consistency for the replicated DSF data.

NOTE 7 – The data consistency means that CSP:DMP correctly backup current DSF data in order to recover CSC:CSU's data on storage failure.

(10) It is required that CSP:DMP support CSC:CSU's data transparency.

NOTE 8 – The data transparency means to access CSC:CSU's data without knowing location.

8.3 Storage federation requirements

(1) It is recommended that CSP:SFP provide the performance information of DSF local storage from storage management metadata.

(2) It is recommended that CSP:SFP provide the optimization of virtual storage pool considering the characteristics of DSF local storage.

NOTE 1 – The characteristics of DSF local storage to optimize virtual storage pool includes storage mirroring, storage prioritization, CSC:CSU's access geo-location, and their combinations.

(3) It is recommended that CSP:SFP provide the optimization of single virtual volume considering the CSC:CSU's requirements

NOTE 2 – The optimization of single virtual volume include the optimization of storage capacity, data safety, storage performance, mobility of the usage environment, and their combinations.

(4) It is required that CSP:SFP provide the configuration to create single virtual volume from CSC:CSU requirements.

(5) It is required that CSP:SFP provide a read/write cache to access data.
NOTE 3 – The read/write cache enables to enhance the performance of the storage and the device storing the data is used by various devices for fast cache operation.
NOTE 4 – The various devices for fast cache are main memory, RAM based disk, SSD, and etc.

(6) It is recommended that CSP:SFP provide the hierarchical cache management using cache multi-tiering.

NOTE 5 – Cache multi-tiering means that for the high-speed access, cache hierarchy is extended to various devices for fast caching.

NOTE 6 – For capacity limit, if main-memory cache area is exhausted, it is automatically expanded to RAM based disk cache and expanded to SSD cache.

NOTE 7 – When CSC:CSU performs the data operation, the data operation is performed in the memory area in advance for fast write response.

(7) It is required that CSP:SFP provide the backup of global registry for high availability.
NOTE 8 – The backup of the global registry is synchronized with most recently updated CSC:CSU's data.

(8) It is recommended that CSP:SFP provide in-parallel access to DSF local storage.

(9) It is required that CSP:SFP provide the registration of CSC:CSU's credential to DSF local storage.

(10) It is recommended that CSP:SFP support monitoring the performance information of DSF local storage.

(11) It is required that CSP:SFP provide the management of DSF local storage interface.

(12) It is recommended that CSP:SFP support to access the secured storage interface for DSF local storage.

(13) It is required that CSP:SFP provide the storage operation for DSF local storage.

NOTE 9 – Storage operation for DSF local storage includes create, delete, scaling, partitioning, and checking volume, and etc.).

(14) It is required that CSP:SFP provide the scaling of single virtual volume on CSC:CSU demand.

8.4 Metadata and policy management requirements

(1) It is recommended that CSP:SFP provide a configuration of single virtual volume by data storage policy for CSC:CSU.

(2) It is recommended that CSP:SFP provide default data storage policies when policy is not configured.

NOTE 1 – Default data policy is reconfigured by customer's requests.

(3) It is recommended that CSP:DMP provide a transformation of DSF data by data manipulation policy.

NOTE 2 – Data manipulation policy for transformation of DSF data includes the policies of fragmentation, encryption, compression, de-duplication, and etc.

(4) It is recommended that CSP:DMP provide the default data manipulation policy.

(5) It is required that CSP:SFP provide the global registry for customer data access.

(6) It is required that CSP:SFP provide high-speed access of global registry.

(7) It is required that CSP:DMP provide the management of data operation metadata automatically according to execution of data operation.

(8) It is required that CSP:SFP provide storage management metadata to communicate with DSF local storage.

9 Security considerations

It is recommended that the security framework for cloud computing described in [b-ITU-T X.1601] be considered for data storage federation. [b-ITU-T X.1601] analyses security threats and challenges in the cloud computing environment, and describes security capabilities that could mitigate these threats and meet security challenges.

[b-ITU-T X.1631] provides guidelines supporting the implementation of information security controls for cloud service customers and cloud service providers. Many of the guidelines guide the cloud service providers to assist the cloud service customers in implementing the controls, and guide the cloud service customers to implement such controls. Selection of appropriate information security controls, and the application of the implementation guidance provided, will depend on a risk assessment as well as any legal, contractual, regulatory or other cloud-sector specific information security requirements.

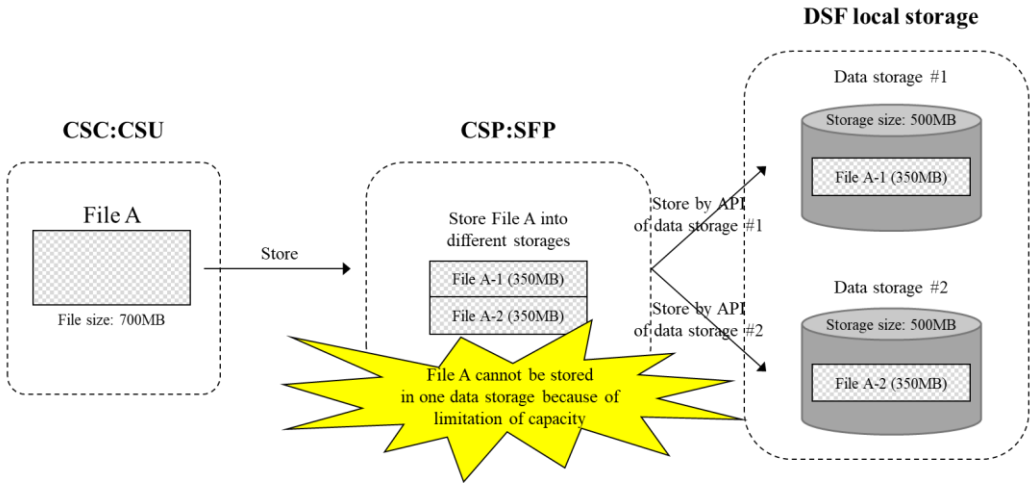
It is also recommended that the guidelines for cloud service customer data security described in [b-ITU-T X.1641] be considered. It provides generic security guidelines for the cloud service customer (CSC) data in cloud computing, analyses the CSC data security lifecycle and proposes security requirements at each stage of the data lifecycle.

