TELECOM INFRA PROJECT

TIP MANTRA Whitepaper

IPoDWDM PoC 2024 results readout

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Table of Contents

List of Figures

List of Tables

Introduction

This Use Cases Definition document extends the current MANTRA Whitepaper: IPoWDM convergent SDN architecture - Motivation, technical definition & challenges [1] with an extended description of the target applicability scenarios and use cases targeted by the TIP OOPT MANTRA operators subgroup.

1. Introduction

The Telecom Infra Project (TIP) MANTRA subgroup within the Open Optical & Packet Transport (OOPT) community, promoted the execution of a Proof of Concept (PoC) to explore the feasibility and effectiveness of integrating Internet Protocol (IP) over Dense Wavelength Division Multiplexing (DWDM) within a multi-vendor, open, and standardized environment. The primary objectives of the PoC were to validate the interoperability of coherent pluggable transceivers across different platforms and to establish a standardized management framework that can be applied universally across different vendors.

1.1 Scope and Methodology

The scope of this proof of concept was previously defined in the MANTRA IP over DWDM use cases described in [1], which extends the work previously started with the definition of the target IPoDWDM management architecture by the MANTRA subgroup defined in the Whitepaper released in 2022 [2].

The PoC was conducted in two phases, each with specific objectives and expected outcomes:

- Phase I focused on integrating coherent pluggable modules with router platforms using partially standardized or proprietary interfaces. The goal was to evaluate the management functions available for optical coherent pluggable transceivers and identify gaps between standard integration through the Common Management Interface Specification (CMIS) and proprietary solutions. In this phase, the project focused more on the proposed use cases' operational aspects.
- Phase II aimed at defining and testing the Open Router's Management Interface which provides vendor-agnostic management of pluggable modules. This phase involved a comprehensive gap analysis of the OIF-IA-CMIS-5.0 [4] interface and the development of use cases for standard-based implementation. As the project moved into Phase 2, the discussions shifted to more complex topics such as DWDM network planning, performance monitoring, and fault management. One of the critical areas of focus was the platform's ability to manage extensive performance monitoring tasks.

- The second phase also introduced using OpenConfig as a management interface for the pluggable modules. The team discussed how OpenConfig could be used to standardize the management processes across different platforms, reducing reliance on proprietary interfaces. This approach was intended to enhance interoperability and simplify the integration of new components into the network. The participants aimed to explore the use of OpenConfig for managing pluggable modules and to address any limitations identified during Phase 1.

1.2 Use Cases

The PoC evaluated several critical use cases for IPoDWDM-capable routers, focusing on coherent pluggable integration and management:

1. **Use Case 1:** Inventory discovery and visualization of IPoDWDM routers after pluggable installation and network commissioning (Day 0).

    a. **Use Case 1.1 – Coherent pluggable discovery**
        i. Verify and characterize the correct detection of the pluggable by the IP Router host in different scenarios:
            1. Hot insertion is the discovery of the pluggable when the IP Router host is up and running.
            2. Cold insertion, insertion of the pluggable when the router is switched off, and verification of the correct discovery when the router is started.
        ii. Once the ZR/ZR+ coherent pluggable is inserted (hot or cold insertion), the objective will be to verify the IP router correctly detects the new transceiver with its configuration (if it already exists, i.e., central-frequency range, operational/administrative status, Tx/Rx power range and performance counters among other parameters).
        iii. The integration and discovery process shall be vendor-agnostic through a common and standard implementation of the Open Pluggable Interface (potentially OIF-IA-CMIS-5.0 or newer versions)

    b. **Use Case 1.2: ZR/ZR+ coherent pluggable transceiver hardware inventory information discovery**
        i. Inventory chassis/line card location, hosting port identification.
        ii. Pluggable component information part-no, serial-no, pluggable manufacturer.
        iii. HW status (admin-state, operational-state).

    c. **Use Case 1.3 - ZR+ coherent transceiver pluggable discovery logical inventory.**
        i. Characterize the default configuration mode of the transceiver after the module is plugged, including the logical mapping between client (host) and line (media) interfaces (I.e., Ethernet Interface to Optical Channel).

ii. Characterize the discovery process in hot and cold pluggable insertion scenarios.

