TECHNICAL REPORT

TR-319

Achieving Packet Network Optimization using DWDM Interfaces

Issue: 1
Issue Date: June 2015

Notice

Issue History

Issue Number	Approval Date	Publication Date	Issue Editor	Changes
1	1 June 2015	10 June 2015	Manuel Paul, Deutsche Telekom	Original

Comments or questions about this Broadband Forum Technical Report should be directed to help@broadband-forum.org.

Editors	Manuel Paul	Deutsche Telekom
	Diane Patton	Cisco Systems
	Paul Doolan	Coriant
IP/MPLS & Core WG Chairs	David Sinicrope	Ericsson
	Drew Rexrode	Verizon

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Network Operators are at crossroads with their access, aggregation and core networks. Beyond the need to bring new services and service models faster to the market, by easier to manage infrastructures that radically reduce the operational complexity, they need to cope with the steadily growing traffic from IP services and content-centric applications, and need to significantly improve the efficiency of the network infrastructures. Networks worldwide are being transformed and optimized for the delivery of IP services.

By integrating optical (DWDM) interfaces into IP networks, service providers can build robust and more efficient aggregation, metro and long haul networks. Optical networking is a key enabler for high capacity, scalable backhaul. Technology advancements (at all levels of Data, Control and Management Plane) allow for better integrated network infrastructures, e.g. integrated colored optical transceivers in routers and packet switches, whose optical carriers are transported over DWDM networks, as well as for a better control and management integration.

The Broadband Forum has specified an architecture to support this new era with a paradigm shift. TR-319 specifies the use of optical transport and IP network standards for IP and optical integration, along with various advances in the technology, supporting multi-vendor interoperability, enabling to achieve packet network optimization using DWDM interfaces.

1 Purpose and Scope

1.1 Purpose

Network Providers have identified the potential to better integrate their packet and DWDM/optical networks to address growing network capacity demands, increase efficiency and reduce OPEX. TR-319 specifically addresses packet and DWDM/optical integration.

Integrated packet/optical networks and network node equipment are based on a variety of protocols and functional specifications (e.g., physical layer, Data Plane, Control Plane, Management Plane, etc.) from different Standards Developing Organizations (SDO). TR-319 identifies the set of specifications that are necessary for implementation of integrated packet optical networking equipment. TR-319 is aimed at fostering the development of interoperable solutions from multiple vendors for the benefit of consumers and suppliers of broadband services alike.

Enabling physical layer interoperability is key to interconnection of packet/optical equipment which is necessary for carrier network deployments. One key component of TR-319 is ITU-T G.698.2 [3] for the physical layer which enables the usage of multi-vendor interoperable optical transceiver technology for optical interconnections.
A Control Plane allows easier operation of the network. The Control Plane specified in TR-319 is based on GMPLS [7]. Some combination of GMPLS-based or SDN-based network control and User to Network Interfaces may be applied to improve the interconnection of the packet and DWDM network domains.
Specific interfaces and protocols to exchange the information to provide packet and DWDM connectivity and set optical channels must be specified. To do this, equipment must be able to be provisioned with the same protocol attributes and values. This requires standard data models of management information. TR-319 profiles those models and the management information exchange between the Packet Node and optical network.

TR-319 is the framework document, while other parts address specific Models, e.g. Physically Integrated, Physically Separated, Logically Integrated.

1.2 Scope

TR-319 addresses intra-domain architectures, requirements and use cases for packet and DWDM/optical transport integration, including:

a. The Data Plane as defined by Recommendations ITU-T G.698.2 [3], G.694.1 [6], and G.709[5].
   TR-319 refers to ITU-T for the data plane specifications and is not intended to redefine any ITU-T architecture, interface, or physical layer specifications or parameters defined for optical networks.
b. The Control Plane protocols and their applicability aspects, as defined by IETF RFCs.
   Intra-optical network Control Plane aspects are not in scope.
c. The Management Plane and operational aspects. TR-319 refers to relevant ITU-T and IETF management documents and specifications for definitions of e.g. data models and protocols.

The following items are out of scope of TR-319:

- OTN switching
- Structure/format/NNI definitions (including FEC) for the OTN digital layers
- Physical layer definition for the intra-domain Optical Supervisory Channel (OSC) between the client node and optical network supporting the exchange of control and management information.

TR-319 addresses the definition of the interface between the packet and transport networks. TR-319 does not address optical transport network design.

