

ccamp  
Internet-Draft  
Intended status: Informational  
Expires: 31 October 2025

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29 April 2025

Use cases, Network Scenarios and gap analysis for Packet Optical  
Integration (POI) with programmable pluggables under ACTN Framework  
draft-ietf-ccamp-actn-poi-pluggable-usecases-gaps-01

## Abstract

This document provides general overarching guidelines for control and management of packet over optical converged networks with programmable pluggables and focuses on operators' use cases and network scenarios. It provides a set of use cases which are needed for the control and management of the packet over optical networks which comprise devices with mixes of packet and optical functions where the optical functions may be provided on programmable pluggables. The document provides a gap analysis to solve the use cases.

## Discussion Venues

This note is to be removed before publishing as an RFC.

Discussion of this document takes place on the Common Control and Measurement Plane Working Group mailing list ([ccamp@ietf.org](mailto:ccamp@ietf.org)), which is archived at <https://mailarchive.ietf.org/arch/browse/ccamp/>.

Source for this draft and an issue tracker can be found at <https://github.com/oscarddd/draft-poidt-ccamp-actn-poi-pluggable-usecases-gaps>.

## Status of This Memo

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## 1. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in the document are to be interpreted as described in RFC2119}}.

The following terms abbreviations are used in this document:

- \* Coherent plug/pluggable: A small form factor coherent optical module
- \* O-PNC: The control functions specializing in management/control of optical and photonic functions (virtual or physical). See RFC8453}}
- \* P-PNC: The control functions specializing in management/control of packet functions (virtual or physical). See RFC8453}}

- \* xPonder: Short for Transponder and/or Muxponder
- \* MDSC: Multi-Domain Service Coordinator. see See RFC8453}}

## 2. Introduction

Packet traffic is predominatly transferred over optical interfaces, some of which connect to optical networks or Optical Line Systems. Optical Line systems have been separated from packet systems, both of which have had specific dedicated devices. In many existing network deployments, packet networks including direct connect electrical and optical interfaces and the optical networks are engineered, operated and controlled independently. The operation of these packet and optical line networks is often siloed which results in non-optimal and inefficient networking. Both packet and optical systems have had relatively independent evolution. Optical interface technology has been developed with increasing capacity. Meanwhile standardization has been progressed to a point where interoperable optical specifications are available, especially with the emergence of coherent optical techniques.

Optical component design has continued to improve density to the point where a whole coherent optical terminal system that use to require many circuit packs can now fit onto a single small form factor "coherent plug". Placing coherent plugs in a device with packet functions can reduce network cost, power consumption and footprint as well as improve data transfer rates, reduce latency and expand capacity (note that in some cases, other engineering and deployment considerations still lead to separate packet and optical solutions).

Optical transmission/switching is analogue and requires complex and holistic analog control. Consequently, coordination of control of the coherent plugs (in a device with packet functions) with the control of the rest of the optical network is highly desirable as this best enables robust network functionality and simplifies network operations.

The combination of these above trends along with the desire to select best in breed components has led to the need for a standard way to control Coherent Modules. Coherent Modules are more complex than non-coherent modules and led to extensions of the host-to-module management interface: Coherent CMIS [OIF-CMIS]. Standardization of CMIS is intended such that a plug from vendor X can be installed in vendor Y's device.

Current draft is applicable to programmable pluggables in general. By programmable we mean to include both coherent and non coherent pluggables. Depending on the technology of the pluggable there might be several parameters to configure. One configuration aspect is the ability to select the operational mode

[I-D.draft-ietf-ccamp-optical-impairment-topology-yang] (in case several modes are supported), and, for a particular operational mode, the specific parameters to be specified (e.g. frequency, output power... ) and read. Operational mode is described in IETF in [I-D.draft-ietf-ccamp-optical-impairment-topology-yang] . ITU-T Rec G.698.2 refers to application codes, while CMIS refers to AppSel code (Application Selector). In Openconfig, it is referred as Operational mode.

The applicability of Abstraction and Control of TE Networks (ACTN) architecture [RFC8453] to Packet Optical Integration (POI) in the context of IP/MPLS and optical internetworking has been analyzed in [I-D.draft-ietf-teas-actn-poi-applicability]. This document further extends to applicability of ACTN with the integration of coherent pluggables in IP/MPLS devices. An architecture analysis has been carried out by the MANTRA sub-group in the OOPT / TIP group (Open Optical & Packet Transport / Telecom Infra Project) [MANTRA-whitepaper-IPoWDM-convergent-SDN-architecture].