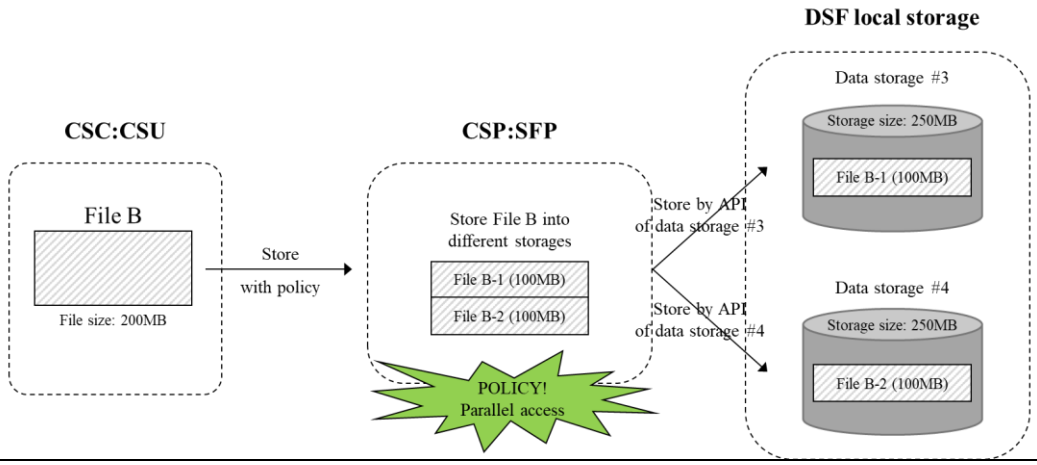
Appendix I

Use case of data storage federation

(This appendix does not form an integral part of this Recommendation)

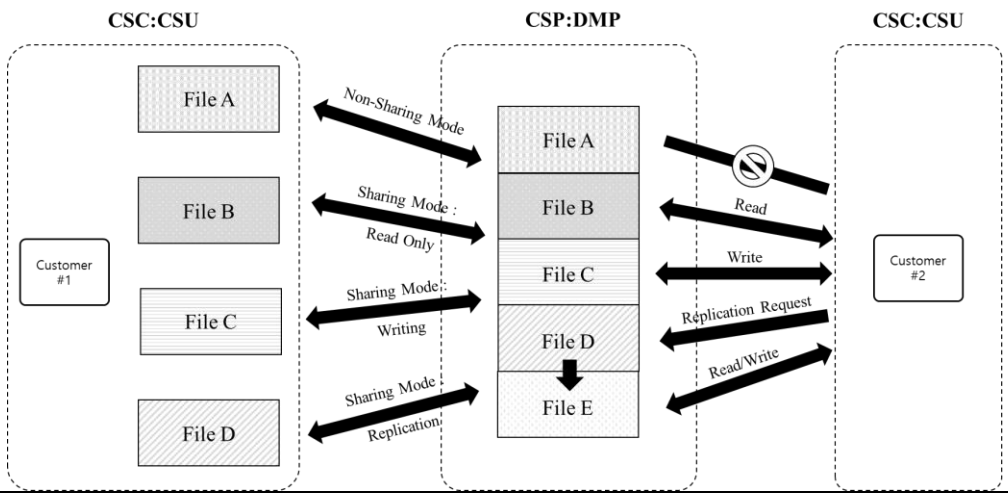
I.1 Storing a user file dispersedly

Title	Storing a user file dispersedly
Description	In this scenario, a data storage customer having two data storages on DSF local storage requests a large file storing to DSF service provider. DSF service provider splits the file into several parts in case that DSF local storage have not enough space (Case 1) or needs to access it in parallel for better performance (Case 2), and stores the parts into different distributed DSF local storage.
Role/Sub-role	DSF service provider (CSP:SFP) DSF service customer (CSC:CSU)
Figure (optional)	Case 1: limited capacity of data storage in DSF local storage  Case 2: CSC:CSU's parallel access requirement

	
Pre-conditions (optional)	- CSP:SFP is available to access DSF local storage. - CSC:CSU requests a single virtual volume to CSP:SFP.
Post-conditions (optional)	
Derived requirements	- Clause 8.1 requirement (2) - Clause 8.4 requirement (2) - Clause 8.1 requirement (4)