2 References and Terminology

2.1 Conventions

In this Technical Report, several words are used to signify the requirements of the specification. These words are always capitalized. More information can be found be in RFC 2119 [1].

MUST or SHALL	This word, or the term "REQUIRED", means that the definition is an absolute requirement of the specification.
MUST NOT	This phrase means that the definition is an absolute prohibition of the specification.
SHOULD	This word, or the adjective "RECOMMENDED", means that there could exist valid reasons in particular circumstances to ignore this item, but the full implications need to be understood and carefully weighed before choosing a different course.
SHOULD NOT	This phrase, or the phrase "NOT RECOMMENDED" means that there could exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications need to be understood and the case carefully weighed before implementing any behavior described with this label.
MAY	This word, or the adjective "OPTIONAL", means that this item is one of an allowed set of alternatives. An implementation that does not include this option MUST be prepared to inter-operate with another implementation that does include the option.

2.2 References

The following references are of relevance to this Technical Report. At the time of publication, the editions indicated were valid. All references are subject to revision; users of this Technical Report are therefore encouraged to investigate the possibility of applying the most recent edition of the references listed below.
A list of currently valid Broadband Forum Technical Reports is published at www.broadband-forum.org.

Document		Title	Source	Year
[1]	RFC 2119	Key words for use in RFCs to Indicate Requirement Levels	IETF	1997
[2]	RFC 4208	Generalized Multiprotocol Label Switching (GMPLS) User-Network Interface (UNI): Resource ReserVation Protocol-Traffic Engineering (RSVP-TE)	IETF	2005

		Support for the Overlay Model		
[3]	ITU-T G.698.2	Amplified multichannel dense wavelength division multiplexing applications with single channel optical interfaces	ITU-T	2009
[4]	ITU-T G.872	Architecture of optical transport networks	ITU-T	2012
[5]	ITU-T G.709	Interfaces for the optical transport network	ITU-T	2012
[6]	ITU-T G.694.1	Spectral grids for WDM applications: DWDM frequency grid	ITU-T	2012
[7]	RFC 3473	Generalized Multi-Protocol Label Switching (GMPLS) Signaling Resource ReserVation Protocol-Traffic Engineering (RSVP-TE) Extensions	IETF	2003
[8]	RFC 6241	Network Configuration Protocol (NETCONF)	IETF	2011
[9]	RFC 6020	YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)	IETF	2010
[10]	RFC 4204	Link Management Protocol (LMP)	IETF	2005
[11]	RFC 3945	Generalized Multi-protocol Label Switching (GMPLS) Architecture	IETF	2004
[12]	RFC 2578	Structure of Management Information Version 2 (SMIv2)	IETF	1999

2.3 Definitions

The following terminology is used throughout this Technical Report:

Black Link A Black Link, as used in ITU-T G.698.2 [3], provides a Network Media Channel (optical path) of a defined center frequency to support Colored Interfaces of a single vendor or from different vendors. The network providing a Black Link can be composed of amplifiers, filters, add-drop multiplexers which may be from a different vendor.

Colored Interface Single channel optical interface modulates a signal on an individual wavelength of a defined center frequency according the CWDM grid or DWDM grid, which is ready to be multiplexed into an optical fiber.

DWDM Network Element	Any device located in a DWDM transport network that is capable of multiplexing and demultiplexing wavelengths. An example of this could be a ROADM, Wavelength Cross Connect, or passive multiplexer/demultiplexer.
IPoverDWDM	Integration of DWDM/Colored Interfaces into IP routers.
Network Media Channel	Network Media Channel as defined in ITU-T G.872 [4].
Optical Channel	Optical layer (OCh) as defined in ITU-T G.872 [4].
Packet Node	Device that generates packets into the optical network, e.g. an IP router or an Ethernet Switch.