This document provides guidellines for control and management of packet over optical converged networks and it is divided into following sections:

- \* Section 3 Packet over optical converged network context
- \* Section 4 Network Scenarios
- \* Section 5 Use cases for the control and management of Packet over Optical Converged Networks
- \* Section 5 Gap analysis

### 3. Packet over Optical Converged Network Context

A packet over optical network represents an efficient paradigm that harnesses the power of both packet-switching and optical technologies. In this approach, some of the links of an overlay IP or MPLS packet network interface an underlying optical network. The fusion of packet and optical networks offer a host of advantages, including accelerated data transfer rates, diminished latency, and expanded network capacity.

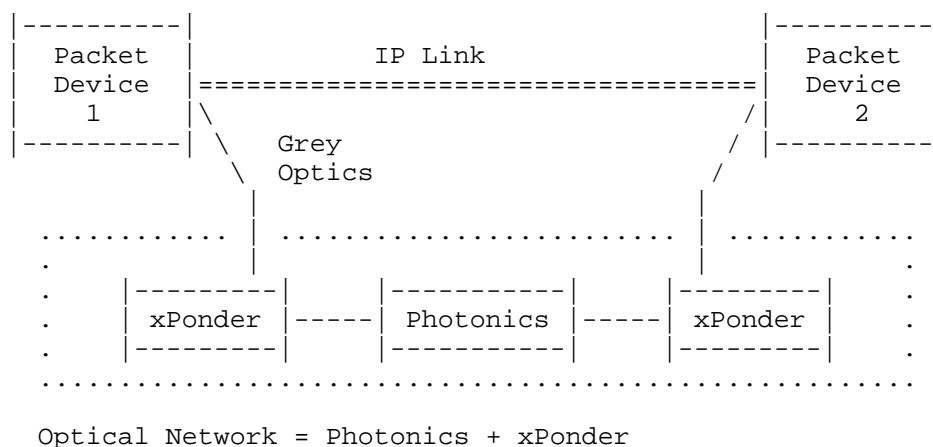
In general, two deployment models can be used to deploy the packet over optical networks:

- \* Traditional architecture deployment model
- \* Deployment model with coherent pluggables

### 3.1. Traditional Architecture Deployment Model

The traditional architecture involves separation of the packet network from an optical network as shown in Figure 1. In a traditional approach, the packet network responsible for packet routing and forwarding is logically decoupled from the underlying optical transport network. Traditionally, packet devices are managed through published management models either individually or by use of independent centralized management tools. In contrast, optical networks are traditionally single-vendor networks that are managed by proprietary management systems provided by the same vendor. This approach offers several benefits, including the ability to scale each network independently, optimize resource utilization, and simplify network management through dedicated software control.

(TODO: where is "disaggregation" defined?) Disaggregation enables network operators to choose best-of-breed components for each layer, fostering innovation and competition in the networking industry. However, implementing and managing a disaggregated network also comes with challenges related to interoperability, integration, and maintaining end-to-end performance across the various networks.



## Legend:

==== IP Link  
 ---- Optical fibers  
 ++++ Coherent pluggables  
 xPonder: Muxponder or transponder  
 Photonics: ROADM + Amp + Regen  
 .... Optical Line System

Figure 1: Packet over Optics Traditional Architecture Deployment Model

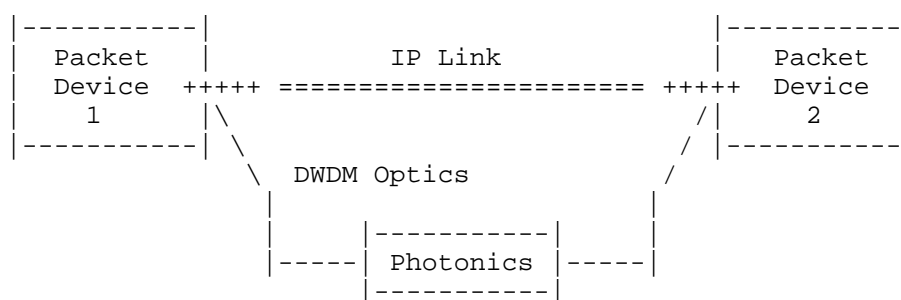
### 3.2. Deployment Model with Coherent Pluggables

The second approach is to take advantage of the implementation footprint of single small form factor pluggables (aka Coherent pluggables) and then place plugs directly into the packet devices as shown in Figure 2(A). Placing this small form factor pluggable in a device with packet functions can reduce network cost, power consumption and footprint (when these benefits are not outweighed by other engineering considerations). Depending on the application, distance between packet devices, quality of fibers and other considerations, it is possible that there is no need for a ROADM network. In case direct connectivity between packet devices via plugs is possible the corresponding pluggables are managed as part of the packet network itself.