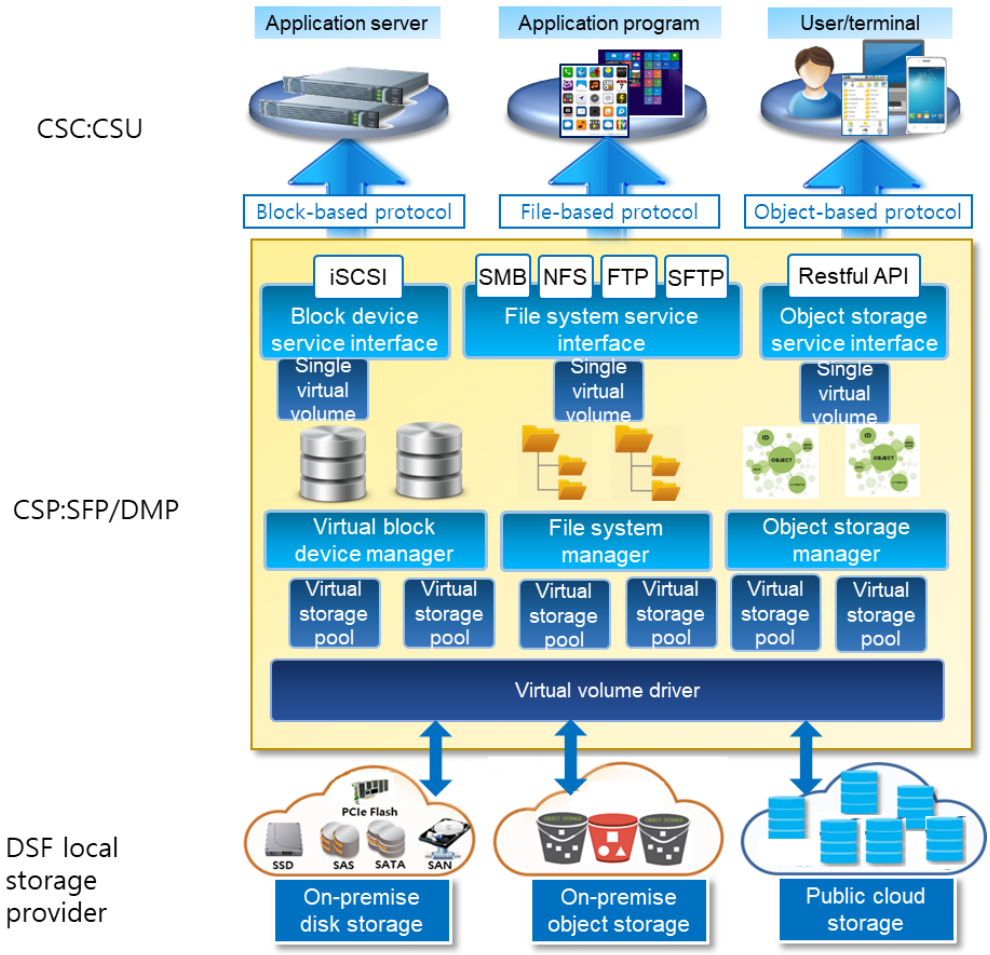
I.2 Data sharing between customers

Title	Data sharing between customers
Description	In this scenario, the DSF service customer #1 stored file A~D with data sharing mode policy setting. The File A is non-sharing mode, the file B is read-only data sharing mode, the file C is over-writable data sharing mode, and the file D is replicable data sharing mode. The other DSF service customer #2 uses file A~D with data sharing policy set by DSF service customer #1. DSF service customer #2 cannot access file A because of non-sharing mode policy setting. And DSF service customer #2 can read file B but not writable. In file C case, DSF service customer #2 can overwrite it and store it with changes. In file D case, by a replication request by DSF service customer #2, the original file D is preserved and a new file E is generated and stored to DSF service customer #2's single virtual volume.
Role/sub-role	DSF service provider (CSP:DMP) DSF service customer (CSC:CSU)

Figure (optional)	
Pre-conditions (optional)	
Post-conditions (optional)	
Derived requirements	- Clause 8.1 requirement (2)

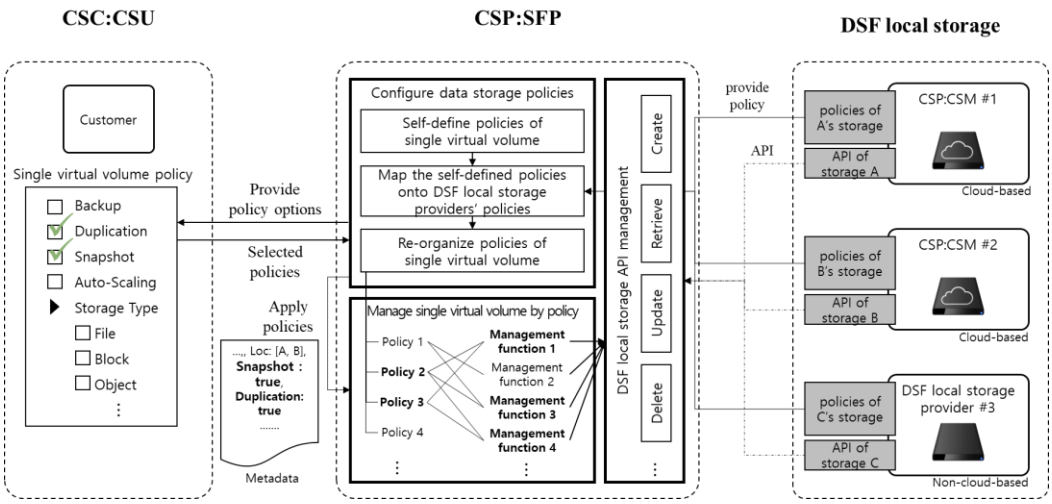
I.3 Multiple storage types and access mechanisms for data access

Title	Multiple storage types and access mechanisms for data access
Description	In this scenario, DSF service customer requests a variety of service interfaces and storage types to DSF service provider. Also, DSF service provider provides service interfaces to DSF service customer with the corresponding access mechanisms.
Role/Sub-role	DSF service customer (CSC:CSU) DSF service provider (CSP:SFP, CSP:DMP)

Figure (optional)	
Pre-conditions (optional)	- CSC:CSU use its own storage types - CSC:CSU can be general user(which own storage individually), some application programs, application servers and other cloud system.
Post-conditions (optional)	
Derived requirements	- Clause 8.4 requirement (3) - Clause 8.1 requirement (3)

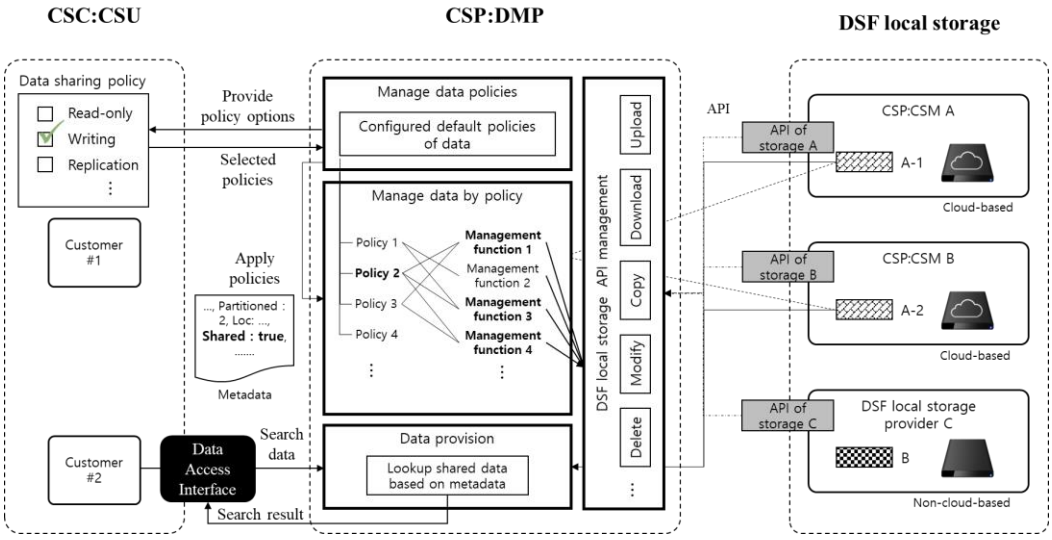
I.4 Policy-driven provision and management of DSF local storage

Title	Policy-driven provision and management of DSF local storage
Description	DSF service provider manages and provides a single virtual volume based on DSF local storage policies. DSF service provider organizes DSF local storage policies by using default policies configured by DSF service provider, and re-configured by DSF service provider from multiple data storages. That is, DSF service provider's policies are dependent on storage providers' storage policies in DSF local storage. DSF service provider provides the default policies as multiple options (e.g., backup, replication, snapshot, auto-scaling and storage type). DSF service customer selects options and DSF service provider applies options onto

	metadata. The options are matched onto corresponding storage policies in DSF local storage. DSF service provider manages the DSF local storage by matched functions onto storage policies. All communications with DSF local storage between the DSF service provider and DSF local storage provider is occurred by storage API managed.
Role/Sub-role	DSF service customer (CSC:CSU) DSF service provider (CSP:SFP, CSP:DMP) DSF local storage provider (CSP:CSM)
Figure (optional)	
Pre-conditions (optional)	-
Post-conditions (optional)	-
Derived requirements	- Clause 8.4 requirement (1) - Clause 8.4 requirement (4)