2.4 Abbreviations

This Technical Report uses the following abbreviations:

API	Application Programming Interface
CWDM	Coarse Wavelength Division Multiplexing
DWDM	Dense Wavelength Division Multiplexing
EMS	Element Management System
FRR	Fast Reroute
GMPLS	Generalized Multiprotocol Label Switching
LMP	Link Management Protocol
LSP	Label Switched Path
MIB	Management Information Base
NBI	North Bound Interface
NE	Network Element
NMS	Network Management System
NNI	Network to Network Interface
OA	Optical Amplifier
OADM	Optical Add-Drop Multiplexer
OAM	Operations, Administration and Maintenance
OEO	Optical-Electrical-Optical
OID	Object Identifier
OM	Optical Multiplexer
OD	Optical Demultiplexer

OSC	Optical Supervisory Channel
OTN	Optical Transport Network
P	Provider
PE	Provider Edge
POP	Point Of Presence
ROADM	Reconfigurable Optical Add-Drop Multiplexer
RSVP	Resource Reservation Protocol
Rx	Receiver
SDN	Software-Defined Networking
SDO	Standards Developing Organization
SNMP	Simple Network Management Protocol
TR	Technical Report
Tx	Transmitter
UNI	User to Network Interface
WG	Working Group

3 Technical Report Impact

3.1 Energy Efficiency

TR-319 does not explicitly address energy efficiency provisions. However, the integrated solution contained herein, supporting network convergence, can enable a reduction in components and chassis, which may result in energy and resource savings.

3.2 IPv6

TR-319 does not explicitly address IPv6 used in the data plane. The architecture and solutions covered in this document provide coverage for several data traffic formats which are agnostic to IPv6. IPv6 can be used for Control Plane and Management Plane address space.

3.3 Security

TR-319 has no impact on security.

3.4 Privacy

TR-319 has no impact on privacy.

4 Reference Architecture

TR-319 addresses IP and Optical Integration. The components involved include the Packet Node, the Colored Interface and the DWDM Network Element.

Two reference points are defined in the Data Plane:

- D_a exists between the Colored Interface and the DWDM Network Element,
- D_b exists between the Packet Node and the Colored Interface.

Three reference points are defined in the Control Plane:

- C_p exists between the Packet Node and the Control Plane
- C_c exists between the Colored Interface and the Control Plane
- C_d exists between the DWDM Network Element and the Control Plane

Three reference points are defined in the Management Plane:

- M_p exists between the Packet Node and the Management Plane
- M_c exists between the Colored Interface and the Management Plane
- M_d exists between the DWDM Network Element and the Management Plane

Depending on the Model, some Data Plane reference points may not exist. The existence of a management or control reference point in the architecture does not mandate that there is an instance of it in a particular implementation. Figure 1 depicts the high level architecture.

