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 Abstraction and Control of TE Networks (ACTN) architecture to Packet Optical Integration (POI)in the context of IP/MPLS and Optical internetworking, identifying the YANG data models being defined by the IETF to support this deployment architecture as well as specific scenarios relevant for Service Providers.

Existing IETF protocols and data models are identified for each multi-layer (packet over optical) scenario with particular focus on the MPI (Multi-Domain Service Coordinator to Provisioning Network Controllers Interface)in the ACTN architecture.

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# 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)(and optionally an Optical Transport Network (OTN)layer). 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 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).

ACTN framework enables this complete multi-layer and multi-vendor integration of packet and optical networks through MDSC and packet and optical PNCs.

In this document, key scenarios for Packet Optical Integration (POI) are described from the packet service layer perspective. The objective is to explain the benefit and the impact for both the packet and the optical layer, and to identify the required coordination between both layers. Precise definitions of scenarios can help with achieving a common understanding across different disciplines. The focus of the scenarios are IP/MPLS networks operated as client of optical DWDM networks. The scenarios 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 (and optionally OTN layer), in an end-to-end multi-vendor service provisioning perspective.

# Reference architecture and network scenario

This document analyses a number of deployment scenarios for Packet and Optical Integration (POI) in which ACTN hierarchy is deployed to control a multi‑layer and multi-domain network, with two Optical domains and two Packet domains, as shown in Figure 1:

+----------+

| MDSC |

+-----+----+

|

+-----------+-----+------+-----------+

| | | |

+----+----+ +----+----+ +----+----+ +----+----+

| P-PNC 1 | | O-PNC 1 | | O-PNC 2 | | P-PNC 2 |

+----+----+ +----+----+ +----+----+ +----+----+

| | | |

| \ / |

+-------------------+ \ / +-------------------+

CE / PE ASBR \ | / / ASBR PE \ CE

o--/---o o---\-|-------|--/---o o---\--o

\ : : / | | \ : : /

\ : AS Domain 1 : / | | \ : AS Domain 2 : /

+-:---------------:-+ | | +-:---------------:--+

: : | | : :

: : | | : :

+-:---------------:------+ +-------:---------------:--+

/ : : \ / : : \

/ o...............o \ / o...............o \

\ Optical Domain 1 / \ Optical Domain 2 /

\ / \ /

+------------------------+ +--------------------------+

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 ABSR 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, using YANG‑based service models, such as L2SM [RFC8466] and L3SM [RFC8299].

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

* 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;
* Inter-domain links exist only between Packet domains (i.e., between ASBR routers) and between Packet and Optical domains (i.e., between routers and Optical NEs). In other words, there are no inter-domain links between Optical domains;
* The interfaces between the Routers and the Optical NEs are “Ethernet” physical interfaces;
* The interfaces between the ASBR routers are “Ethernet” physical interfaces.

This version of the document assumes that the IP Link supported by the Optical netork are always intra-AS (PE-ASBR, PE-P or P-P) and that the ASBRs are co-located and connected by an IP Link supported by an Ethernet physical link.

The possibility to setup inter-AS IP Links (e.g., ASBR-ASBR or PE-PE), supported by Optical network, is for further study.

Therefore, if inter-domain links between the Optical domains exist, they would be used to support multi-domain Optical services, which are outside the scope of this document.

The Optical NEs within the optical domains can be ROADMs or OTN switches, with or without a ROADM.

## 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. Extensions to RESTCONF, as defined in [RFC8527], to be compliant with Network Management Datastore Architecture (NMDA) defined in [RFC8342], are assumed to be used as well at these MPI interfaces and also at CMI 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.

## L2/L3VPN/VN Service Request by the Customer

A customer can request L2/L3VPN services with TE requirements using ACTN CMI models (i.e., ACTN VN YANG, TE & Service Mapping YANG) and non-ACTN customer service models such as L2SM/L3SM YANG together. Figure 2 shows detailed control flow between customer and service/network orchestrator to instantiate L2/L3VPN/VN service request.