2. **Use Case 2 -** DWDM network planning (including physical impairment validation) for IPoDWDM-based services.

   a. **Discovery of optical-channel capabilities.**

      i. Operational modes and their characteristics available (Bit rate, Baud Rate, Modulation Format, FEC coding).
      ii. Physical Rx tolerances (minOSNR, minRxPower, maxCD, maxPDL, maxDGD).
      iii. Optical channel configuration constraints (min/maxTxOutputPower, min/maxCentralFrequency, frequency grid, adjustment granularity, available modes).

3. **Use Case 3** - Creation and deletion of IP links over Ethernet transport services over a ZR+ OTSi optical channel over WDM.

   b. **Use Case 3.1 - Creation/Deletion of an IP link over an Ethernet transport service over a ZR+ OTSi optical channel over WDM.**

      i. Basic provisioning of the optical channel configuration (operational modes, central frequency, output power, admin state).
      ii. Correlation of operational state between Optical Channel and Ethernet interface once deployed.

   c. **Use Case 3.2 - Change of the operational mode (different bit rate) and discovery of the correlation with the IP layer.**

      i. Modify the operational mode or transmission mode associated to the line interface, e.g., from 400G DP-16QAM to 300G DP-8QAM.
      ii. Verify the new logical mapping between client to line interfaces.
      iii. Verify client Ethernet layer correlation once the offered client bit rate changes.

   d. **Use Case 3.3 - Change the client mapping mode from 4x100GE to 1X400GE and vice versa.**

      i. Discovery of the two possible client mapping mode configurations (1x400GE, 4x100GE) and the associated logical mapping between client and line interfaces.

1. **Use Case 4 - E2E Ethernet interface and OTSi service performance monitoring through streaming telemetry (gNMI subscription).**
    i. OTSi optical channel performance monitoring. Streaming telemetry of the performance of the optical channel (pre/post-fec-ber, input-power, OSNR, q-value, CD/PMD...)
    ii. Ethernet interface performance monitoring.
2. **Use Case 5 - E2E Ethernet+Optical fault management troubleshooting with events/alarms correlation.**
    i. Evaluate basic optical conditions such LOS, AIS, PRE-FEC-BER degradation.
    ii. Operational and Administrative status correlation between Optical Channel and Ethernet interfaces.

1.3 PoC Setup

The PoC involved collaboration among several key industry players, including:

- TIP OOPT MANTRA subgroup
- IP Infusion (platform and software)
- UfiSpace (router platforms)
- Ciena (coherent pluggable modules)
- NEC (additional hardware and support)

The PoC was conducted in a lab environment provided by IP Infusion, where the following equipment was used:

- UfiSpace S9510-28DC and S9610-36D routers
- Ciena 176-3580-900 ZR+ Coherent Pluggable optics
- NEC pluggable optics

