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**Applicability of Abstraction and Control of Traffic Engineered
Networks (ACTN) to Packet Optical Integration (POI)**

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Abstract

This document considers the applicability of ACTN to Packet Optical Integration (POI) and IP and Optical DWDM domain internetworking, and specifically the YANG models being defined by the IETF to support this deployment architecture.

In this document we highlight the IETF protocols and data models that may be used for the ACTN and control of POI networks, with particular focus on the interfaces between the MDSC (Multi-Domain Service Coordinator) and the underlying Packet and Optical Domain Controllers (P-PNC and O-PNC) to support Packet Optical Integration (POI) use cases.

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1. Introduction

Packet Optical Integration (POI) is an advanced use case of traffic engineering. In wide area networks, a packet network based on the Internet Protocol (IP) and possibly Multiprotocol Label Switching (MPLS) is typically realized on top of an optical transport network that uses Dense Wavelength Division Multiplexing (DWDM). In many existing network deployments, the packet and the optical networks are engineered and operated independently of each other. There are technical differences between the technologies (e.g., routers vs. optical switches) and the corresponding network engineering and planning methods (e.g., inter-domain peering optimization in IP vs. dealing with physical impairments in DWDM, or very different time scales). In addition, customers and customer needs can be different between a packet and an optical network, and it is not uncommon to use different vendors in both domains. Last but not least, state-of-the-art packet and optical networks use sophisticated but complex technologies, and for a network engineer it may not be trivial to be a full expert in both areas. As a result, packet and optical networks are often operated in technical and organizational silos.

This separation is inefficient for many reasons. Both capital expenditure (CAPEX) and operational expenditure (OPEX) could be significantly reduced by better integrating the packet and the optical network. Multi-layer online topology insight can speed up troubleshooting (e.g., alarm correlation) and network operation (e.g., coordination of maintenance events), multi-layer offline

topology inventory can improve service quality (e.g., detection of diversity constraint violations) and multi-layer traffic engineering can use the available network capacity more efficiently (e.g., coordination of restoration). In addition, provisioning workflows can be simplified or automated as needed across layers (e.g, to achieve bandwidth on demand, or to perform maintenance events).

Fully leveraging these benefits requires an integration between the management and control of the packet and the optical network. The Abstraction and Control of TE Networks (ACTN) framework defines functions and interfaces between a Multi-Domain Service Coordinator (MDSC) and Provisioning Network Controllers (PNCs) that can be used for coordinating the packet and optical layers.

In this document, key use cases for Packet Optical Integration (POI) are described both from the point of view of the optical and the packet layer. The objective is to explain the benefit and the impact for both the packet and the optical layer, and to identify the required interaction between both layers. Precise definitions of use cases can help with achieving a common understanding across different disciplines. The focus of the use cases are IP networks operated as client of optical DWDM networks. The use cases are ordered by increasing level of integration and complexity. For each multi-layer use case, the document analyzes how to use the interfaces and data models of the ACTN architecture.

Understanding the level of standardization and the gaps will help to better assess the feasibility of integration between IP and Optical DWDM domain, in an end-to-end multi-vendor service provisioning perspective.

2. Reference Scenario

This document is considering a network scenario with multiple Optical domains and multiple Packet domains.

Figure 1 shows this scenario in case of two Optical domains and two Packet domains:

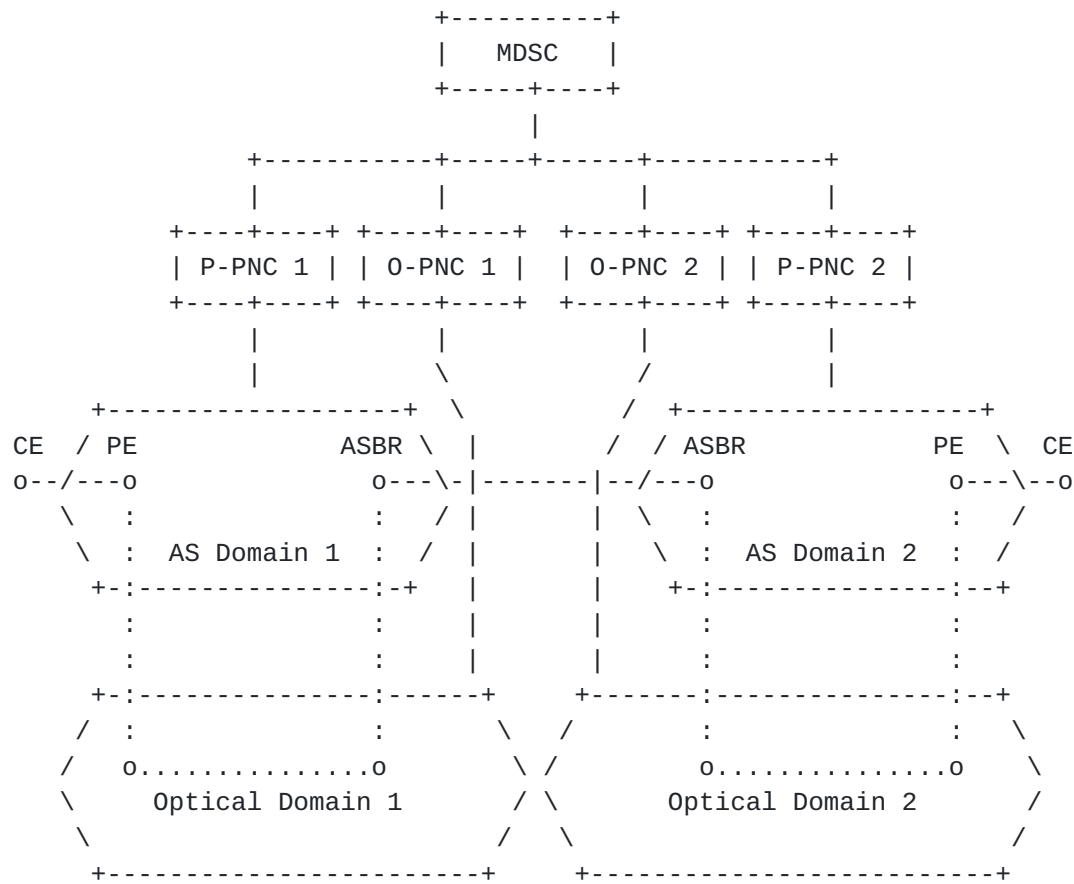


Figure 1 - Reference Scenario

The ACTN architecture, defined in [RFC8453], is used to control this multi-domain network where each Packet PNC (P-PNC) is responsible for controlling its IP domain (AS), and each Optical PNC (O-PNC) is responsible for controlling its Optical Domain. The MDSC is responsible for coordinating the whole multi-domain multi-layer (Packet and Optical) network. A specific standard interface (MPI) permits MDSC to interact with the different Provisioning Network Controller (O/P-PNCs). The MPI interface presents an abstracted topology to MDSC hiding technology-specific aspects of the network and hiding topology details depending on the policy chosen regarding the level of abstraction supported. The level of abstraction can be obtained based on P-PNC and O-PNC configuration parameters (e.g. provide the potential connectivity between any PE and any ASBR in an MPLS-TE network).

The MDSC in Figure 1 is responsible for multi-domain and multi-layer coordination across multiple Packet and Optical domains, as well as

to provide IP services to different CNCs at its CMIs (e.g., using L2SM, L3SM).

The multi-domain coordination mechanisms for the IP tunnels supporting these IP services are outside the scope of this document and described in [\[ACTN-VPN\]](#). In some cases, the MDSC could also rely on the multi-layer Packet Optical Integration mechanisms, described in this draft, to support multi-layer optimizations for these IP services and tunnels.

In the network scenario of Figure 1, it is assumed that:

- o The domain boundaries between the IP and Optical domains are congruent. In other words, one Optical domain supports connectivity between Routers in one and only one Packet Domain.
- o Inter-domain links exist only between Packet domains (i.e., between ASBR routers) and between Packet and Optical domains (i.e., between routers and ROADMs). In other words, there are no inter-domain links between Optical domains
- o The interfaces between the routers and the ROADM's are "Ethernet" physical interfaces
- o The interfaces between the ASBR routers are "Ethernet" physical interfaces

[2.1.](#) Generic Assumptions

This section describes general assumptions which are applicable at all the MPI interfaces, between each PNC (Optical or Packet) and the MDSC, and also to all the scenarios discussed in this document.

The data models used on these interfaces are assumed to use the YANG 1.1 Data Modeling Language, as defined in [\[RFC7950\]](#).

The RESTCONF protocol, as defined in [\[RFC8040\]](#), using the JSON representation, defined in [\[RFC7951\]](#), is assumed to be used at these interfaces.