Customer

+-------------------------------------------+

| +-----+ +------------+ |

| | CNC |--------------| Service Op.| |

| +-----+ +------------+ |

+-------|------------------------|----------+

2. VN & TE/Svc | | 1.L2/3SM

Mapping | | |

| | ^ | |

| | | | |

v | | 3. Update VN | v

| & TE/Svc |

Service/Network | mapping |

Orchestrator | |

+------------------|------------------------|-----------+

| +----------------------------------+ | |

| |MDSC TE & Service Mapping Function| | |

| +----------------------------------+ | |

| | | | |

| +------------------+ +---------------------+ |

| | MDSC NP Function |-------|Service Config. Func.| |

| +------------------+ +---------------------+ |

+-------|-----------------------------------|-----------+

NP: Network Provisioning

1. Service Request Process

* ACTN VN YANG provides VN Service configuration, as specified in [ACTN-VN].
  + It provides the profile of VN in terms of VN members, each of which corresponds to an edge-to-edge link between customer end-points (VNAPs). It also provides the mappings between the VNAPs with the LTPs and between the connectivity matrix with the VN member from which the associated traffic matrix (e.g., bandwidth, latency, protection level, etc.) of VN member is expressed (i.e., via the TE-topology’s connectivity matrix).
  + The model also provides VN-level preference information (e.g., VN member diversity) and VN-level admin-status and operational-status.
* L2SM YANG [RFC8466] provides all L2VPN service configuration and site information from a customer/service point of view.
* L3SM YANG [RFC8299] provides all L3VPN service configuration and site information from a customer/service point of view.
* The TE & Service Mapping YANG model [TE & Service] provides TE-service mapping as well as site mapping.
  + TE-service mapping provides the mapping of L3VPN instance from [RFC8299] with the corresponding ACTN VN instance.
  + The TE-service mapping also provides the service mapping requirement type as to how each L2/L3VPN/VN instance is created with respect to the underlay TE tunnels (e.g., whether the L3VPN requires a new and isolated set of TE underlay tunnels or not, etc.). See Section 2.3. for detailed discussion on the mapping requirement types.

Site mapping provides the site reference information across L2/L3VPN Site ID, ACTN VN Access Point ID, and the LTP of the access link.

## Service and Network Orchestration

The Service/Network orchestrator shown in Figure 2 interfaces the customer and decouples the ACTN MDSC functions from the customer service configuration functions.

An implementation can choose to split the Service/Network orchestration functions, as described in [RFC8309] and in section 4.2 of [RFC8453], between a top-level Service Orchestrator interfacing the customer and two low-level Network Orchestrators, one controlling a multi-domain IP/MPLS network and the other controlling the Optical networks.

Another implementation can choose to combine the L-MDSC functions of the Optical hierarchical controller, providing multi-domain coordination of the Optical network together with the MDSC functions in the Service/Network orchestrator.

One of the important service functions the Service/Network orchestrator performs is to identify which TE Tunnels should carry the L3VPN traffic (from TE & Service Mapping Model) and to relay this information to the IP/MPLS domain controllers, via non-ACTN interface, to ensure proper IP/VRF forwarding table be populated according to the TE binding requirement for the L3VPN.

***[Editor’s Note]*** *What mechanism would convey on the interface to the IP/MPLS domain controllers as well as on the SBI (between IP/MPLS domain controllers and IP/MPLS PE routers) the TE binding policy dynamically for the L3VPN? Typically, VRF is the function of the device that participate MP-BGP in MPLS VPN. With current MP-BGP implementation in MPLS VPN, the VRF’s BGP next hop is the destination PE and the mapping to a tunnel (either an LDP or a BGP tunnel) toward the destination PE is done by automatically without any configuration. It is to be determined the impact on the PE VRF operation when the tunnel is an optical bypass tunnel which does not participate either LDP or BGP.*

Figure 3 shows service/network orchestrator interactions with various domain controllers to instantiate tunnel provisioning as well as service configuration.

+-------|----------------------------------|-----------+

| +----------------------------------+ | |

| |MDSC TE & Service Mapping Function| | |

| +----------------------------------+ | |

| | | | |

| +------------------+ +---------------------+ |

| | MDSC NP Function |-------|Service Config. Func.| |

| +------------------+ +---------------------+ |

+-------|------------------------------|---------------+

| |

| +-------------------+------+ 3.

