TELECOM INFRA PROJECT

MANTRA Whitepaper

IPoWDM convergent SDN architecture - Motivation, technical definition & challenges

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1. Introduction

New transport network architectures are becoming increasingly interesting for telecom operators to drive lower CAPEX into the next generation of network deployments. These are three major technology innovations that allow a possible paradigm shift:

- The development of next-generation 400G coherent pluggable transceivers in QSFP-DD form factor with increased transmission range is enabling integrated IPoWDM solutions to replace traditional transponders/muxponder devices.
- These new coherent pluggable modules are becoming interoperable through the 100-400G single wavelength optical port definitions addressed by multi-source agreements such, as OIF 400ZR [2], OpenROADM MSA [3] and OpenZR+ [4], and common implementation agreements for the management interface between the router and the coherent transceiver pluggable such, OIF IA-CMIS [5] and TIP TAI [6]. This interoperability allows a plug-and-play business model for the coherent pluggable market.
- The optical disaggregation, enabled by the SDN open and standard management interfaces for the optical transport networks, allows DWDM channels to be transmitted by third-party Open Optical Terminals (O-OTs) over a different supplier Open Optical Line Systems (O-OLS).

The Open Optical & Packet Transport group (OOPT) is a project group within the Telecom Infra Project (TIP) that works on the definition of open technologies, architectures, and interfaces in optical and internet protocol (IP) networking. The primary aim of the OOPT group is to focus directly and contextually on enabling operators to plan and deploy disaggregated, open systems across a wide span of their infrastructure.

MANTRA (Metaverse ready Architectures for Open Transport) former CANDI, is a new full-rebranded subgroup of OOPT, aiming at constructing an end-to-end reference network architecture, to evolve from monolithic/aggregated to multi-vendor disaggregated Open Optical Networks (OON). We are enabling also, a new generation of IPoWDM networks based on IP routers equipped with 400G (and beyond) coherent pluggable transceivers.

In this whitepaper, we explore the opportunities, use cases, and challenges of IP/Optical convergence through IP-over-WDM capable routers and we highlight the main objectives of the MANTRA Operator's signing this whitepaper.

1.1 IP-over-WDM concept definition

The central concept of this whitepaper is the IP-over-WDM architecture based on the integration of the coherent optical transceivers or Optical Line Interfaces (OLIs) into the IP router equipment.

This integration occurs in the new generation of coherent pluggable optics products which extends the range of optical WDM-based transmission beyond the current distances provided by the grey interfaces, which typically transmit over short optical spans of less than 40km or 80km in the best cases, without wavelength multiplexing capabilities.

IPoWDM capable routers are the term used here to refer to the IP equipment which integrates these coherent transceivers directly into their backplane within the same chassis and provides standalone management for both the IP and optical WDM channels.

Figure 1, illustrates the comparison between the IP and Optical traditional network architecture including dedicated optical transponder/muxponder network elements and the target IPoWDM architecture.

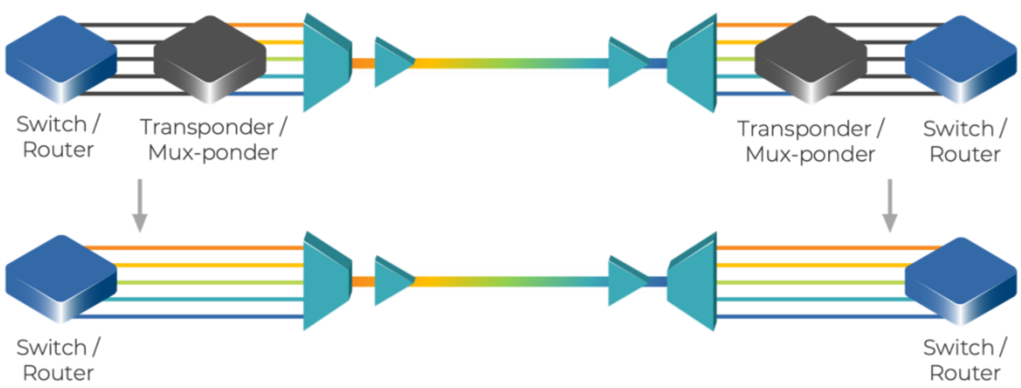

Figure 1. Traditional versus IPoWDM network architecture.