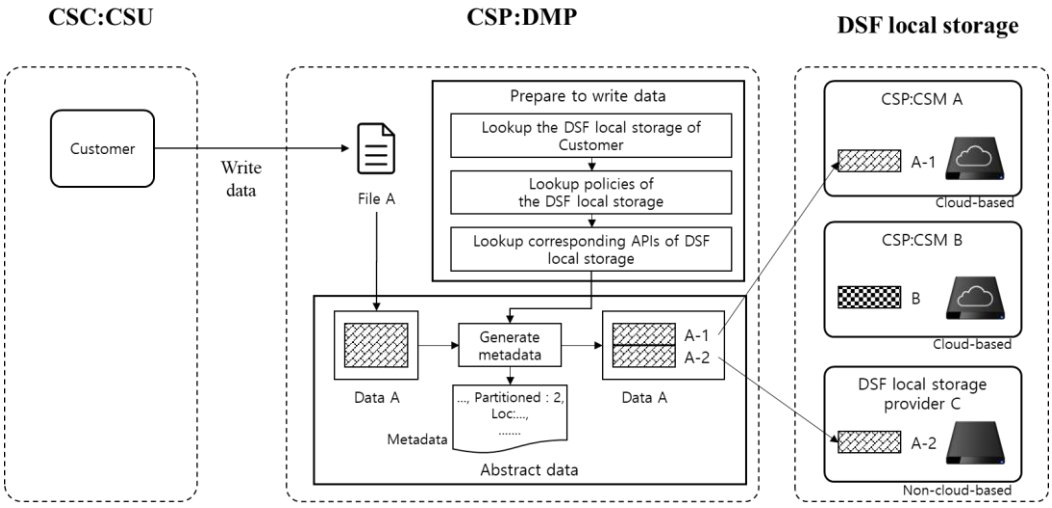
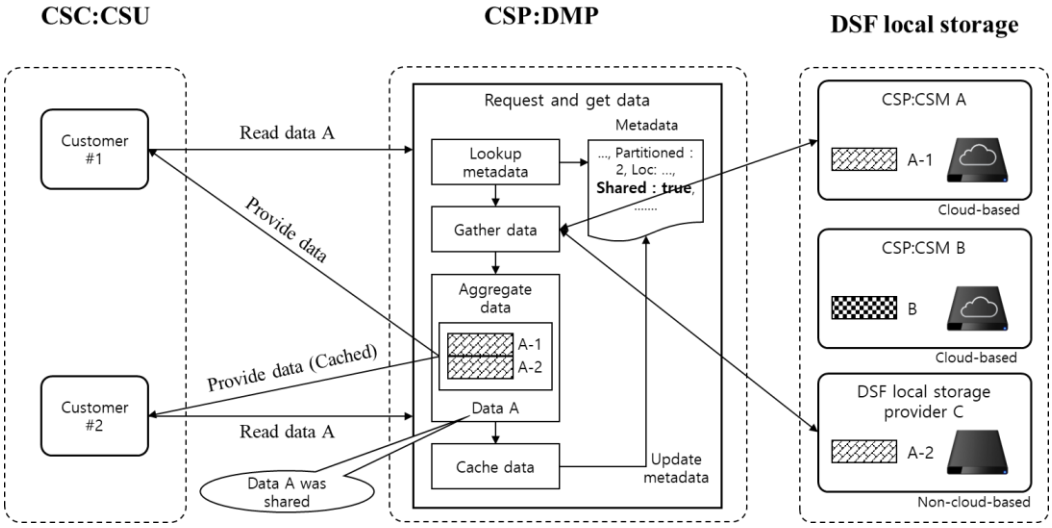
I.5 Policy-driven provisioning and management of data

Title	Policy-driven provisioning and management of data
Description	DSF service provider provides a unified interface to use DSF local storage and options to set data manipulation policies. DSF service provider configures the data manipulation policies because the data manipulation policies are independent from multiple data storages in DSF local storage. DSF service customer uses a single virtual volume (e.g., upload, download, copy, modify, delete and so on) and sets data manipulation policies (e.g., non-sharing, read-only, overwrite, replicate and so on) to saved files. DSF service provider applies data manipulation policies onto data operation metadata. DSF service provider manipulates data by corresponding functions and APIs with data manipulate policies. DSF service customer #1 sets data manipulation policy. DSF service provider modifies data operation metadata of target data. Another DSF service customer (e.g., DSF service customer #2) searches and gets data by using catalogue. In this

	procedure, the data operation metadata is used in order to lookup data from DSF local storage.
Role/Sub-role	DSF service customer (CSC:CSU) DSF service provider (CSP:SFP) DSF locals storage provider (CSP:CSM)
Figure (optional)	
Pre-conditions (optional)	- Policies for data storage are configured by CSP:SFP and selected by CSC:CSU, or set to default. - CSC:CSU save files on a single virtual volume.
Post-conditions (optional)	
Derived requirements	- Clause 8.1 requirement (7) - Clause 8.2 requirement (2) - Clause 8.2 requirement (3)