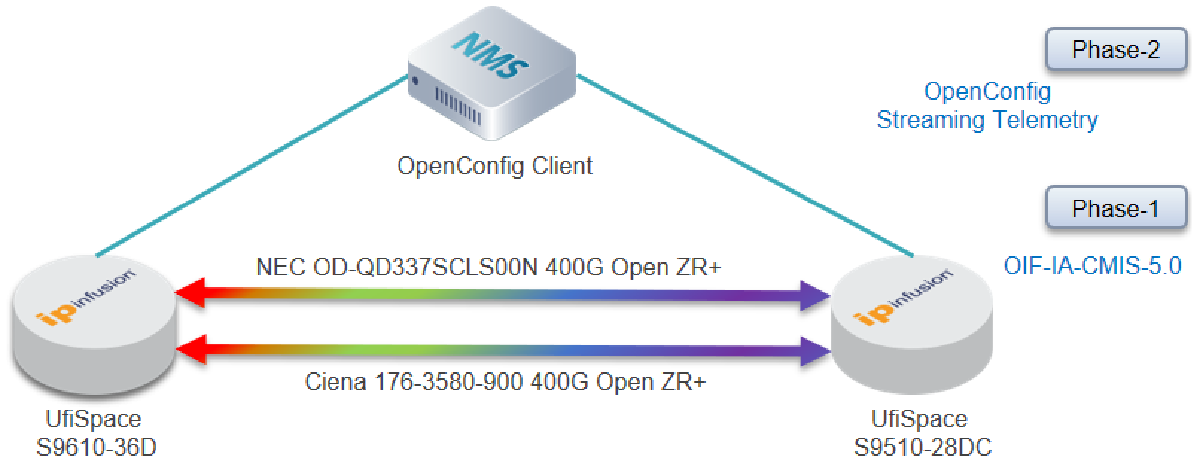

Figure 1 Proof-of-Concept lab setup.

2

Technical analysis of the standard interfaces

The vendor test reports provided a comprehensive overview of the technical performance of the IPoDWDM system across both phases of the PoC. Below is a summary and analysis of the key findings.

2. Technical analysis of the standard interfaces

The vendor test reports provided a comprehensive overview of the technical performance of the IPoDWDM system across both phases of the PoC. Below is a summary and analysis of the key findings.

2.1 OIF CMIS Implementation Analysis

The PoC has reviewed two different vendor implementations of the OIF CMIS interface version 5.0 for the management of ZR+ coherent pluggable transceivers.

The analysis done consisted of comparing the required management/control attributes intended to be used in the use cases proposed in the available OpenConfig models. The assumption is the router host must be able to retrieve/configure that information from the pluggable through CMIS and then map it to the reference router's management interface for coherent pluggable modules. Please note this analysis might be also helpful if other standard models are used to implement the management interface.

2.1.1 Detailed analysis description

The full detailed analysis is presented in Annex A of this whitepaper. The structure of the analysis is as follows:

Each **OpenConfig attribute** (xpath) was provided to the vendors for their analysis. Then each coherent pluggable vendor was required to provide:

- The **minimum available version** of OIF CMIS / and Coherent CMIS [6] where the mapped feature is available.
- **CMIS / C-CMIS Field Name** – the name of the field in CMIS.
- **CMIS / C-CMIS Register (Page/Byte/Bits)** – implementation detail based on the standard.

Based on the information provided the evaluation concluded the following:

- Whether there is an available feature (field name) in CMIS to be mapped to the required OpenConfig feature/attribute.
- Whether there is an alignment between vendors on the mapped feature.
- Highlight differences in the implementation of the standard through the

comparison of the register's data provided.

According to the analysis done the following high-level conclusions have been agreed upon by the participants on this PoC.

- The detailed analysis allows to understand the gaps or limitations of CMIS 5.0 and Coherent CMIS 1.3 standard interface definitions and will serve as a solid foundation to develop a detailed requirements set for coherent pluggable modules in the future. Please note that CMIS 5.1 or 5.2 releases have not been analyzed in detail and there might be some of the features concluded in this analysis as "non-standardized" that might be available in the newer versions of CMIS.
- From the set of OpenConfig attributes proposed, a small subset presents different interpretations from the vendors or unresolved conclusions. In these cases, a deeper understanding of the purpose/use cases impact that these attributes might have from a router's management interface perspective shall be addressed. In other words, it is unclear whether these attributes are relevant or applicable in the way they have been currently presented.