1.2 Operator's motivation

The primary motivation for the IP/Optical integration is to reduce the number of elements in the whole transmission chain that need to be planned, installed, managed, and maintained. On one hand, it can eliminate intermediate transponder/muxponder, on the other hand, the "grey" client transceivers interconnecting switches or routers and transponder/muxponders can be eliminated.

The main drivers to adopt the integration of 3rd party vendor coherent pluggable in the IP/MPLS routers are:

- CAPEX savings for capacity growth by removing the "grey" interconnection with the WDM transponders where reach/performance allow it (Metro and Regional spans today)
- Reduce equipment footprint and power consumption.
- Secure supply chain by enabling vendor interoperability between routers and coherent pluggable modules, thus reducing dependency on a single vendor in the coherent transmission market.
- Foster innovation by picking up the latest coherent pluggable vs targeted scenarios (in terms of power consumption, capacity, spectral efficiency, reach, etc.)
- Simplified network architecture and enhanced automated discovery, service mapping, and deployment functions enabled by the Hierarchical SDN architecture.
- IP-Optical integration can be used to optimize the protections in the different domains of the network (IP+Optical), avoiding over-provisioning of resources.

TIP's mission is to be able to assure a healthy open (and possibly disaggregated ecosystem) in the IPoWDM router market in the next years.

1.3 Terminology

In this document the following terms are employed with the definitions specified below:

- **IPoWDM**: IP-over-Wavelength Division Multiplexing. This concept refers to a network architecture where independent transponder/muxponder network elements are suppressed in favor of routers equipped with integrated coherent transceiver modules (either as pluggable modules or fixed modules).
- **Open**: Generally, when this term is prefixed to a target (e.g., an Open Line System, O-OLS), it implies that the target (system, piece of equipment, software (SW), network function, etc.) exposes interfaces, often Application Programming Interfaces (API), with a well-known and standard protocol, model and rules for use for the integration by the Operators in their networks and OSS/BSS systems. These interfaces are specified by MUST. The specific meaning of this attribute, as applied to an architectural component, is clarified, and extended in the relevant specific chapters within this document.

- **Open-Optical Line System (O-OLS**): a complete and autonomously managed optical transport network also supporting (together with digital clients), or exclusively supporting optical analogical DWDM channels as clients. In the context of this document, the term “open” refers to the fact that an O-OLS allows, as analogical clients, any signal which follows a given behavior, specified by the O-OLI definition in this document. It exposes an open and standard-based programmable NBI (such as per the implementation proposed by TIP MUST [ref]).
- **Optical Terminal (OT):** in the context of this document, the term designates a category of NEs in an Optical Transport Network, including the network functions of Transponders (1:1 mapping of clients to line side interfaces); Muxponders (N:1 mapping and multiplexing); Switchponders (N: M mapping, digital switching, and multiplexing). Their role is to adapt digital clients of the Optical Transport Network over DWDM channels. Sometimes, in the document, the term ‘Legacy Terminal’ is used instead of Optical Terminal to refer to the same.
- **Open-Optical Terminal (O-OT):** this term as defined in this paper, extends the definition of Optical Terminal to all the categories of devices housing Open Optical Line Interfaces (O-OLIs), which fulfills the set of requirements, also included in this document. In summary, these are the support of Open and Standard management interfaces; the standalone deployment and management, independently from the Open Optical Line System (O-OLS). An O-OT adapts digital clients and generates one or more “alien wavelength” optical DWDM channels to be transparently transported by one, or a chain of O-OLS.
- **Open-Optical Line Interface (O-OLI**): in the context of “partial disaggregation”, an O-OLI specifies the physical and logical single optical DWDM channel interface between O-OTs or IP routers, and the O-OLS. An O-OLI is therefore the functional and administrative demarcation point between an O-OLS and the set of O-OTs generating the analogical “alien wavelength” channels. O-OLI provides all the required physical, control, and management information to allow and adapt “alien wavelengths” and possible OTN capabilities over the O-OLS for the aggregated optical transport network.
- **Open-Planning and Impairment Validation (O-PaIV):** an open planning functionality that provides: (1) OLS network design and (2) verification of EoL margins for connections (wavelengths) between optical line interfaces. This definition implies that any third party can perform (1) and (2) since necessary data is shared by the O-OLS and the O-OLI vendors.
- **Small Form-factor Pluggable (SFP):** compact, hot-pluggable network interface module that can be plugged into network devices/servers.
- **Transport Abstraction Interface (TAI):** The Transponder Abstraction Interface, or TAI, defines the API to provide a form-factor/vendor-independent way of controlling transponders and transceivers from various vendors and implementations in a uniform manner. For further information go to: https://github.com/Telecominfraproject/oopt-tai