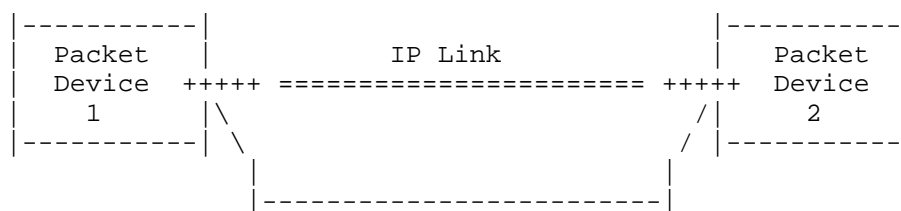
Coherent pluggable optics can be deployed on routers independently of POI integration and many benefits can be achieved such as the elimination of transponders. However, the major benefits from coherent pluggable optics in IP routers are best combined with a ROADM network yielding high capacity point to point links for geographically diverse Core and Data Center Interconnect use cases.

One of the key advantages of using coherent plugs in routers is the potential to bridge the gap between long-haul and metro networks, providing a seamless and efficient transition of data across various network segments. This technology can contribute to the evolution of high-speed data centers, interconnection between data centers, and the overall growth of data-intensive applications.

As noted above, for some use-cases when the distance between packet devices is short and optical power of pluggables are enough, the photonics devices might not be needed as shown in Figure 2(B).



(A)



(B)

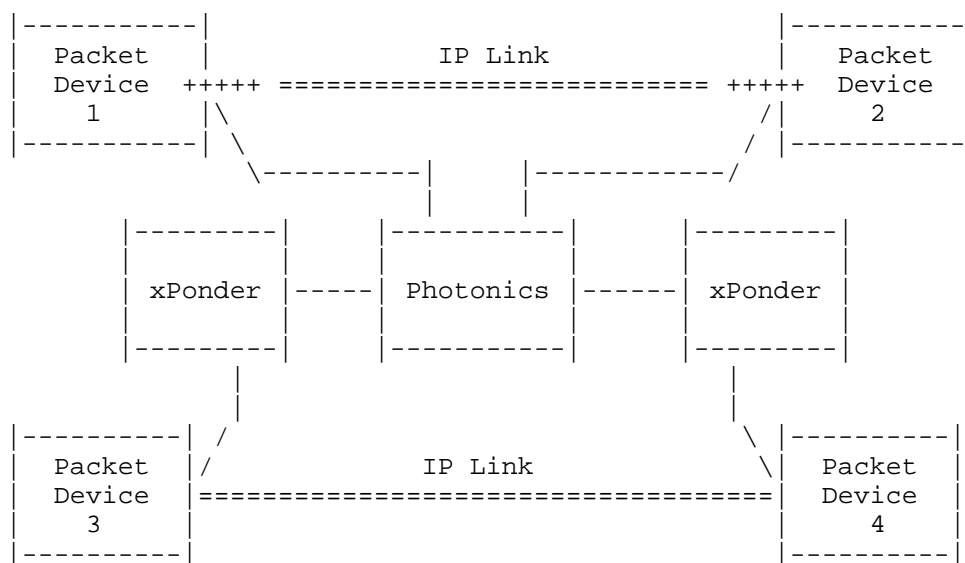
#### Legend:

==== IP Link  
 ---- Optical fibers  
 ++++ Coherent pluggables  
 xPonder: Muxponder or transponder  
 Photonics: ROADM + Amp + Regen  
 Optical Network: Photonics + pluggables

Figure 2: Packet over Optics Deployment Model with Coherent Plugs

In many cases, the operators' packet over optical networks will most likely be a combination of networks shown in Figure 1 and Figure 2 where the optical network contains both coherent pluggables and xPonders as shown in Figure 3.





Optical Network: Photonics + pluggables + xPonder

Legend:

==== IP Link  
 ---- Optical fibers  
 ++++ Coherent pluggables  
 xPonder: Muxponder or transponder  
 Photonics: ROADM + Amp + Regen

Figure 3: Packet over Optics Deployment Model with Coherent Plugs and xPonders

#### 4. Network Scenarios

This section provides a set of packet over optical network scenarios, starting with the most common ones.

##### 4.1. Scenario A - High capacity point to point connection over dedicated direct fiber

As depicted in Figure 4, this scenario considers a point-to-point optical service over a short distance (e.g., up to 100 km) using dedicated fiber.