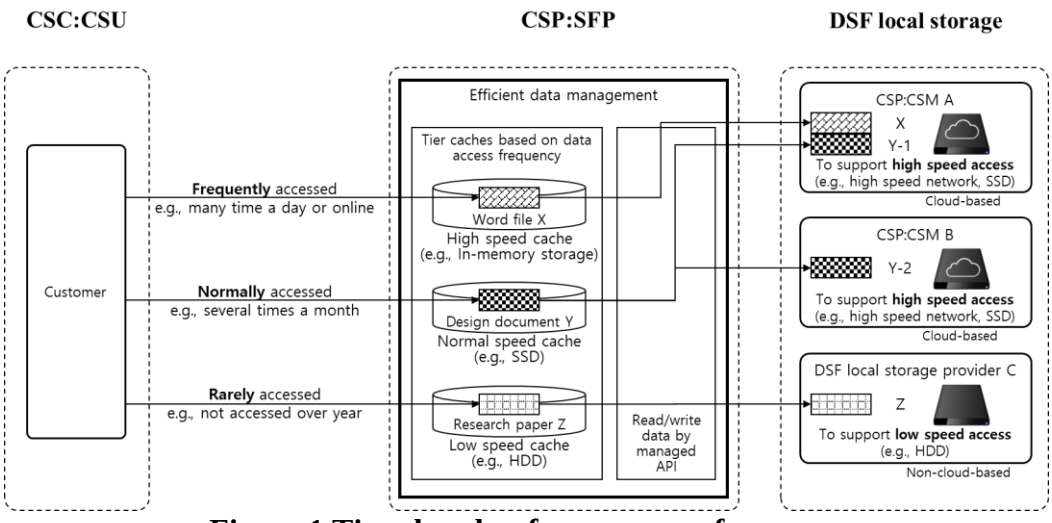
I.6 Data virtualization CSP:SFP

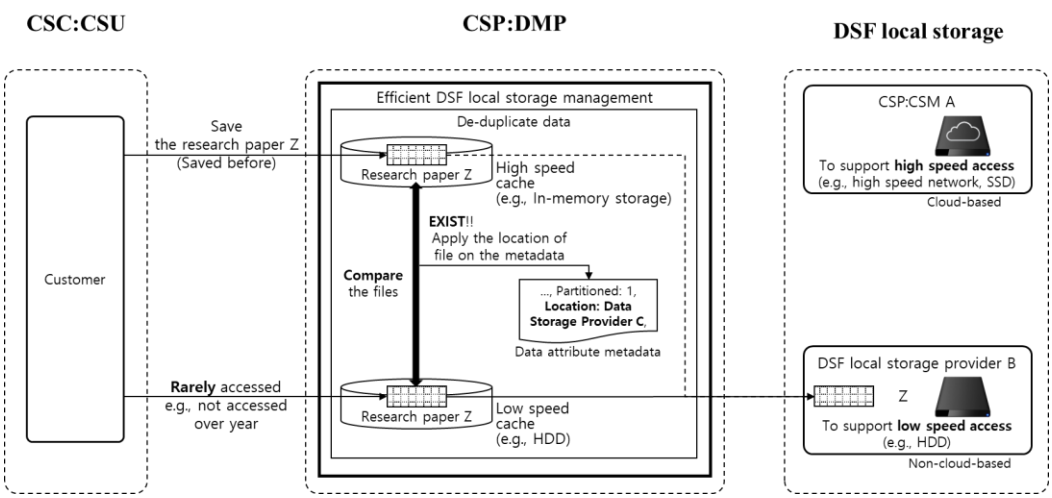
Title	Data virtualization by CSP:SFP
Description	This scenario shows data virtualizations through the description of read and write data. DSF service customer #1 writes a file through the DSF service. DSF service provider prepares to write data because file A is saved on a single virtual volume. As the preparation information (e.g., owner, policies, and corresponding APIs of data storage, etc.), data operation metadata for the file A is generated. The file A namely data A, is saved and managed by the data operation metadata, such as number of data portioning, data location, etc... In this procedure, the file A was abstracted for data provisioning and management by policies. DSF service customer #1 reads a file through the DSF service. DSF service provider gathers data based on the data operation metadata. DSF service provider aggregates partitions of data, and then data is provided to DSF service customer #1. It is possible for the provided data to be used again. Therefore, the data is cached and reflected on data operation metadata. For this reason, DSF service customer #2 quickly reads the cached data. In this procedure, data A was

	virtualized because the partitioned data A was aggregated as if originally single data A was, and then was used for multiple DSF service customer. That is, DSF service customer #1 and #2 read same data.
Role/Sub-role	DSF service customer (CSC:CSU) DSF service provider (CSP:SFP) DSF local storage provider (CSP:CSM)
Figure (optional)	 **Figure 1 Writing data by abstracting data**  **Figure 2 Read data by virtualized data**
Pre-conditions (optional)	- CSC:CSU has one or more data storage. - CSC:CSU sets policies for DSF local storage. - The data A is shared in Figure 2.
Post-conditions (optional)	
Derived requirements	- Clause 8.4 requirement (7) - Clause 8.4 requirement (7) - Clause 8.4 requirement (8) - Clause 8.1 requirement (2)

	- Clause 8.2 requirement (10) - Clause 8.2 requirement (9)

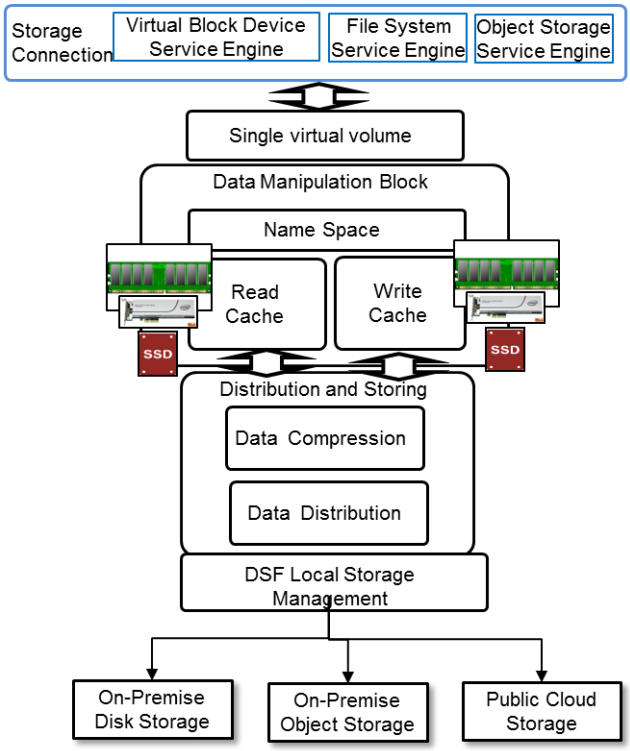
I.7 Efficient data storage management

Title	Efficient data storage management
Description	As shown in Figure 1, DSF service provider efficiently manages data to support better storage access performance and to reduce management burden. Tiering is a technique to fulfil efficient data management. By organizing tiered caches, frequently accessed files are stored in high speed cache. While rarely access files are stored in low speed one. Cached files are stored on corresponding data storages by managed API. As shown in Figure 2, DSF service customer saves a same file on a single virtual volume. It occurs waste of data storage capacity. To avoid the waste, DSF service provider performs to de-duplicate data to save capacity of data storage. For example, when a file is stored, data replication checking is accomplished. As the result of the checking, a file is stored. If same file is already stored, the file is managed by data operation metadata.
Role/Sub-role	DSF service customer (CSC:CSU) DSF service provider (CSP:SFP)
Figure (optional)	 **Figure 1 Tiered caches for access performance**

	 **Figure 2 De-duplication data for saving storage capacity**
Pre-conditions (optional)	-
Post-conditions (optional)	-
Derived requirements	- Clause 8.3 requirement (10) - Clause 8.3 requirement (6) - Clause 8.2 requirement (4)