- **Common Management Interface Specification (CMIS)**: Interface, initially defined by the QSFP-DD Multi-Source Agreement and currently as a work item of OIF, to communicate between a QSFP-DD pluggable and a network device.

2. Challenges

Despite the potential benefits, IP/Optical integration faces several challenges that have prevented its widespread adoption. Currently, packet-optical integration is only adopted in point-to-point links over dark fiber or passive optical networks without any management or control plane.

In the last decade, the interaction (management and operation) between a pluggable and a router required either adaptation of the pluggable interface to each router or developing a specific driver in the router. Therefore, the integration depended on the willingness of router and pluggable vendors to cooperate. Today some standardizations and open source initiatives are trying to address this integration, such as OIF IA–CMIS 5.2 [5] and TIP TAI [6], however, these standards will go through several new releases until becoming mature and their adoption may be slow.

Even the packet optical integration has been there for more than 10 years, it has not been widely adopted in Telco networks due to several reasons:

- Impact on IP routers dimensioning. The port density was impacted by the available IP-colored cards.
- Operational complexity, currently in the whole telco industry. The IP and the Optical transport domains are managed independently, by separate departments with scarce interactions between them.
- A gap has traditionally existed in the transmission rates, between routers' interfaces and optical transponders/muxponders.
- Lack of availability of the complete performance and fault management capabilities in the pluggable in the router (e.g., pre-FEC BER).

While some of these challenges (such as the transmission rate gap) have been overcome with the new generation of 400G QSFP-DDs coherent pluggable modules, there are still other challenges that are still present:

- Full multi-layer IP over Optical manageability for auto-commissioning, end-to-end visibility, and performance monitoring and troubleshooting over the OLS network is required for the target solution. These features are not yet assumed by state-of-the-art IP SDN Controllers solutions.

- Coherent pluggable parameters to be embedded in current and future optical planning tools (either proprietary solutions from current OLS incumbent vendors and/or open-source planning tools like GNPy [11]). Standard libraries to expose optical coherent transmission performance metrics such as minimum required OSNR on the receiver side needs to be implemented (see OpenConfig [13] and IETF [14] works).

- Current limitations of ZR and ZR+ families vs WDM transponders:
    - Today only Ethernet client types supported.
    - The power consumption of coherent pluggable in IPoWDM routers is still a limiting factor to achieve the same port density as traditional routers. The power consumption of these pluggable transceivers, typically 17.5 W for 400ZR and up to 20 W for 400ZR+, exceeds the defined power rating of 14.5 W for QSFP-DD ports [12].
    - Limited transmission performance due to the low output power of current available ZR+ products compared to traditional standalone transponder/muxponders.
    - C-Band support (4THz) vs extended C-band (4,8THz) in WDM transponders, L-band coherent pluggable availability.
    - The optical performance of the ZR and ZR+ modules cannot compete with the WDM transponders of leading vendors in the market, especially in long-haul applications.

3. Technical scope definition

The technical scope to be considered as part of the evaluation of MANTRA IPoWDM activity is summarized in this section. The IPoWDM scenarios considered shall accommodate the following requirements:

- The IPoWDM router must provide an open and standard SDN interface for control, management, and monitoring functions.
- The IPoWDM router must assure interoperability with multiple vendor coherent transceivers to avoid vendor lock-in.
- The focus is on disaggregated O-OLS-based scenarios (Metro, Long Haul) where coordination between the IP and the Optical transport domain is needed.
- The applicable network scenarios are not constrained here, the objective is to evaluate this technology over any possible scenario such as P2P or ROADM based, and any feasible distances allowed by the transmission capabilities of the coherent transceiver modules.