Note that there is no amplification and no protection in this scenario.

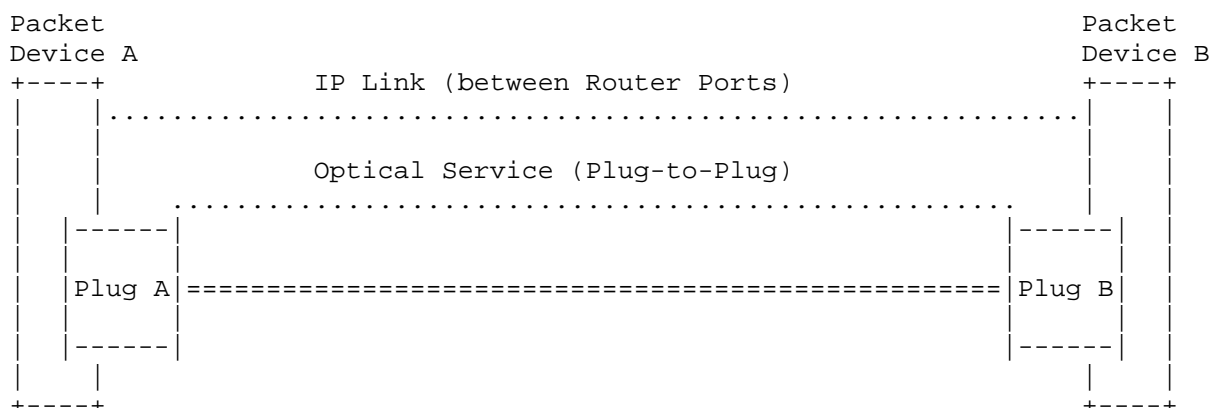


Figure 4: Network topology with dedicated direct fiber

#### 4.2. Scenario B - High capacity point to point over shared fiber

This scenario extends Figure 4 by making more efficient use of the deployed fiber infrastructure.

As shown in Figure 5, this scenario considers a point-to-point optical service over a short distance (e.g., up to 100 km) using a physical optical network with DWDM filters and amplifiers. Several point-to-point connections can be multiplexed from the same packet devices. A variant of this use case is mobile fronthaul, analyzed in [MOPA-Tech-Paper], where coherent pluggables in packet aggregation switches would use WDM but no amplification for distances up to 20 km or so.

Note that there is no protection in this scenario. [TODO: optical switch for protection??]

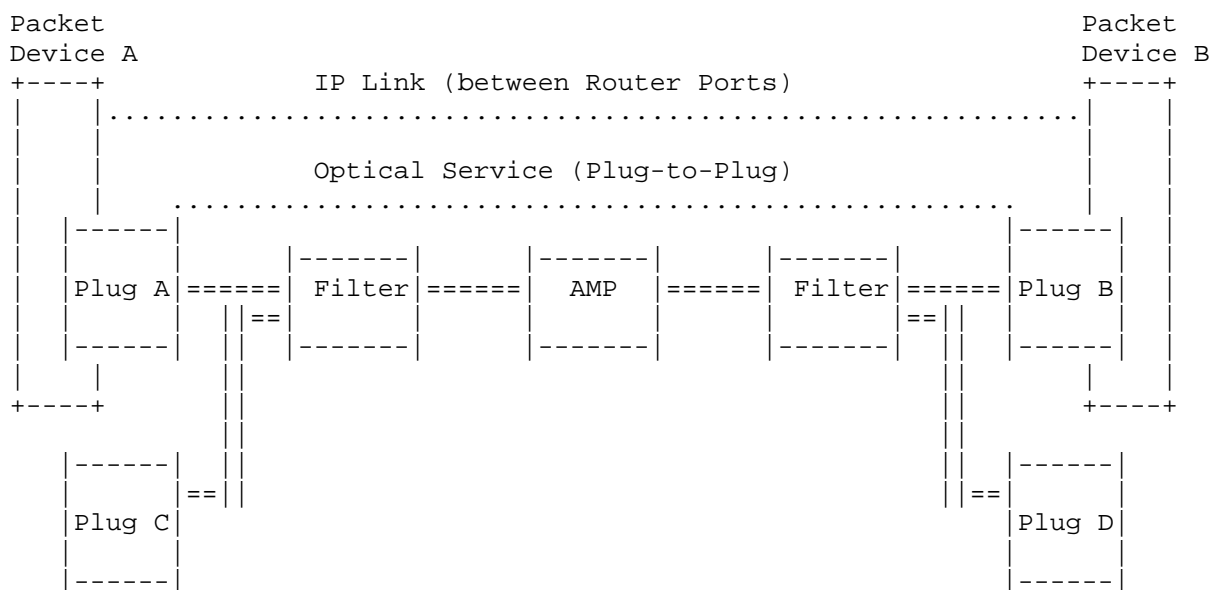


Figure 5: Network topology with shared direct fiber network

#### 4.3. Scenario C - High capacity point to point over metro-regional shared meshed network

This scenario extends Figure 5 by making more flexible use of the fiber network infrastructure.