As required in [\[RFC8040\]](#), the "ietf-yang-library" YANG module defined in [\[RFC8525\]](#) is used to allow the MDSC to discover the set of YANG modules supported by each PNC at its MPI.

3. Scenario 1 - Multi-Layer Topology Coordination

In this scenario, the MSDC needs to discover the network topology, at both WDM and IP layers, in terms of nodes (NEs) and links, including inter AS domain links as well as cross-layer links.

Each PNC provides to the MDSC an abstract topology view of the WDM or of the IP topology of the domain it controls. This topology is abstracted in the sense that some detailed NE information is hidden at the MPI, and all or some of the NEs and related physical links are exposed as abstract nodes and logical (virtual) links, depending on the level of abstraction the user want. This detailed information is key to understand both the inter-AS domain links (seen by each controller as UNI interfaces but as I-NNI interfaces by the MDSC) as well as the cross-layer mapping between IP and WDM layer.

The MDSC also maintains an up-to-date network inventory of both IP and WDM layers through the use of IETF notifications through MPI with the PNCs.

For the cross-layer links it is key for MDSC to be able to correlate automatically the information about the physical ports from the routers (single link or bundle links for LAG) to client ports in the ROADM.

3.1. Discovery of existing Och, ODU, IP links, IP tunnels and IP services

In this scenarios MDSC must be able to automatically discover network topology of both WDM and IP layers (links and NE, links between two domains).

- o An abstract view of the WDM and IP topology must be available.
- o MDSC must keep an up-to-date network inventory of both IP and WDM layers and it should be possible to correlate such information (e.g.: which port, lambda/OTSi, direction is used by a specific IP service on the WDM equipment).
- o It should be possible at MDSC level to easily correlate WDM and IP layers alarms to speed-up troubleshooting.

3.1.1. Common YANG models used at the MPIs

Both Optical and Packet PNCs use the following common topology YANG models at the MPI to report their abstract topologies:

- o The Base Network Model, defined in the "ietf-network" YANG module of [[RFC8345](#)]
- o The Base Network Topology Model, defined in the "ietf-network-topology" YANG module of [[RFC8345](#)], which augments the Base Network Model
- o The TE Topology Model, defined in the "ietf-te-topology" YANG module of [[TE-TOPO](#)], which augments the Base Network Topology Model

These common YANG models are generic and augmented by technology-specific YANG modules as described in the following sections.

3.1.1.1. YANG models used at the Optical MPIs

The Optical PNC also uses at least the following technology-specific topology YANG models, providing WDM and Ethernet technology-specific augmentations of the generic TE Topology Model:

- o The WSON Topology Model, defined in the "ietf-wson-topology" YANG modules of [[WSON-TOPO](#)], or the Flexi-grid Topology Model, defined in the "ietf-flexi-grid-topology" YANG module of [[Flexi-TOPO](#)].
- o The Ethernet Topology Model, defined in the "ietf-eth-te-topology" YANG module of [[CLIENT-TOPO](#)]

The WSON Topology Model or, alternatively, the Flexi-grid Topology model is used to report the DWDM network topology (e.g., ROADMs and links) depending on whether the DWDM optical network is based on fixed grid or flexible-grid.

The Ethernet Topology is used to report the access links between the IP routers and the edge ROADMs.

3.1.1.2. Required YANG models at the Packet MPIs

The Packet PNC also uses at least the following technology-specific topology YANG models, providing IP and Ethernet technology-specific augmentations of the generic Topology Models:

- o The L3 Topology Model, defined in the "ietf-l3-unicast-topology" YANG modules of [[RFC8346](#)], which augments the Base Network Topology Model

- o The Ethernet Topology Model, defined in the "ietf-eth-te-topology" YANG module of [[CLIENT-TOPO](#)], which augments the TE Topology Model

The Ethernet Topology Model is used to report the access links between the IP routers and the edge ROADMs as well as the inter-domain links between ASBRs, while the L3 Topology Model is used to report the IP network topology (e.g., IP routers and links).

[3.1.2. Inter-domain link Discovery](#)

In the reference network of Figure 1, there are two types of inter-domain links:

- o Links between two IP domains (ASes)
- o Links between an IP router and a ROADM

Both types of links are Ethernet physical links.

The inter-domain link information is reported to the MDSC by the two adjacent PNCs, controlling the two ends of the inter-domain link.