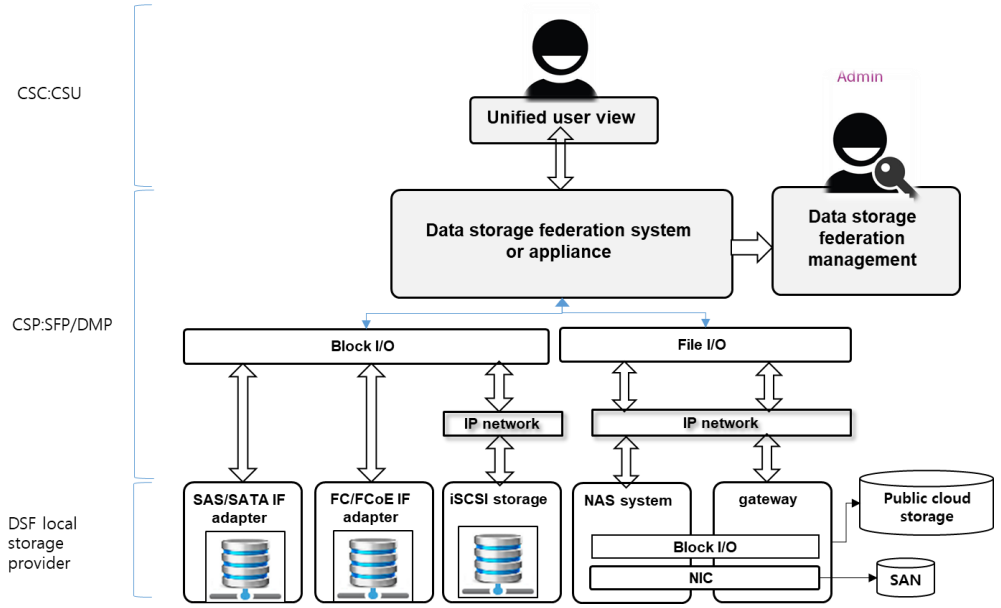
I.8 The data read/write cache and parallel distributed file for performance enhancement

Title	The data read/write cache and parallel distributed file for performance enhancement
Description	DSF service provider provides a cache function for data stored in a public cloud storage. Data stored in public cloud storage is slower than on-premises storage because data is transmitted over the Internet. In addition, since the data is automatically distributed to the public cloud storage in the state DSF service customer does not recognize, the data stored in the public cloud storage needs a high-speed access function. DSF service provider caches the data stored in the public cloud storage to the storage device inside the cloud integrated storage operating platform to provide an on-premise storage-level access speed to the public cloud storage.
Role/Sub-role	DSF service provider (CSP:SFP, CSP:DMP) DSF local storage provider (CSP:CSM)

Figure (optional)	 NOTE – This figure is aligned with logical component.
Pre-conditions (optional)	- CSC:CSU requests single virtual volume to CSP:SFP and has own data storage. - CSP:SFP provide storage system, appliance or device to federate the other storages
Post-conditions (optional)	
Derived requirements	- Clause 8.3 requirement (5) - Clause 8.4 requirement (16) - Clause 8.3 requirement (7) - Clause 8.2 requirement (5) - Clause 8.3 requirement (8) - Clause 8.3 requirement (9)

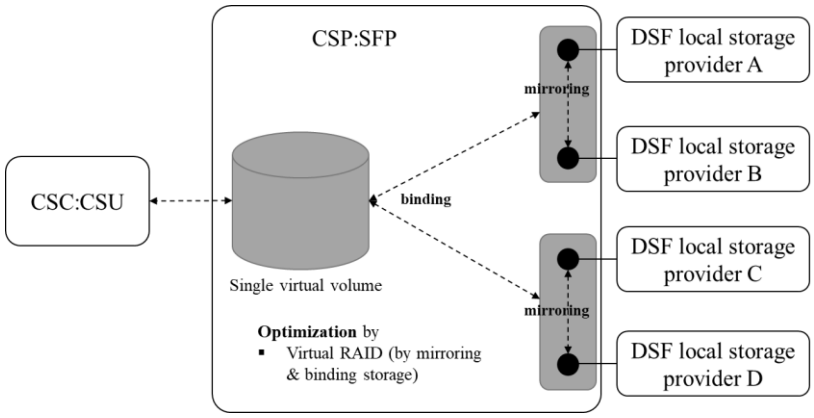
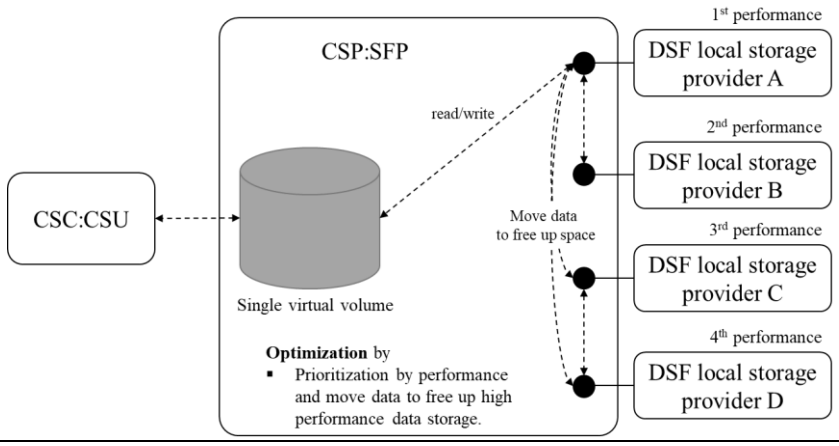
I.9 Data storage federation and management

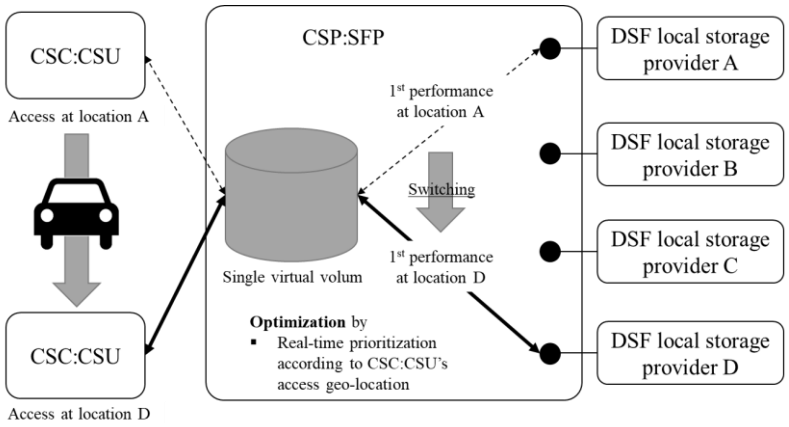
Title	The use case for data storage federation and management
Description	In this scenario, it is a use case for one storage system connected to various storage types. In the figure on this use case, no matter what type of storage the storage system has, DSF service customer is seen as the federated storage and DSF service customer doesn't care about what storage they use. Thus, a federated storage system or appliance in this figure is responsible for making multiple storage systems of a storage visible to a single system. Similarly, management has a unified management interface.
Role/Sub-role	DSF service customer (CSC:CSU) DSF service provider (CSP:SFP/DMP) DSF local storage provider (CSP:CSM)