3.1 Use Cases

As an initial input, the following use cases are considered to be evaluated through the IPoWDM scenarios proposed in this whitepaper.

1. DWDM network planning (including physical impairment validation) for IPoWDM-based services.
2. Convergent IP and Optical multi-layer service planning and optimization (avoid redundant protection in both layers).
3. L2 (Ethernet) over L1/L0 Service life-cycle management.
4. Dynamic reconfiguration of line transmission modes to adjust to changes in the O-OLS media-channel path constraints (due to a channel degradation or a dynamic restoration).
5. Multi-layer topology and service mapping. To allow convergence on the hierarchical controller level.
6. Restoration of DWDM optical layer. How to preserve optical restoration over this new architecture.
7. The dynamic control loop of line transmission optical parameters (power, central-frequency, admin-state) for different failure conditions including O-OLS coordination.
8. Fault and performance monitoring of services, including streaming telemetry.
9. IPoWDM routers and DWDM O-OLS links connectivity verification and if possible, autodiscovery, functions should be assured. The goal should be to avoid manual intervention in the network creation process.

3.2 Target SDN Architecture

In this section, the characteristics/requirements to be fulfilled by the target architecture are described and discussed through the high-level definition of two possible proposals that the MANTRA project is open to discussing with vendors and other members of the TIP community.

Above the concrete proposals discussed later in the section, the following characteristics should be the primary design guidelines of the target architecture:

- IP and DWDM network domains have remained separated from the management perspective. Current management and SDN architectures deployed must be compatible (to some extent) with the introduction of the IPoWDM paradigm shift. For example, end-to-end DWDM channels transmitted by traditional transponders/muxponders, O-OT, or IPoWDM capable routers shall co-exist on the same management systems, network visualization, and fault and performance management systems.
- The SDN solutions foreseen must rely on the standard and open interfaces.
- Out-of-sync problem **-** if two controllers are configuring the router at the same time, the configuration database at the controllers can go often to an out-of-sync state, and typically the recovery time spans from several seconds to minutes, to reconverge at the SDN Controller level.
- Open Network planning by the exposure of operational-modes capabilities.
- Define and validate the hierarchical SDN architecture to provide full management (provisioning, performance monitoring, troubleshooting, alarms, and inventory) of coherent pluggable in IP/MPLS routers over existing optical OLS networks (brownfield scenarios)

3.2.1 Proposal 1 – Dual SBI management of IPoWDM routers

The first proposal is summarized in this section. The main characteristic is that the management of the IPoWDM routers is shared among the IP and the Optical SDN Controllers.