As shown in Figure 6, this scenario considers a point-to-point optical service over a metro/regional network (e.g., up to 500 km). The metro/regional network contains DWDM filters, amplifiers and optical switching.

Note that there is no resilience in this scenario. (TODO: CHECK AS RESTORATION COULD BE A CHOICE)

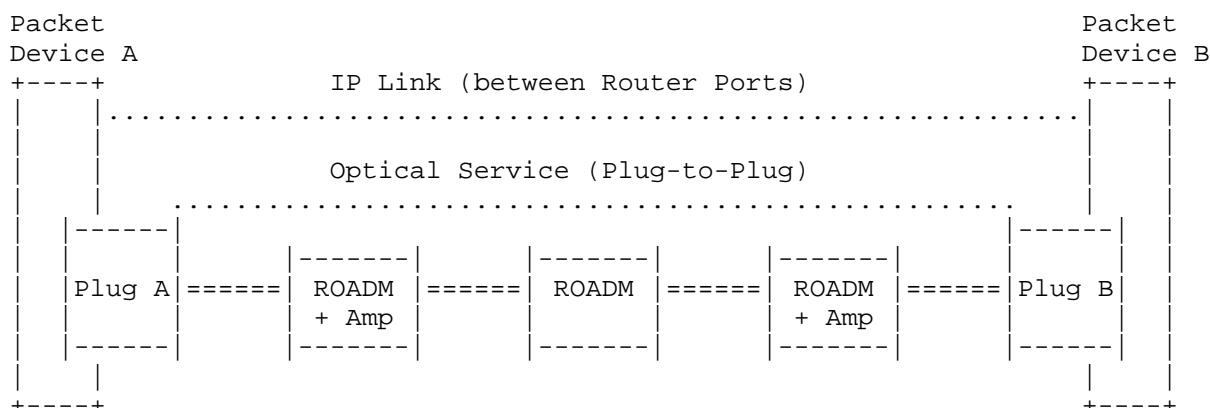


Figure 6: Network topology with shared switched fiber network

#### 4.4. Sceanrio D - High capacity point to point optical connection between plug and xPonder

This scenario, shown in Figure 7 and extends network topologies Figure 4 to Figure 6 and covers a case, where one end of an optical service is terminated on a plug and the other end is terminated on a traditional xPonder (transponder or muxponder) with grey optics to a packet device. This scenario is encountered when one of the packet device does not support coherent pluggables or as part of an optical regenerator device.

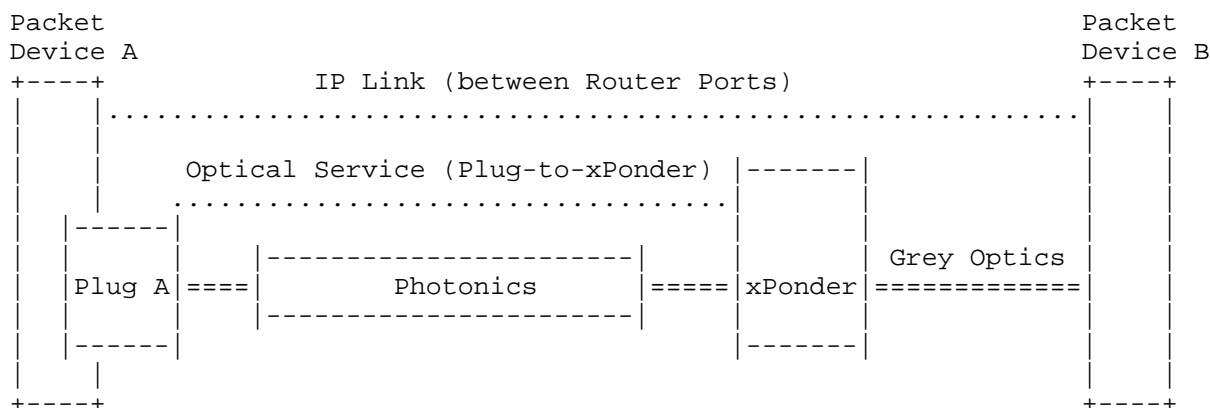


Figure 7: Network topology with symmetric plug and transponder

#### 4.5. Other Network scenarios.

- \* Network topology with shared switched fiber network with regenerators: This is extension of scenario C Figure 6 when the photonic network has regenerators.
- \* Asymmetric interconnect Network topology where the protection open at one end but both protection legs are terminated on separate xPonder or coherent pluggables.
- \* IP Lag Network topology where the IP link between two packet devices are provided by multiple coherent plugs.
- \* Practical network deployments which includes the mix of many network topologies explained above.