2.1.2 Outstanding conclusions of the analysis per use case.

The main gaps and highlighted conclusions per use case are listed here:

- **Use Case 1 - Inventory discovery and visualization of IPoDWDM routers after pluggable installation and network commissioning, without services deployed (Day 0).**
    - The **min-channel spacing** (Adjusted granularity) in CMIS can be either ITU-T grid-based or gridless. The current OpenConfig definition of this attribute, when is gridless or unspecified does not allow to define the "fine-tunning resolution" supported by the implementation, which is actually available in CMIS.
    - **Min-tolerable-input-power**, the alignment reached concludes that this attribute shall be mappable to the Lane-Related Monitor Thresholds (CMIS Page 02h) included in Table 8-55 of CMIS 5.0, in particular, *OpticalPowerRxLowAlarmThreshold* was proposed by one of the vendors however it is observed that the mapping to OpenConfig is not 1:1.

- **Use Case 1.2 - Physical Inventory discovery. a. ZR+ coherent transceiver pluggable hardware inventory information discovery**
    - **Operational status, administrative status**. These two features, when they apply to the coherent transceiver module, are mappable to the FirmwareStatus (0100h:9Fh:136) Byte, which represents status information about the firmware images stored in the module. In the case of CMIS, the FirmwareStatus allows to represent the state of two firmware images simultaneously while in the case of OpenConfig all the information available only represents the status of a single firmware state. This should be considered in more detail while defining the use cases, a clear mapping between the OpenConfig transceiver module oper-status and admin-status respect to CMIS firmware status might be needed.

- **Use Case 1.3 - ZR+ coherent transceiver pluggable discovery logical inventory.**
    - **Client-mapping-mode.** Each transmission mode is represented in OpenConfig as a set of logical-channels "cross-connecting" the host and media interfaces (client and line side transmission). The OpenConfig data model allows to configure the client mapping (i.e., 1x400G, 2x200G, 4x100G…) for a given logical channel. In CMIS 5.0, this is mappable to the information provided by the Application Descriptors (00h:86-117), which represents each application with a single identifier (AppSel Code) embedding in a single identifier the Host Interface (Application Bit Rate, Lane Count, Lane Signaling Rate and the Modulation format), the Media Interface (same information than the host interface), HostLaneAssignmentOptions and MediaLaneAssignmentOptions. Please see the conclusions of the analysis of this use case in section 3.5.

- **Use Case 2 - DWDM network planning (including physical impairment validation) for IPoDWDM-based services.**
    - **Media Interface vs Operational Mode.** As described in the previous "client-mapping-mode" analysis, in CMIS, a single ID per application represents the

Media Interface description. All standard Host and Media interface IDs are defined in SFF 8024 - SFF Module Management Reference Code Tables [10]. The data required to complete the OpenConfig operational mode descriptors are defined in openconfig-terminal-device-properties.yang model, shall be provided offline based on the data provided by SFF 8024.

- **Operational Mode Ids.** We have observed that the standard Media Interface IDs are defined in SSF 8024, thus we conclude these IDs should be included as a reference in the operational-mode-descriptors model in OpenConfig, specifically in the subtree "interoperable-modes" which allows to include of the mode-name (MediaInterfaceId) and the publisher-organization, in this case SFF 8024.
- **Optical Planning and Physical impairment's validation data.** Key media interface's performance degradation thresholds such as the minimum receiver's OSNR tolerance, pre-FEC Bit Error Rate (BER) thresholds, maximum Chromatic Dispersion (CD), Differential Group Delay (DGD) or Polarization Dependent Loss (PDL) are available in CMIS through the Alarm Thresholds associated to the Versatile Diagnostics Monitoring (VDM) registers. The fact that these attributes are available as alarm thresholds, is not ideal for the target planning and impairment validation use cases of the telco operators. Operators expressed their target format in OpenConfig terminal device manifest files.
- Besides, the main issue detected is that each vendor might implement VDMs in a proprietary manner (please check the detail of this analysis in Use Case 4 in this section), thus introducing a degree of flexibility that the host router software needs to consider and the mapping logic per vendor needs to be implemented. In the cases of standard transmission modes (media interfaces) such as the ones included in OpenZR+ MSA, all the data required for planning is available in section 11.1 DWDM link specifications.
- **FEC coding overhead and gain** information are not explicitly available in CMIS, however, standard FEC codes' features such as OFEC are comprehensively detailed in OpenZR+ MSA.
- **Optical Channel Spectrum width or filter characteristics,** again not explicitly available through CMIS but in the case of OpenZR+ standard media interfaces, this information is available in the MSA.