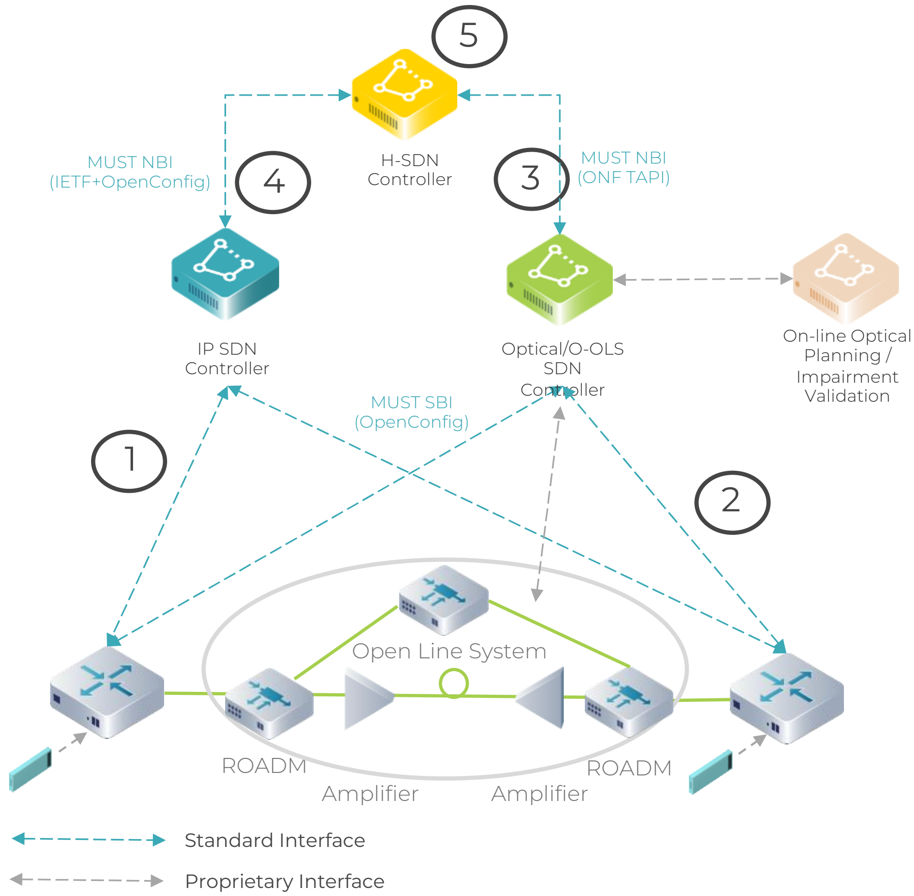

Figure 2. Dual SBI management of IPoWDM routers.

1. **IP SDN Controller SBI** – The IP SDN Controller is the only entity configuring IPoWDM routers including coherent pluggable. These are mainly four parameters right now defined at OpenConfig: target-central-frequency, target-output-power, operational-mode, admin-state on/off.
2. **Optical/O-OLS SDN Controller SBI** – The Optical/O-OLS SDN Controller is granted with read-only permissions to avoid the out-of-synch issue (data access permissions need to be implemented in the router management level to not allow configuration to any other entity but the IP SDN Controller) for the IPoWDM router's configuration/state data to perform:
    a. <u>Device discovery</u> - through gNMI or NETCONF, to poll or stream configuration, state and static capabilities/properties data from the O-OLI interfaces in IPoWDM routers.

   b. Performance Monitoring – through gNMI to periodically poll/stream performance counters of the O-OLI interface associated with the OTSi service.

   c. Fault management – through gNMI/NETCONF to receive asynchronous notifications about alarms.

3. **The Optical/O-OLS SDN controller NBI** shall expose, path-computation (for OTSi services planning) and service provisioning services for OLS media channel services. In this case, the O-OLI information is already consolidated by the Optical/O-OLS SDN controller into the topology and service database. This allows end-to-end OTSi service planning by the optical layer.

   a. Network Planning:

      i. To compute optical impairments associated to the end-to-end OTSi service, considering the available transmission modes available at the O-OLI interface of the IPoWDM pluggable in the router.

      ii. [Alternatively] this computation can be delegated to a third-party online planning and Impairment validation tool (e.g., GNPy).

      iii. *Result 1* – IPoWDM Router coherent interface target configuration: selected central-frequency, target-output power, selected operational-mode.

      iv. *Result 2* – Open Line System (OLS) Media-channel (MC) service target configuration: MC service end-points (Add/Drop ports), media-channel target power equalization (expected input power received at add ports and intended output power to be delivered in the drop ports), and the target explicit route constrains.

   b. O-OLS Service provisioning API for Media Channel (MC) services with explicit constrains allowed (i.e., target power equalization constrains and target explicit route). The Optical SDN Controller will be requested to create the MC with some constraints related to the O-OLI interface connected to the target Add/Drop ports.

   c. Performance and fault management of IPoWDM alien services, remains responsibility of the Optical/O-OLS SDN Controller. They shall be managed as any other service initiated by transponder/muxponder solutions managed by the controller.

4. **The IP SDN Controller NBI** shall expose the optical line interface O-OLI configuration API.

5. **The H-SDH Controller** shall be able to orchestrate the whole workflow (other alternatives can be explored).