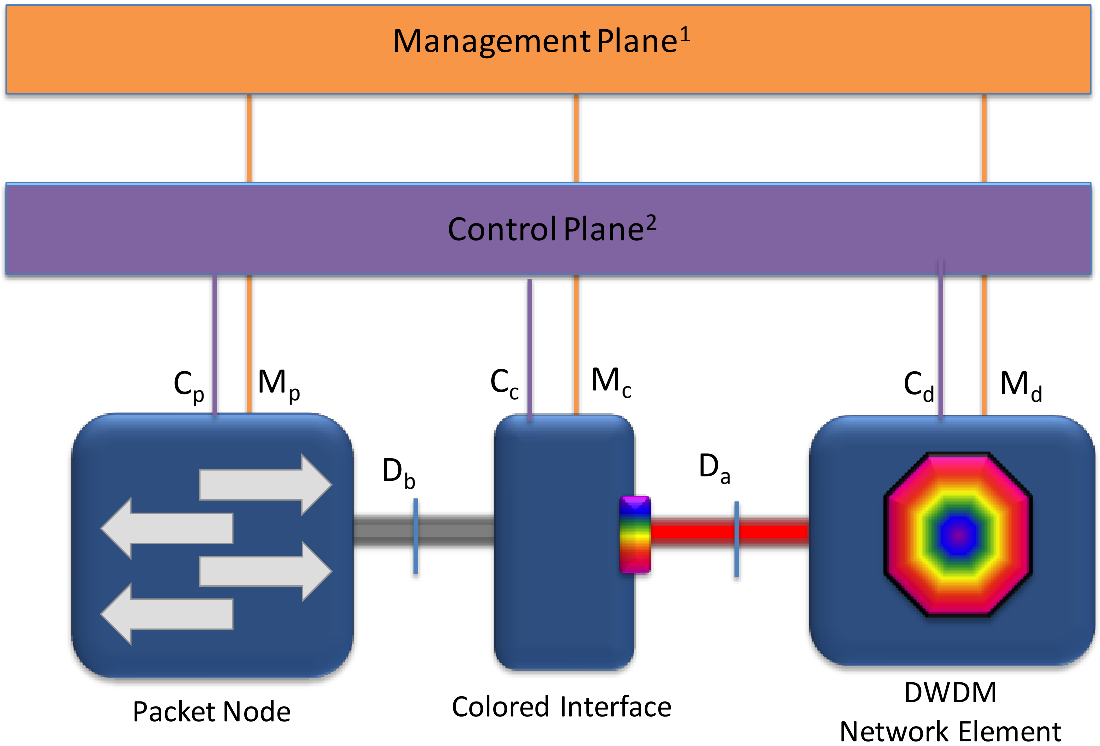

Figure 1: Reference Architecture[1,2]

TR-319 Physically Integrated Model addresses full integration by moving the Colored Interface physically and logically into the Packet Node. Therefore, D_b will be located internal in the Packet Node and is not applicable for this scenario. Both the Packet Node and the DWDM Network Element have interfaces to both the Control and Management Plane, as the Colored Interface is integrated into the Packet Node. The physically integrated solution uses ITU-T G.698.2 [3], instantiating D_a, for multi-vendor interoperability. The architecture is flexible enough to accommodate a number of different applications including point to point and Packet Node back to back applications over passive optical networks.

TR-319 Physically Separated Model addresses moving the Colored Interface in the DWDM Network Element, instantiating D_b. Therefore, D_a will be located physically inside the DWDM Network Element and D_a is not applicable for this scenario. Both the Packet Node and the DWDM Network Element have interfaces to both the Control and Management Plane, as the Colored Interface is integrated into the DWDM Network Element.

TR-319 Logically Integrated Model addresses leaving the three elements physically separate, but the Packet Node will logically control and manage the Colored Interface. In this scenario, both D_a and D_b exist. Only the Packet Node and the DWDM Network Element have interfaces to both the Control and Management Plane, as the Colored Interface is controlled and managed by the Packet Node.

5 Common Aspects for all Models

[1] The Management Plane can consist of one or more management domains that may or may not be interconnected.
[2] The Control Plane can consist of one or more control domains that may or may not be interconnected.

5.1 Data Plane

TR-319 addresses packet and DWDM/optical integration and supports Physically Integrated, Logically Integrated, and Physically Separated Models.

The Physically Integrated Model consists of having the DWDM Colored Interface directly within the Packet Node. In this scenario, the G.709 [5] frame as well as wavelength are both originated and terminated physically within the Packet Node.

The Logically Integrated Model consists of having the DWDM Colored Interface in a separate unit, but managed by the Packet Node using proprietary mechanisms. Although the G.709 [5] frame and wavelength originate and terminate on the separate unit, the Packet Node may be kept aware of the optical characteristics of the DWDM circuit.

In the Physically Separated Model, the DWDM interface is part of the ROADM or optical network. The Packet Node is connected to DWDM interface unit on a ROADM using Ethernet or OTN interface.

The Models are different and support different Forwarding or Data Plane. Regardless of the Model, connectivity is established between two Packet Nodes across the optical network.
The nodal requirements and Data Plane specifications are provided in respective parts of TR-319.

5.2 Control Plane

Depending on the use case, a dynamic, Generalized Multiprotocol Label Switching (GMPLS)-based Control Plane, including routing and signaling protocols, can optionally be used to establish Label Switched Paths (LSP) between two Packet Nodes across an optical network. GMPLS architecture (RFC3945 [11]) supports multiple switching types, payload types, forwarding hierarchies, and traffic engineering requirements with dynamic behavior.

An overlay model is used per RFC4208 [2] in the perspective of GMPLS Control Plane. GMPLS UNI is implemented between a Packet Node and its directly connected DWDM Network Element, and there is a single end-to-end GMPLS RSVP session between the two Packet Nodes.

The nodal requirements and Control Plane specifications are provided in respective parts of TR-319.

5.3 Management Plane & OAM

TR-319 addresses packet and DWDM/Optical integration and supports Physically Integrated, Logically Integrated, and Physically Separated Models.
The nodal requirements and Management Plane specifications are provided in respective parts of TR-319.

5.3.1 Data Plane Management

Data Plane management can be provided using at least one of the following methods:

1. Support Simple Network Management Protocol (SNMP) protocol to manage and monitor network elements. Structure of Management Information Version 2 (SMIv2) (RFC 2578 [12]) describes the structure of management data that is structured in Management Information Base (MIB). MIB uses object identifiers (OID). Each OID identifies a variable that can be read or set via SNMP. In particular, it defines objects for managing optical parameters associated with DWDM interfaces.