#### 5. Operators' Use cases

This section provides a set of packet over optical general use cases which are applicable to any network topologies in Section 4 and both for multi-layer networks using or not coherent pluggables in the routers. These use cases are presented following current operators' priorities order.

The use cases are generally applicable for both the traditional packet over optical integration based on grey interfaces in the IP routers and use of transponders/muxponders in the optical domain and for the packet over optical integration considering coherent DWDM pluggables in the IP routers over a media channel/Network Media channel in the optical domain. For clarification purposes, the mention 'valid for both' has been added in the name of each use case else 'valid for O-OLS' when the use case is specific to the open optical line systems approach.

##### 5.1. End-to-end multi-layer visibility and management (valid for both)

###### 5.1.1. End-to-end multi-layer network and service topology discovery and inventory

The objective of the use case is to have a full end-to-end multi-layer view from all the layers and their inter-dependencies: service layer (e.g. L3VPN/L2VPN), transport layer (RSVP-TE, SR-TE), IP layer (IGP), Ethernet layer, OTN L1 layer (optional), photonic L0 layer (OCh, OMS, OTS and fibre). The discovery process, in addition to the layered logical view, includes the inventory discovery by each controller and exposure to the MDSC of the required information for a complete end-to-end multi-layer view of the network. [TODO: rephrase in architecture independent manner]

#### 5.1.1.1. Coherent DWDM pluggable insertion in the router linecard port ('valid for coherent pluggable')

Once a pluggable module is inserted in the proper linecard port, the host device must recognise the hardware component (e.g. 400G ZR+ pluggable module) and expose its attributes and capabilities to its controller. For example, ZR+ modules can share the operational-mode-IDs supported that summarize the most important pluggable characteristics (such as FEC type, modulation format, baud rate, bit rate, etc.). If the hardware component has been successfully recognised, the host device is then ready to create and expose the necessary logical arrangements. [TODO: Last sentence is unclear. suggest to remove]

Some coherent pluggables seem to come with a factory default set of provisioning parameters (e.g. default channel number, default launched power, default application code id, laser-on, admin-state enabled etc.). This factory default set of provisioning parameters varies from manufacturer to manufacturer. This can allow a "plug&play" mode of operation over point-to-point connections (e.g. single wavelength over dark fiber). However, when the optical connection between two pluggables is targeted to run over a DWDM Open Line System (OLS) network, optical validation & planning step is first required to determine the right target provisioning parameters values to be set in the pluggables before interconnecting them to their respective ROADMs to avoid to impact any other existing optical channels already up and running in the OLS network. It is critical for operators to have the same kind of commissioning phase independently of the deployment scenario: point-to-point vs ROADM meshed OLS network. As a consequence, the use of factory default provisioning parameters may be fine but they shall always be able to be overwritten through router CLI or through Packet PNC to another set of default provisioning parameters defined by the operator that will change from pluggable to pluggable when deployed over an OLS network. A reset of the coherent pluggable (through router CLI or through Packet PNC or due to a power off/on) shall always go back to this operator's default set of provisioning parameters where, for example, the laser-state shall be 'Off' and admin-state 'disabled' .

#### 5.1.1.2. Inventory of Coherent DWDM pluggable ('valid for coherent pluggable').

The domain controller exposes to the MDSC hardware inventory information of the devices under its supervision. [TODO: re-phrase in architecture independent manner] For full router inventory (linecards, ports, etc.) see draft-ietf-ivy-network-inventory-yang. In addition, capability information shall include the coherent pluggable transceiver capabilities. These include, for instance,

operational-modes supported (ITU-T application codes, organizational modes), min/max central-frequency range supported, min/max output power supported, min/max received power supported etc. In case of discovery of any HW mismatch between coherent pluggable and router linecard port capabilities the controller shall report HW mismatch alarm to MDSC. An example is a linecard multi-rate port vs coherent pluggable with only one client/line rate (e.g. 1x400GE).