3.2.2 Proposal 2 – Single SBI management of IPoWDM routers

This second proposal assumes the IP SDN Controller as the only entity which directly interfaces with the IPoWDM routers and implements all management capabilities. This approach impacts the IP SDN Controller's NBI which needs to expose O-OLIs physical impairment and performance data, including transmission mode's capabilities, such as required OSNR, and tolerable TX and RX power levels, required for the Optical Channel network planning, in addition to the above-mentioned O-OLI configuration API.

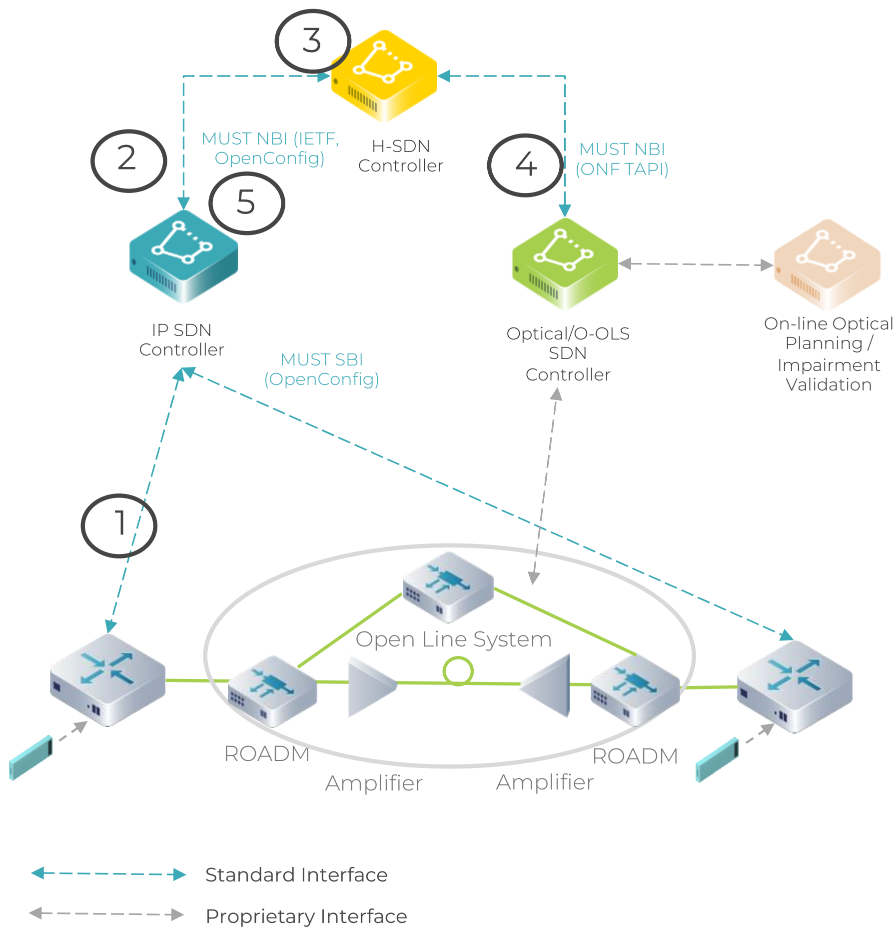

Figure 3. Single SBI management of IPoWDM routers.