Figure (optional)	
Pre-conditions (optional)	- CSC:CSU requests a data storage to DSF service provider and has own data storage. - CSP:SFP provide storage system, appliance or device to federate the other storages
Post-conditions (optional)	
Derived requirements	- Clause 8.2 requirement (7) - Clause 8.3 requirement (14) - Clause 8.1 requirement (2) - Clause 8.2 requirement (6) - Clause 8.4 requirement (5) Clause 8.1 requirement (8) - Clause 8.2 requirement (8)

I.10 A use case of storage optimization

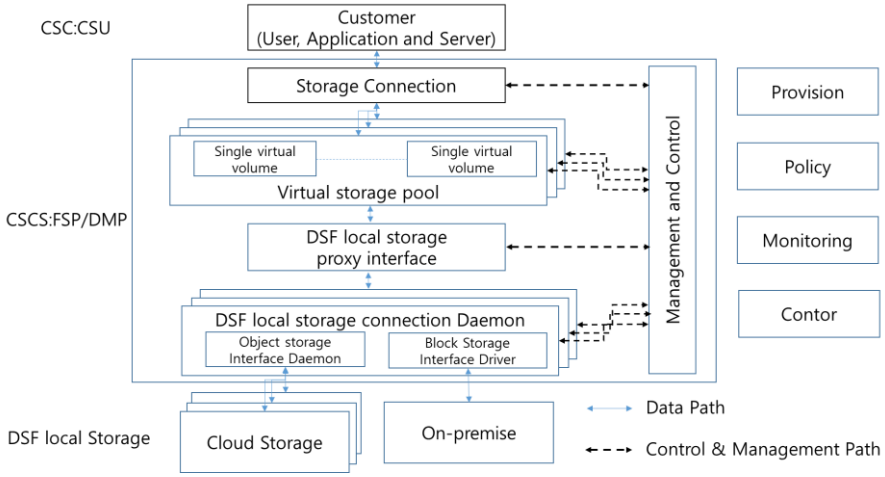
Title	A use case for storage optimization based on the customer's purpose in data storage federation
Description	When a DSF locals storage provider provides the information of his/ her cloud storage services with a DSF service provider, the DSF service provider optimizes single virtual volume according to the requirements of the user, such as data safety and storage performance. A detailed explanation is as follows.The DSF service provider configures the single virtual volume based on the cloud storages provided by DSF local storage provider. The following optimization policies can be applied, and the decision of the optimization policy can be done by the DSF service customer according to his requirements. (1) The DSF local storage provider registered multiple cloud storages to the DSF service provider. (2) DSF service provider provides optimization tool for s. **(3)** DSF service customer chooses optimization policy related with;

	A. **data safety and storage performance (a)**: DSF service providers provide a binding function that configures a virtual, single data storage for efficient management of distributed data storage that is available to customers. In addition, DSF service providers provide real-time monitoring of the performance of each data storage and use it with a mirroring mechanism to provide optimized services for stability and performance. For example, when a DSF service customer uses his or her own data, virtual data storage provides a service by selecting a data storage that can provide optimal service among the mirrored data storage; B. **enhancement of performance without storage mirroring (b)**: DSF service provider provides real-time performance monitoring for each data storage. Using this, the DSF service provider determines the priority of the data storage that can provide the optimal service and then transfers the data to that storage in appropriate timing. Therefore, customers can always receive service from optimal data storage; C. **enhancement of performance considering user mobility (c):** Basically, since the DSF service is affected by the data transmission performance of the network, the performance of the DSF service can be greatly influenced by the location of the customer. Therefore, the DSF service provider provides optimization not only for the performance for each data storage but also for the network situation at the user's location. Virtual data storage provides real-time switching function to the best possible data storage depending on the customer's location. (4) Based on the optimization policy selected by the customer, the DSF service provider optimizes the service. After this processing, (5) DSF service customers use services optimized for their purposes.
Role/Sub-role	DSF service provider (CSP:SFP) DSF service customer (CSC:CSU) DSF local storage provider (CSP:CSM)
Figure (optional)	 (a) Mirroring and binding storage for data safety and performance 

	(b) Prioritization of data storages and move data for performance  (c) Real-time prioritization and switching data storage related with user's access geo-location for performance
Pre-conditions (optional)	- CSP:SFP has an access interface with multiple DSF local storage.
Post-conditions (optional)	
Derived requirements	- Clause 8.1 requirement (1) - Clause 8.3 requirement (1) - Clause 8.3 requirement (2) - Clause 8.3 requirement (3)

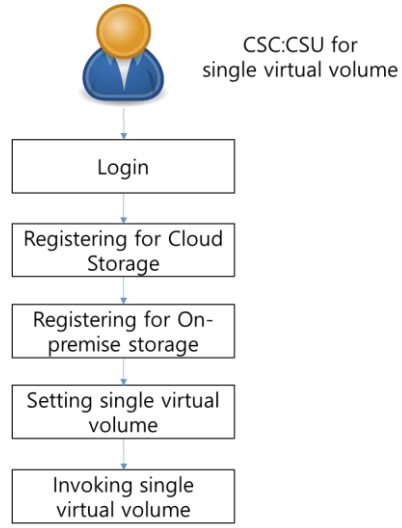
I.11 The use case for data storage federation management

Title	The use case for data storage federation management
Description	The management is generally separate from the data path and the management control path, and management is driven through the provisioning and policy management. The management provides the ability to display, create, modify and delete the contents of on-premises and public cloud services integrated into a single storage. In backend storage management, the storage configuration is different from the on-premises and the public cloud storage service. The interface for backend storage are made in the form of the separate software daemon. When there are multiple cloud storage devices, DSF local storage management can be configured, and a proxy interface can be configured to interface with them, and an interface for registering and using on-premises storage is provided.