2. Support Network Configuration Protocol (NETCONF) (RFC 6241 [8]) mechanisms to install, manipulate, and delete the configuration of Packet Node and DWDM/optical network devices. YANG (RFC 6020 [9]) is used as data modeling language for model definitions as needed.

5.3.2 Control Channel Management

LMP (IETF RFC 4204 [10]) may be used to maintain control channel connectivity for link management (e.g. connectivity verification and fault management). The control channel must terminate on the same two nodes that the bearer channels span.

6 Use of SDN for Configuration and Management

Software-Defined Networking (SDN) is being developed in the Open Networking Foundation (ONF) and other SDOs as a technology with wide applicability in data and communications networking. Like packet optical integration in general, integrated SDN management offers CAPEX and OPEX benefits including the promise of increased network automation. The key notion in SDN that allows this is that of 'programmability', the key architectural element that supports programmability is the SDN Controller.

An SDN controller has a North Bound Interface (NBI) that provides Application Programming Interfaces (API) that allow manipulation of the controller and the network resources below it. The South Bound Interfaces from the SDN controller use open protocols (e.g OpenFlow, SNMP, NETCONF/YANG, XML, PCEP, etc.) to interface with Network Elements (NE).

SDN can be used for the configuration and management of NEs. In the context of TR-319, SDN provides the ability for an application or applications, to configure the Packet Nodes and the DWDM transport system appropriately to allow an optical signal generated by one Packet Node to transit the transport system and be received by the other Packet Node.

Management by SDN can be achieved by use of SDN interfaces on the EMS systems, on the NMS systems, on the NEs themselves or by any combination of the forgoing. The term orchestrator is used for an application that coordinates the control of different resources in the creation of a service; in the context of TR-319 an orchestrator[3] might use (independent) SDN controllers for the packet and transport resources to coordinate the end-to-end setup of an optical channel between them.

Figure 2 shows some of the possibilities: notably that legacy EMS and NMS systems have a role to play; that multiple controllers can exist in a system; and that EMS and NMS systems can both support and use SDN interfaces.

Note that Figure 2 could be used to illustrate the use of SDN for both control and management but this section focuses on management only.

[3] In this example there is no difference between orchestrator and the application example given in the previous paragraph.