1. **IP SDN Controller SBI :**
    a. O-OLI configuration - The IP SDN Controller is the only entity in configuring IPoWDM routers including coherent transceivers. As in proposal 1, these are mainly 4 parameters right now defined at OpenConfig : target-central-frequency, target-output-power, operational-mode, admin-state Up/Down.
    b. Device discovery - through gNMI or NETCONF, to expose/notify configuration, state and static capabilities/properties data from the O-OLI interfaces in IPoWDM routers.
    c. Performance monitoring - through gNMI to periodically stream performance counters of the O-OLI interface in IPoDWDM routers.
    d. Fault management – through gNMI/NETCONF to receive asynchronous notifications about alarms.
2. **IP SDN Controller NBI :**
    a. Device discovery – The IP SDN Controller shall expose the O-OLI interface capabilities. This might be exposed through a multi-layer TE topology information through IETF models (e.g. draft-ietf-ccamp-dwdm-if-param-yang-06 or draft-ietf-ccamp-optical-impairment-topology-yang-09 [14])
    b. Performance monitoring - the IP SDN Controller will expose the O-OLI performance metrics and the alarms. gNMI/gRPC or notification buses (e.g., Kafka) might be the preferred solutions to allow streaming telemetry in North Bound of the IP SDN controller
    c. Fault management – through gNMI/NETCONF to receive asynchronous notifications about alarms.
3. **The H-SDN SDN controller functions :**
    a. Discovery of O-OLI interfaces capabilities in each IP routers through RESTCONF and IETF data models used between IP SDN Controller and Hierarchical SDN controller (e.g. draft-ietf-ccamp-dwdm-if-param-yang-06 or draft-ietf-ccamp-optical-impairment-topology-yang-09 [14])
    b. Multi-layer topology and service model – consolidation of the l3/L0 network and service model where the correlated information from IP and Optical domains will be consolidated.
    c. Service provisioning - when a new multi-layer service needs to be provisioned the H-SDN Controller will try to setup the maximum delivered capacity of the O-OLI into the Optical network. To do so, the end-to-end

OTSi service shall be computed including the physical impairment validation. This computation can be done by the H-SDN or delegated to the Optical/O-OLS SDN Controller. In the latter case, the H-SDN shall be able to introduce the O-OLI interface target transmission mode's details to the Optical/O-OLS Controller through the NBI.

d. Performance monitoring and alarm management: multi-layer link between the IPoWDM routers shall be managed and monitored by Hierarchical SDN controller in proposal as it is the only entity to receive both performance and alarm information from IP SDN Controller(for O-OLI interfaces) and from Optical/O-OLS SDN Controller (for O-OLS Network Media Channel supporting the end-to-end OTSi signal).

4. **Optical/O-OLS SDN Controller NBI –** NBI is based on RESTCONF ONF T-API as described in details in [1][8]. Since the O-OLI interface is not commissioned through the Optical/O-OLS SDN controller SBI, the NBI shall provide, as a target, a path computation API which allows to provide the required O-OLI interface details for the end-to-end OTSi path computation and impairment validation. Interim solution could be based on O-OLI interface maximum capacity based on a trial and error approach between Hierarchical SDN Controller and Optical/O-OLS SDN Controller

   a. Network Planning and Path computation:

      i. To compute optical impairments associated to the end-to-end OTSI service, considering the available transmission modes available at the O-OLI interface of the IPoWDM router.

      ii. [Alternatively] this computation can be delegated to a third-party on-line planning and Impairment validation tool (e.g., GNPy).

      iii. **Result 1** - IPoWDM Router coherent interface target configuration: selected central-frequency, target-output power, selected operational-mode is sent by Hierarchical SDN Controller to the IP SDN Controller and configured in the IPoWDM router through Openconfig.

      iv. **Result 2 -** Open Line System (OLS) Media-channel (MC) service target configuration: MC service end-points (Add/Drop ports), media-channel target power equalization (expected input power received at add ports and intended output power to be delivered in the drop ports), and the target explicit route constraints.

   b. O-OLS Service provisioning using ONF T-API [ref] between Hierarchical SDN Controller and Optical/O-OLS SDN Controller for Media Channel (MC) services with explicit constraints allowed (i.e., target power equalization constraints and target explicit route)between the target source and destination Add/Drop ports.

5. **The IP SDN Controller NBI** shall expose the optical line interface O-OLI configuration API.

   c. O-OLI configuration – The IP SDN Controller NBI shall expose the optical line interface O-OLI configuration API (RESTCONF with IETF data models). Since the service planning depends on the Optical layer, the H-SDN Controller must be able to configure the O-OLI according to the selected optical media-channel characteristics (central-frequency, in/out power constrains, target operational mode given the distance and impairments computation).

3.3 Open IPoWDM-capable router definition

In this section the intention is to summarize the characteristics which MANTRA project foreseen for the so-called IPoWDM capable routers.