#### 5.1.1.3. Coherent pluggable OTSi service discovery information ('valid for coherent pluggable').

Once a router-to-router connection with coherent pluggables has been created over a Network Media Channel in the optical Line system, then it is required by the O-PNC to expose the OTSi service. The relevant OTSi information could be nominal-central-frequency, tx-output-power, operational-mode-ID, operational-status, admin-status etc. [TODO: consider rewriting in architecture neutral form and without sequence. It is unclear what is required here]

#### 5.1.1.4. Discovery of layer relationships

The physical connectivity needs to be exposed. This includes the port, patch fiber between Router and ROADM, ROADM and optical fiber and amplifiers.

#### 5.1.2. End-to-end multi-layer event/fault management (valid for both)

The Target in this use case is to have a full end-to-end multi-layer correlation of events at different layers and domains (e.g. operational-status changes reported at OTS/OMS/OCh/ODUk (optional), IP link level, LSP level, L3VPN/L2VPN level etc.) so that final root cause can be quickly identified and fixed (e.g. fibre cut vs coherent DWDM pluggable failure). [TODO: the example seems to be an OLS-only feature] This use case is divided in two: \* Correlation of ZR+ connection (OTSi service) operational-status with MC/NMC operational-status ('valid for coherent pluggable') In this case, the target is to expose to the MDSC both the events/faults from the ZR+ connection (OTSi service) and ZR+ pluggables as well as for the MC/NMC associated to this ZR+ connection (OTSi service) in the DWDM Line system so that proper correlation can be performed \* Correlation of coherent pluggable operational status, port status, OLS (ROADM, AMP) status, Ethernet link operational status, IP link status

### 5.1.3. End-to-end multi-layer performance management (valid for both)

In this use case, the goal is to have the possibility to analyse through performance monitoring of the different layers mentioned above and be able, in case of end-to-end L2VPN/L3VPN service degradation, to identify the root cause of the degradation. For scaling purposes, the target should be, upon service fulfilment phase, to set up the right TCAs associated to each layer that can allow to meet the L2VPN/L3VPN service SLA (e.g. in terms of latency, jitter, BW, etc.). This use case is divided in two: (Note: why is this divided in two subsections. After all this is telemetry/PM reporting and listeners can subscribe to any of those.)

#### 5.1.3.1. Performance management of the ZR+ connection (OTSi service) ( 'valid for coherent pluggable)

Target is to have the basic performance parameters of each OTSi service running between two pluggables exposed. Best for operators could be to defined TCA (Threshold crossing alerts) for each OTSi service and be notified only when the Thresholds defined are not met. Operator shall be able to decide which parameters and for which OTSi service. But all the parameters shall be visible if needed by operators.

Note: Router shall provide also all the possible performance counters not only for OTSi service/Ethernet service etc. but also for the pluggable itself, as needed for p2p operations as well.

As an example operators should have the ability to get visibility on pre-FEC-BER for a given OTSi service and see the trend before post-FEC-BER is affected

#### 5.1.3.2. Performance management of the Ethernet link running over the OTSi service and also of the IP link running over this Ethernet link.

TBC

### 5.2. Inter-domain link validation (valid for coherent pluggable)

Documenting the patch cord that connects the port of the coherent DWDM pluggable in the routers to the optical node (e.g. to the right Add/Drop port of the ROADM) is performed. This manual operation is prone to human mistakes. It would be highly beneficial for operators to have a mean to check/discover that the right pluggable has been connected to the desired ROADM port. This use case requires the ability to inject optical power and expose power levels at coherent DWDM pluggable side and at ROADM port side and vice versa to perform



the right correlation and validation. [TODO: is there IETF work we can point to? ROADMs usually cannot send signals by themselves that can be retrieved by an attached transponder]

### 5.3. End-to-end L3VPN/L2VPN service multi-layer fulfilment with SLA constraints (TE constraints) (valid for both)

This use case is described in [I-D.draft-ietf-teas-actn-poi-applicability] for the SR-TE case which is relevant as target use case for operators. If new connectivity is required between the routers and at optical level then full automation shall be achieved. The automation of this use case is considered more for future mode of operations (FMO) and has not the same priority as the previous two use cases.

### 5.4. Pluggable to pluggable service Provisioning

The following specific coherent DWDM pluggable provisioning sub-cases are identified: ### Manual Day 1 configuration ( 'valid for coherent pluggable') Knowing the coherent pluggable characteristics (performance and optical impairments for a specific operational-mode-ID), the optical planning and validation process is performed and the following parameters are communicated by optical team to IP team: nominal-central-frequency, tx-output-power, operational-mode-ID and applicable threshold settings so that the coherent pluggables at both ends in the routers can be correctly configured in a manual way. In addition to the coherent pluggable configuration, the optical team needs to properly configure the Media Channel in the line system DWDM network.