Role/Sub-role	DSF service customer (CSC:CSU) DSF service provider (CSP:SFP/DMP) DSF local storage provider (CSP:CSM)
Figure (optional)	
Pre-conditions (optional)	- Each logical component consists of one server or several servers. - Each logical component is organized into a network through servers, virtual machines or containers
Derived requirements	- Clause 8.3 requirement (11) - Clause 8.1 requirement (5)

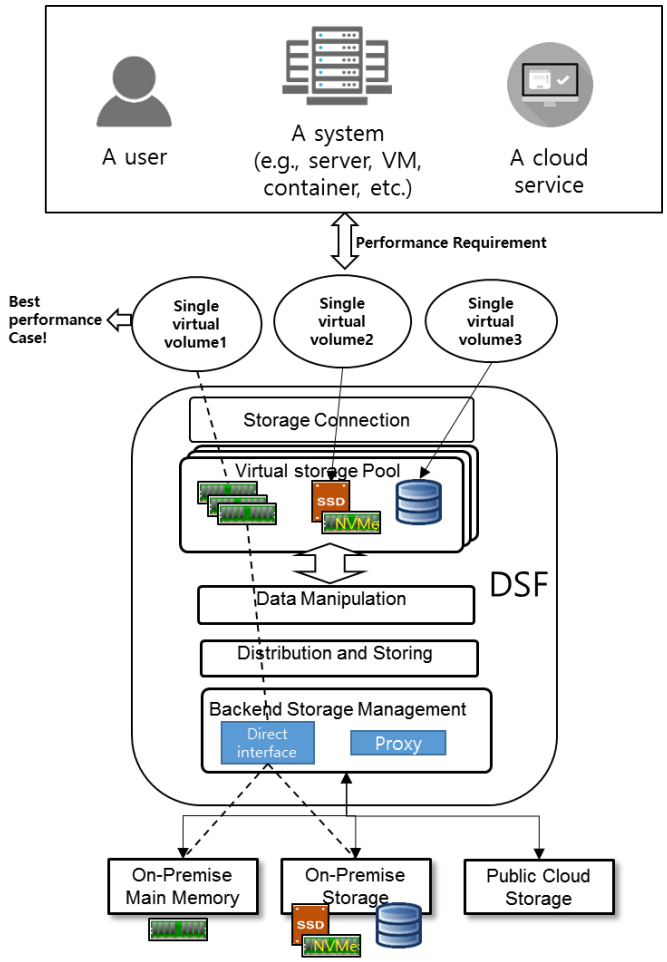
I.12 Registration of data storage for federation service

Title	Registration of data storage for federation service
Description	DSF service customer requests data storage service to DSF service provder. For the data storage registration, DSF service customer logs in through the already registered authentication information, and registers the cloud storage and on-premises storage to use. The registration process is provided by DSF service provider through the GUI. DSF service customer registers the service name, storage specification, data storage service protocol, and cloud storage name and cloud storage type through the GUI for setting virtual data storage and creates the virtual data storage.
Role/Sub-role	DSF service customer (CSC:CSU) DSF service provider (CSP:SFP/DMP)
Figure (optional)	

	 <The example operation of CSP for data storage service>
Pre-conditions (optional)	- CSC:CSU for virtual data storage is a registered user to CSP:DMP. - CSP:DMP has each cloud storage service interfaces
Derived requirements	- Clause 8.1 requirement (6) - Clause 8.3 requirement (4)

I.13 The provision of virtual storage pool for single virtual volume

Title	The provision of virtual storage pool for single virtual volume
Description	This use case is about a method of providing a single virtual volume provided from a virtual storage pool according to CSC:CSU's policy. A virtual storage pool has different characteristics depending on the type of devices in which the virtual storage pool is created (DRAM-based storage pool, SSD or NVMe -based storage pool, HDD-based storage pool, network-based storage pool, and etc.). The characteristics of single virtual volume provided to CSC:CSU are different according to the type of devices in virtual storage pools. CSU selects single virtual volume created in various types of virtual storage pools, which is a means to overcome the performance difference of services. For example, as shown in figure, due to the characteristics of the device, a single virtual volume created in a memory-based storage pool has the fastest speed, and DSF local storage which selects a memory-based device also provides the fastest speed but it needs backup for data loss. CSC:CSU requests various types of single virtual volumes with policy for data storage and DSF provides the type of each storage pool included in data operation metadata. The following specifies the method to provide a single virtual volume according to the performance. 1. Acquire and store the device information of the virtual storage pool 2. Monitor the IO bandwidth of the virtual storage pool.

	3. Request a new single virtual volume through performance requirements from CSC:CSU (I/O Bandwidth and capacity information, and device type, etc.). 4. Select a virtual storage pool that meets CSC:CSU's requirements and create a single virtual volume. 5. Create and provide an interface that meets CSC:CSU's requirements.
Roles	CSC, CSP
Figure (optional)	
Pre-conditions (optional)	
Post-conditions (optional)	
Derived requirements	- Clause 8.1 requirement (4) - Clause 8.1 requirement (6) - Clause 8.1 requirement (8) - Clause 8.1 requirement (9) - Clause 8.2 requirement (4) - Clause 8.3 requirement (1) - Clause 8.3 requirement (2) - Clause 8.3 requirement (3) - Clause 8.3 requirement (4)

Appendix II

Comparison analysis between cloud computing and data storage federation

(This appendix does not form an integral part of this Recommendation.)

Table II-1 shows the mapping between data storage federation ecosystem and CCRA user view. The DSF service customer has two sub-roles and these sub-roles are mapped onto the CSC:cloud service user because two sub-roles has a relationship of using service. The DSF local storage provider, and CSP:cloud service manager and CSP:cloud service operations manager, which provide data storage, are mapped in the perspective of providing service. However, for the DSF service provider, the additional considerations in data storage perspective are needed in the cloud computing. To federate and provide data storage from DSF local storages, such as cloud storage and non-cloud storage, it is proper to be described in CSP as new sub-roles, activities, and involvements.

Table II-1 Mapping between data storage federation ecosystem and CCRA user view

Y.3505 (DSF)		**Y.3502 (Cloud Computing)**		**Note**
Roles	**Activities**	**Sub-roles**	**Activities**	
DSF service customer	▪ use DSF service	CSC:cloud service user	▪ use cloud service	▪ The additional considerations in data storage and data perspective on the federated storage environment are needed.
DSF service provider	▪ provide virtual storage pool ▪ provide single virtual volume ▪ manage storage management metadata ▪ manage data storage policy	-	-	▪ The additional considerations in data storage perspective are needed as sub-roles and activities in CSP. ▪ The sub-roles and activities support the data storage federation service.
	▪ manipulate DSF data ▪ manage data operation metadata ▪ manage data manipulation policy	-	-	▪ The additional considerations in data storage perspective are needed as sub-roles and activities in CSP. ▪ The sub-roles and activities support the data storage federation service.
DSF local storage provider	▪ provide DSF local storage	CSP:cloud service manager	▪ provide services e	▪ Activities and their involvements of the two sub-roles in Y.3502 are supported to provide cloud data storage.

Bibliography

[b-ITU-T X.1601] Recommendation ITU-T X.1601 (2015), *Security framework for cloud computing.*

[b-ITU-T X.1631] Recommendation ITU-T X.1631 (2015), *Information technology – Security techniques – Code of practice for information security controls based on ISO/IEC 27002 for cloud services.*

[b-ITU-T X.1641] Recommendation ITU-T X.1641 (2016), *Guidelines for cloud service customer data security.*

[b-ISO/IEC 2382] ISO/IEC 2382 (2015), Information technology – Vocabulary.