1. Open Pluggable market. Open hardware abstraction layer for coherent transceivers shall be consolidated as part of the IPoWDM solution's development. OIF-IA-CMIS [5] and TIP TAI [6] are promising candidates which may pave the way for industry convergence.
2. Convergence IP over Optical open control and management. The management interface shall properly integrate from the physical layer to the IP. Currently OpenConfig seems the most promising SDN data model which consolidates this IPoWDM network stack to model this new category of routers.
3. Open data for network planning and impairment validation. Device manifest information including DWDM transmission mode such physical performance metrics and threshold levels, shall be open and available through the standard router device management interface.
4. Non-bookended solution through standard transmission modes is highly desirable to simplify the network architecture.

4. PoC Objectives and expected results

This whitepaper has introduced the MANTRA TIP OOPT sub-groups motivation to address the evaluation of the IPoWDM impact on the management SDN architecture. The main objective of this whitepaper is to define the open-ended questions to answer through the assessment of the possible implementation alternatives highlighted in the previous sections.

In summary, the main objective is to define the target SDN architecture to support optical and packet management of IPoWDM within the already defined partially disaggregated open optical architecture [1]. This architecture should be defined that supports the target use cases defined in Section 2.2, clarifying the responsibility matrix between the Optical/O-OLS and the IP SDN domain controllers. The proposals and feasible alternatives presented by the TIP community will be validated within a PoC to verify maturity and gaps.

The proposed SDN architectures need to address the proposed use cases by supporting the technical requirements defined in MUST [7][8][9]. The proposed solutions must support the MUST IP and Optical defined Southbound Interfaces (SBI) to manage the IPoWDM routers using NETCONF/gNMI OpenConfig-based implementations, and the integration with the Hierarchical SDN controller and upper OSS systems through the standard northbound interfaces (NBIs).

A short list of the high-level objectives the MANTRA sub-group is trying to achieve with this PoC is:

- Define the target roles and responsibilities of Hierarchical controllers and Optical and IP SDN domain Controllers to manage networks including IPoWDM capable routers over O-OLSs.
- Define and validate the workflows for the defined use cases proposed. A comparison between the implementation complexity and availability in the market between the architectural choices proposed and maybe other proposals is one of the major accomplishments targeted by this activity.
- Guarantee interoperability between routers and third-party coherent pluggable modules. Evaluate real industry trends and coordinate a clear path forward for the industry to follow.
- Beyond this PoC, operators will be interested in techno-economic analysis studies that evaluate the acceptable (from the economic perspective) capacity reduction

on the IPoWDM-capable routers equipped with coherent colored interfaces compared with traditional routers with grey interfaces.

Following the first implementation proposal (Figure 2) to the proof-of-concept phase, the objectives would be:

- Evaluate a solution consistent with the current separation between IP and Optical layers management, The separation between layers will need to be effectively implemented through the access control to IPoWDM routers' configuration datastores.
- Define the workflows to guarantee effective configuration of the IPoWDM coherent transceiver modules through the IP SDN Controller northbound interface, based on the optical network planning results. The responsiveness of the hierarchical control solution would be especially critical in dynamic scenarios such as an optical restoration use case.

Through the evaluation of the second implementation proposal, the objectives to achieve would be:

- Confirm that IP/MPLS SDN domain controller SBI can re-use NETCONF/OpenConfig for provisioning and gNMI/OpenConfig protocols and data models for PMs and alarms recommended in optical O-OLS partial disaggregation
- Define and validate the interface protocol (e.g. RESTCONF) and the data model(s) to be used in IP/MPLS SDN domain controller NBI to expose coherent pluggable capabilities (discovery) to Hierarchical SDN controller (e.g. draft-ietf-ccamp-dwdm-if-param-yang-06 or draft-ietf-ccamp-optical-impairment-topology-yang-09).
- Define and validate the workflows to set-up a new service between two or more routers (e.g., L3VPN) requiring the creation of a new optical path over the OLS network between the two coherent pluggable equipped in each router, connected to the OLS as well as new IP links between those two routers involved in the L3VPN service. Please note that T-API is used in Optical/O-OLS SDN domain controller for the communication with the Hierarchical SDN controller and Optical/O-OLS SDN domain controller is the entity responsible for the OLS network and therefore for determining the output power, central-frequency and the operational-mode to be set-up in the coherent pluggable in the routers.

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