#### 5.4.1. Semi-manual Day 1 configuration ( 'valid for coherent pluggable' )

Same optical planning and validation is performed first by optical team and then parameters are provided to MDSC operations engineer so that they can be set-up in the corresponding router' s pluggables.

#### 5.4.2. Semi-Automated Day 1 configuration with Path Computation API request ( 'valid for coherent pluggable' )

In this use case the start of the pluggable to pluggable connectivity is triggered by the connectivity needs of a packet service (slice, vpn, etc...). In the context of ACTC, the process would start with MDSC receiving the service request (e.g. L3VPN) (or service provisioning from a GUI) and the MDSC determines that new optical connectivity is needed between two ZR/ZR+ pluggables which are already physically connected (patch cord) to ROADM nodes ports. MDSC sends a path computation request to the O-PNC asking for a specific MC/NMC between source Mux/Dmux and destination Mux/Dmux for a target

bitrate (e.g. 400G) and O-PNC in coordination with planning tool calculates the optical path (after successful PCE computation) for this given bitrate (e.g. 400G) with a specific operational-mode-ID supported by these coherent pluggables. It validates the optical path defining the central-frequency, output-power, operational-mode-ID to be configured in the coherent pluggables. O-PNC updates the MDSC of successful optical path creation exposing this new optical path to the MDSC along with the nominal-central-frequency, the target-output-power, the operational-mode-ID for which this MC/NMC was created, etc. The MDSC requests the relevant PNC to configure both source and target pluggables with the calculated parameters. [TODO: Rewrite in architecture neutral manner]

MDSC uses the coherent pluggable CRUD data model to be used on MPI to configure the corresponding ZR+ connection (OTSi service) in the source and destination coherent pluggables. This operation is supported by the PNC which will be in charge also to turn-on the laser and complete the optical path set-up. At this point the optical path will be moved to operational state and the Packet traffic starts to flow.

[TODO: this section is a description for a procedure. Can it instead be translated in a use-case?)]

#### 5.4.3. Fully automated Day 1 configuration

(For future discussions)

#### 5.5. 4. End-to-end L3VPN/L2VPN service multi-layer provisioning with SLA constraints (TE constraints) (valid for both)

This use case is described in [I-D.draft-ietf-teas-actn-poi-applicability] for the SR-TE case which is relevant as target use case for operators. If new connectivity is required between the routers and at optical level then full automation could be achieved. However considering PMO (Present Mode of Operation) in most operators, before an optical path is setup either between two native transponders or between two coherent pluggables in routers, a detailed optical planning and validation is typically required. So, the automation of this use case is considered more for future mode of operations (FMO) and has not the same priority as the previous two use cases. [TODO: explain how the need for additional optical connectivity is triggered. VPN often does not carry a bandwidth information, so it is hard to figure out when it is "full". Even then the remediation action may be a reroute.]

#### 5.6. End-to-end L3VPN/L2VPN service multi-layer with SLA constraints (TE constraints) with optical restoration support (valid for both but here focusing on the coherent pluggable)

This use case has not the same priority as the previous ones as protection in multi-layer Core/Backhaul networks is usually implemented at IP layer (e.g. FRR with RSVP-TE, TI-LFA with SR and SR policies in SR-TE) to avoid proven protection races. a. ZR+ links over DWDM network can be considered out of the L0 control plane so that no restoration is applied to those links b. ZR+ links over DWDM network can be considered part of the L0 control plane but no restoration is enabled for those links c. ZR+ links over DWDM network can be considered as part of the L0 control plane with restoration enabled for those links but nominal-central-frequency is maintained unchanged after L0 restoration. Only output-power could be tuned for the new restored path determined by the L0 control plane d. ZR+ links over DWDM network can be considered as part of the L0 control plane with restoration enabled for those links and nominal-central-frequency and output power need to be tuned for the new restored path determined by the L0 control plane. [TODO: Unclear description]

#### 6. Security Considerations

TBD

#### 7. IANA Considerations

This document has no IANA actions.

#### 8. References

##### 8.1. Normative References

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## Appendix A. Acknowledgments

This document has been made with consensus and contributions coming from multiple drafts with different visions. We would like to thank all the participants in the IETF meeting discussions. Part of the work has been carried out in the EU Season project (101096120).

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