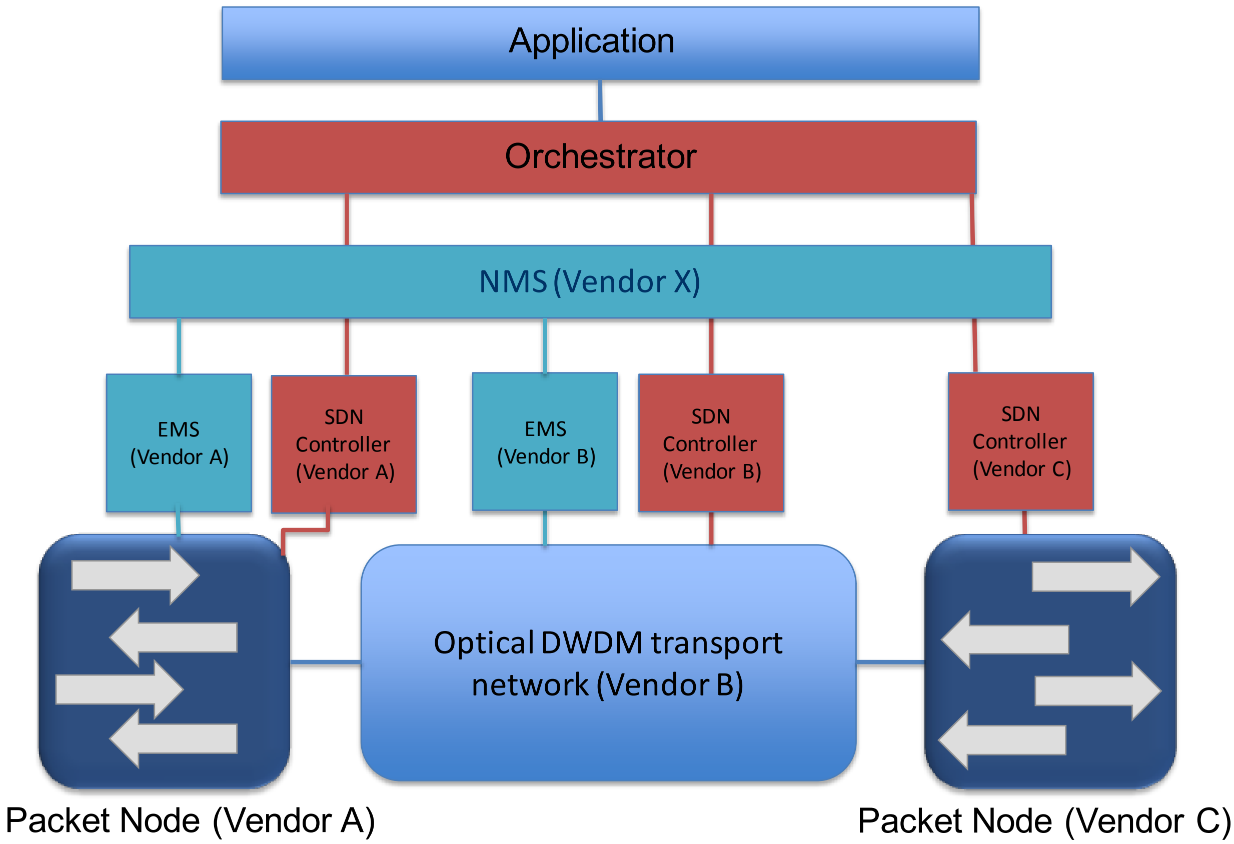

Figure 2: Use of SDN for Configuration and Management

Appendix A: Network Scenarios & Use Cases (appendix/informative)

This section contains use cases and application scenarios for IP/packet network optimization using DWDM interfaces. The capabilities defined in the nodal requirements are used in a network (e.g. for set up and end-to-end connections).
The use cases equally apply to and can represent Physically Integrated and Logically Integrated DWDM interface Models.

A.1 Cloud-Centric Access and Aggregation

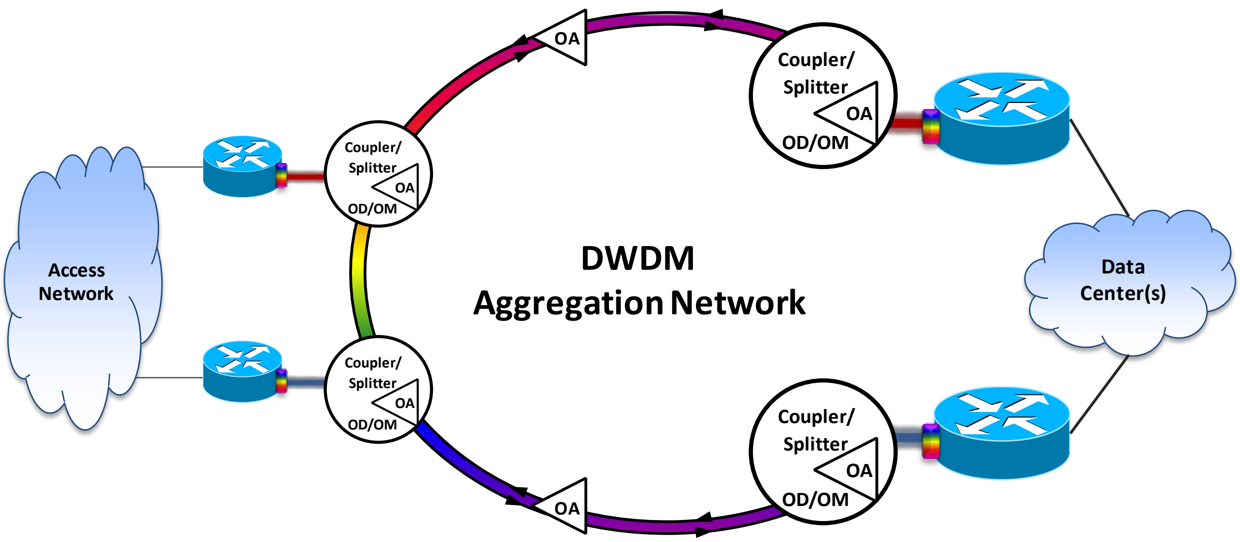

Figure 3: Cloud-Centric Access and Aggregation (Appendix A.1)