2. Inter-layer | / \ VPN Serv.

tunnel +-----+--------/-------+-----------------+ \provision

binding| / | 1. Optical | \

| / | tunnel creation | \

+----|-----------/-+ +---|------+ +-----|-------\---+

| +-----+ +-----+ | | +------+ | | +-----+ +-----+|

| |PNC1 | |Serv.| | | | PNC | | | |PNC2 | |Serv.||

| +-----+ +-----+ | | +------+ | | +-----+ +-----+|

+------------------+ +----------+ +-----------------+

1. Service and Network Orchestration Process

TE binding requirement types [TE-service mapping] are:

1. Hard Isolation with deterministic latency: Customer would request an L3VPN service [RFC8299] using a set of TE Tunnels with a deterministic latency requirement and that cannot be not shared with other L3VPN services nor compete for bandwidth with other Tunnels.
2. Hard Isolation: This is similar to the above case without deterministic latency requirements.
3. Soft Isolation: Customer would request an L3VPN service using a set of MPLS-TE tunnel which cannot be shared with other L3VPN services.
4. Sharing: Customer would accept sharing the MPLS-TE Tunnels supporting its L3VPN service with other services.

For the first three types, there could be additional TE binding requirements with respect to different VN members of the same VN associated with an L3VPN service. For the first two cases, VN members can be hard-isolated, soft-isolated, or shared. For the third case, VN members can be soft-isolated or shared.

* When “Hard Isolation with or w/o deterministic latency” (i.e., the first and the second type) TE binding requirement is applied for a L3VPN, a new optical layer tunnel has to be created (Step 1 in Figure 3). This operation requires the following control level mechanisms as follows:
  + The MDSC function of the Service/Network Orchestrator identifies only the domains in the IP/MPLS layer in which the VPN needs to be forwarded.
  + Once the IP/MPLS layer domains are determined, the MDSC function of the Service/Network Orchestrator needs to identify the set of optical ingress and egress points of the underlay optical tunnels providing connectivity between the IP/MPLS layer domains.
  + Once both IP/MPLS layers and optical layer are determined, the MDSC needs to identify the inter-layer peering points in both IP/MPLS domains as well as the optical domain(s). This implies that the L3VPN traffic will be forwarded to an MPLS-TE tunnel that starts at the ingress PE (in one IP/MPLS domain) and terminates at the egress PE (in another IP/MPLS domain) through the ASBRs. ~~via a dedicated underlay optical tunnel.~~
* The MDSC function of the Service/Network Orchestrator needs to first request the optical L-MDSC to instantiate an optical tunnel for the optical ingress and egress in each optical domain. This is referred to as optical tunnel creation (Step 1 in Figure 3). ~~Note that it is L-MDSC responsibility to perform multi-domain optical coordination with its underlying optical PNCs, for setting up a multi-domain optical tunnel.~~
* Once the optical tunnel is established, then the MDSC function of the Service/Network Orchestrator needs to coordinate with the PNC functions of the IP/MPLS Domain Controllers (under which the ingress and egress PEs belong) the setup of a multi-domain MPLS-TE Tunnel, between the ingress and egress PEs. ~~This setup is carried by the created underlay optical tunnel (Step 2 in Figure 4).~~

It is the responsibility of the Service Configuration Function of the Service/Network Orchestrator to identify interfaces/labels on both ingress and egress PEs and to convey this information to both the IP/MPLS Domain Controllers (under which the ingress and egress PEs belong) for proper configuration of the L3VPN (BGP and VRF function of the PEs) in their domain networks (Step 3 in Figure 3).

## IP/MPLS Domain Controller and NE Functions

To be added

## Optical Domain Controller and NE Functions

To be added

# Multi-layer and multi-domain services scenarios

To be added

## Scenario 1: network and service topology discovery

To be added

## Scenario 2: L3VPN/L2VPN establishment

To be added

# Security Considerations

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

# 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.

# IANA Considerations

This document requires no IANA actions.

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1. Multi-layer and multi-domain resiliency
   1. Maintenance Window

To be added

* 1. Router port failure

To be added

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