The MDSC can understand how to merge these inter-domain links together using the plug-id attribute defined in the TE Topology Model [[TE-TOPO](#)], as described in as described in [section 4.3](#) of [[TE-TOPO](#)].

A more detailed description of how the plug-id can be used to discover inter-domain link is also provided in section 5.1.4 of [[TNBI](#)].

Both types of inter-domain links are discovered using the plug-id attributes reported in the Ethernet Topologies exposed by the two adjacent PNCs. The MDSC can also discover an inter-domain IP link/adjacency between the two IP LTPs, reported in the IP Topologies exposed by the two adjacent P-PNCs, supported by the two ETH LTPs of an Ethernet Link discovered between these two P-PNCs.

Two options are possible to discover these inter-domain links:

1. Static configuration
2. LLDP [[IEEE 802.1AB](#)] automatic discovery

Since the static configuration requires an administrative burden to configure network-wide unique identifiers, the automatic discovery solution based on LLDP is preferable when LLDP is supported.

As outlined in [\[TNBI\]](#), the encoding of the plug-id namespace as well as of the LLDP information within the plug-id value is implementation specific and needs to be consistent across all the PNCs.

[3.2.](#) Provisioning of an IP Link/LAG over DWDM

In this scenario, the MSDC needs to coordinate the creation of an IP link, or a LAG, between two routers through a DWDM network.

It is assumed that the MSDC has already discovered the whole network topology as described in [section 3.1](#).

[3.2.1.](#) YANG models used at the MPIs

[3.2.1.1.](#) YANG models used at the Optical MPIs

The Optical PNC uses at least the following YANG models:

- o The TE Tunnel Model, defined in the "ietf-te" YANG module of [\[TE-TUNNEL\]](#)
- o The WSON Tunnel Model, defined in the "ietf-wson-tunnel" YANG modules of [\[WSON-TUNNEL\]](#), or the Flexi-grid Media Channel Model, defined in the "ietf-flexi-grid-media-channel" YANG module of [\[Flexi-MC\]](#)
- o The Ethernet Client Signal Model, defined in the "ietf-eth-tran-service" YANG module of [\[CLIENT-SIGNAL\]](#)

The TE Tunnel model is generic and augmented by technology-specific models such as the WSON Tunnel Model and the Flexi-grid Media Channel Model.

The WSON Tunnel Model or, alternatively, the Flexi-grid Media Channel Model are used to setup connectivity within the DWDM network depending on whether the DWDM optical network is based on fixed grid or flexible-grid.

The Ethernet Client Signal Model is used to configure the steering of the Ethernet client traffic between Ethernet access links and TE Tunnels, which in this case could be either WSON Tunnels or Flexi-Grid Media Channels. This model is generic and applies to any technology-specific TE Tunnel: technology-specific attributes are provided by the technology-specific models which augment the generic TE-Tunnel Model.

3.2.1.2. Required YANG models at the Packet MPIs

The Packet PNC uses at least the following topology YANG models:

- o The Base Network Model, defined in the "ietf-network" YANG module of [RFC8345] (see [section 3.1.1](#))
- o The Base Network Topology Model, defined in the "ietf-network-topology" YANG module of [RFC8345] (see [section 3.1.1](#))
- o The L3 Topology Model, defined in the "ietf-l3-unicast-topology" YANG modules of [RFC8346] (see [section 3.1.1.1](#))

If, as discussed in [section 3.2.2](#), IP Links created over DWDM can be automatically discovered by the P-PNC, the IP Topology is needed only to report these IP Links after being discovered by the P-PNC.

The IP Topology can also be used to configure the IP Links created over DWDM.

3.2.2. IP Link Setup Procedure

The MDSC requires the O-PNC to setup a WDM Tunnel (either a WSON Tunnel or a Flexi-grid Tunnel) within the DWDM network between the two Optical Transponders (OTs) associated with the two access links.

The Optical Transponders are reported by the O-PNC as Trail Termination Points (TTPs), defined in [TE-TOPO], within the WDM Topology. The association between the Ethernet access link and the WDM TTP is reported by the Inter-Layer Lock (ILL) identifiers, defined in [TE-TOPO], reported by the O-PNC within the Ethernet Topology and WDM Topology.

The MDSC also requires the O-PNC to steer the Ethernet client traffic between the two access Ethernet Links over the WDM Tunnel.

After the WDM Tunnel has been setup and the client traffic steering configured, the two IP routers can exchange Ethernet packets between themselves, including LLDP messages.