DWDM interfaces (Colored Interfaces) are used in an aggregation network to connect to a data center in a cloud centric network. Providers can greatly simplify the network, reduce layers, and reduce OEO conversions by using Colored Interfaces that are integrated into the Packet Nodes (routers) within this scenario. Optical splitters/couplers and Optical Amplifiers (OA) are used to provide pre-provisioned, passive, amplified point to point DWDM links with fixed wavelengths between the routers. Coherent or non-coherent Colored Interfaces are used to setup the wavelength channels between the routers. In case of non-coherent interfaces, such as 10G, optical filters must be used on the receivers. OTN Framing is used and a Forward Error Correction (FEC) is applied to support required link distances for this use case of up to 1000 kilometers.
The network is configured and managed by a centralized, potentially SDN-based, network management approach, without any additional Control Plane functionality in the optical transport layer.

A.2 IP Core

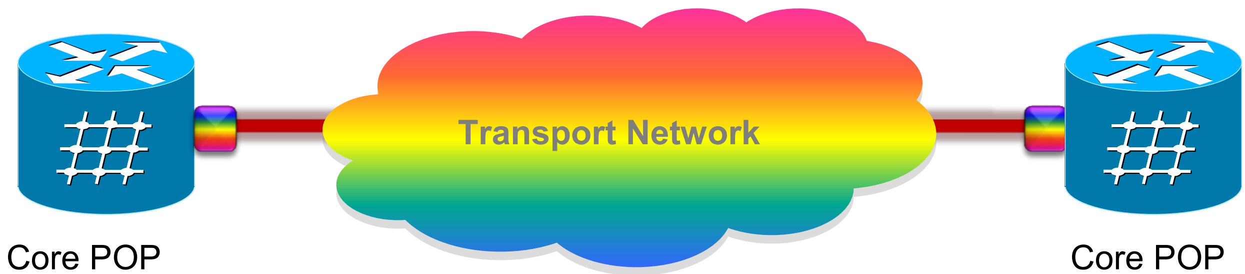

Figure 4: IP Core (Appendix A.2)

DWDM interfaces can be used to connect Core P or PE router with a Core P or PE router located in a remote Point Of Presence (POP). This architecture is used to provide simple high speed connectivity for Internet traffic. This design helps eliminate extra unnecessary layers and OEO conversions in the network by integrating the DWDM interfaces with the Packet Node.