If LLDP [IEEE 802.1AB] is used between the two routers, the P-PNC can automatically discover the IP Link being setup by the MDSC. The IP LTPs terminating this IP Link are supported by the ETH LTPs terminating the two access links.

Otherwise, the MDSC needs to require the P-PNC to configure an IP Link between the two routers: the MDSC also configures the two ETH LTPs which support the two IP LTPs terminating this IP Link.

3.3. Provisioning of an IP link/LAG over DWDM with path constraints

MDSC must be able to provision an IP link with a fixed maximum latency constraint, or with the minimum latency available constraint within each domain but as well inter-domain when required (e.g. by monitoring traffic KPIs trends for this IP link). Through the O-PNC fixed latency path/minimum latency path is chosen between PE and ASBR in each optical domain. Then MDSC needs to select the inter-AS domain with less latency (in case we have several interconnection links) to have the right low latency constraint fulfilled end-to-end across domains.

MDSC must be able to automatically create two IP links between two routers, over DWDM network, with physical path diversity (avoiding SRLGs communicated by O-PNCs to the MDSC).

MDSC must be responsible to route each of this IP links through different inter-AS domain links so that end-to-end IP links are fully disjoint.

Optical connectivity must be set up accordingly by MDSC through O-PNCs.

3.3.1. YANG models used at the MPIs

This is for further study

3.4. Provisioning of an additional link member to an existing LAG with or without path constraints

For adding an additional link member to a LAG between two routers with or without path latency/diversity constraint. MDSC must be able

to force additional optical connection to use the same physical path in the optical domain where the LAG capacity increase is required.

3.4.1. YANG models used at the MPIs

This is for further study

4. Multi-Layer Recovery Coordination

4.1. Ensuring Network Resiliency during Maintenance Events

Before planned maintenance operation on DWDM network takes place, IP traffic should be moved hitless to another link.

MDSC must reroute IP traffic before the events takes place. It should be possible to lock IP traffic to the protection route until the maintenance event is finished, unless a fault occurs on such path.

4.2. Router port failure

The focus is on client-side protection scheme between IP router and reconfigurable ROADM. Scenario here is to define only one port in the routers and in the ROADM muxponder board at both ends as back-up ports to recover any other port failure on client-side of the ROADM (either on router port side or on muxponder side or on the link between them). When client-side port failure occurs, alarms are raised to MDSC by IP-PNC and O-PNC (port status down, LOS etc.). MDSC checks with OP-PNC(s) that there is no optical failure in the optical layer.

There can be two cases here:

- a) LAG was defined between the two end routers. MDSC, after checking that optical layer is fine between the two end ROADMs, triggers the ROADM configuration so that the router back-up port with its associated muxponder port can reuse the OCh that was already in use previously by the failed router port and adds the new link to the LAG on the failure side.

While the ROADM reconfiguration takes place, IP/MPLS traffic is using the reduced bandwidth of the IP link bundle, discarding lower priority traffic if required. Once backup port has been reconfigured to reuse the existing OCh and new link has been added to the LAG then original Bandwidth is recovered between the end routers.

Note: in this LAG scenario let assume that BFD is running at LAG level so that there is nothing triggered at MPLS level when one of the link member of the LAG fails.

- b) If there is no LAG then the scenario is not clear since a router port failure would automatically trigger (through BFD failure) first a sub-50ms protection at MPLS level :FRR (MPLS RSVP-TE case) or TI-LFA (MPLS based SR-TE case) through a protection port. At the same time MDSC, after checking that optical network connection is still fine, would trigger the reconfiguration of the back-up port of the router and of the ROADM muxponder to reuse the same OCh as the one used originally for the failed router port. Once everything has been correctly configured, MDSC Global PCE could suggest to the operator to trigger a possible re-optimisation of the back-up MPLS path to go back to the MPLS primary path through the back-up port of the router and the original OCh if overall cost, latency etc. is improved. However, in this scenario, there is a need for protection port PLUS back-up port in the router which does not lead to clear port savings.

5. Security Considerations

Several security considerations have been identified and will be discussed in future versions of this document.

6. Operational Considerations

Telemetry data, such as the collection of lower-layer networking health and consideration of network and service performance from POI domain controllers, may be required. These requirements and capabilities will be discussed in future versions of this document.

7. IANA Considerations

This document requires no IANA actions.

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9. Acknowledgments

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