A.3 Data Center Interconnect

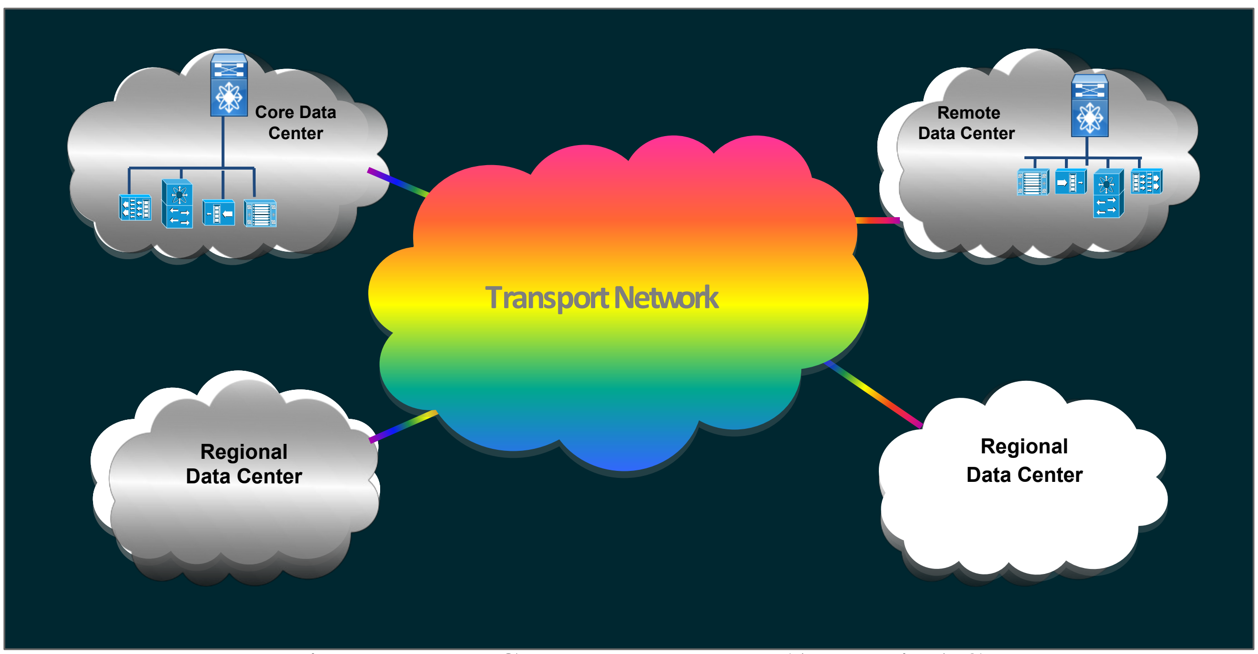

Figure 5: Data Center Interconnect (Appendix A.3)

In this scenario, DWDM interfaces are used to provide high speed data Center Interconnectivity. This interconnectivity can be used for mirroring, backup, load balancing, mobility or data center access. Deploying this solution allows a provider to have simple high bandwidth connectivity while reducing layers and reducing the number of OEO conversions and network elements.

A.4 Edge and Aggregation Router connectivity

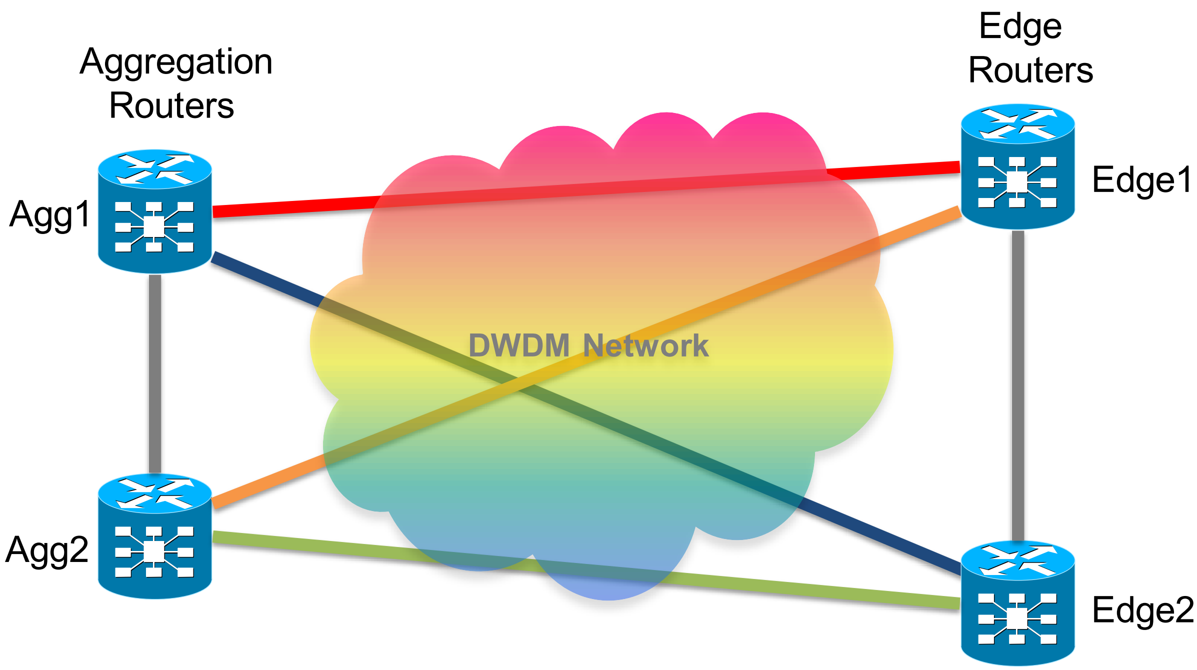

Figure 6: Edge and Aggregation Router connectivity(Appendix A.4)

Service providers can use DWDM interfaces to interconnect their edge and aggregation routers. This scenario is used with a DWDM network between the aggregation sites and the edge sites. This use case along with a dynamic signaled Control Plane (i.e. GMPLS) can add automated control and resiliency.

This use case can be used for mobile backhaul and access and aggregation networks. In A.1 a similar approach is provided between the access network and aggregation network using pre-provisioned links.

End of Broadband Forum Technical Report TR-319