- **Use Case 4 - E2E Ethernet interface and OTSi service performance monitoring**

through streaming telemetry (gNMI subscription).

- Several host and media interface performance counters are not available in CMIS 5.0, such:
  - in-pcs-bip-errors
  - in-pcs-errored-seconds
  - in-pcs-severely-errored-seconds
  - in-pcs-unavailable-seconds
  - out-pcs-bip-errors
  - out-crc-errors
  - out-block-errors
  - errored-seconds
  - severely-errored-seconds
  - unavailable seconds
  - background-block-errors
  - fec-corrected-bytes
  - post-fec-ber instant
  - post-fec-ber average
  - post-fec-ber min
  - post-fec-ber max

- Versatile Diagnostics Monitoring (VDMs) features can be available in different registers depending on the vendor implementation. Hosts need to implement a VDM engine and abstract the register locations out of this.
  In CMIS 5.0 (Table 8-122 VDM Observable Types (Type Coding)) and C-CMIS 1.3 section 7.3, a set of defined VDM IDs associated with specific observable performance attributes, is proposed, which may pave the way for a vendor alignment in this area. However, not all the target performance counters for media interface diagnosis are available in the referenced sources, and thus this point is identified as an area of potential improvement.

2.1.3 Other issues

2.1.3.1 Ambiguity on the definition of host-lane-count in CMIS 5.0

In CMIS 5.0 the lane count is defined as: *"The third byte (Lane Counts) defines the number of lanes for the host interface and for the media interface. These lane counts are derived from the standards identified in the first and second bytes."*

The debate observed is whether the host lane count should represent the number of host lanes for an application defined by the host interface ID or should be the total number of host lanes of a host interface. Let's illustrate this with a couple of examples:

Example 1: An application descriptor with CAUI-4 C2M (Annex 83E) (defined in SFF 8024 as Host Electrical Interface ID 11) as host interface ID over ZR200-OFEC-QPSK media interface.

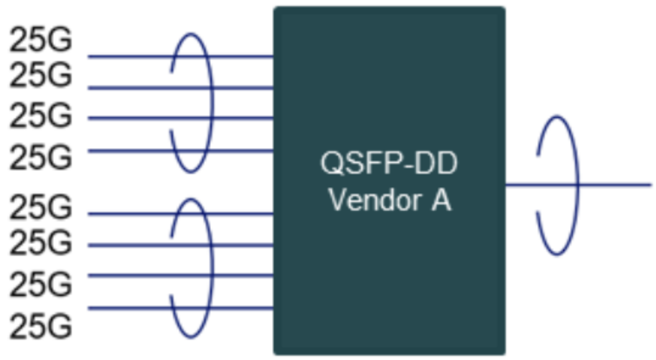

Figure 2 CAUI-4 C2M (Annex 83E) over ZR200-OFEC-QPSK media interface.

The implementation of the application descriptor in CMIS should be:

AppSelCode	Name	Value	Description
0011b	HostInterfaceID	0Bh	'CAUI-4 C2M (Annex 83E)'
	MediaInterfaceID	48h	ZR200-OFEC-QPSK
	HostLaneCount	4	Here it was assumed the number represents the number of host lanes per the application defined in the Host Interface ID
	MediaLaneCount	1	
	HostLaneAssignmentOptions	11h	
	MediaLaneAssignmentOptions	01h	

Example 2: An application descriptor with 100GAUI-2 C2M (Annex 135G) (defined in SFF 8024 as Host Electrical Interface ID 13) as host interface ID over ZR200-OFEC-QPSK media interface.

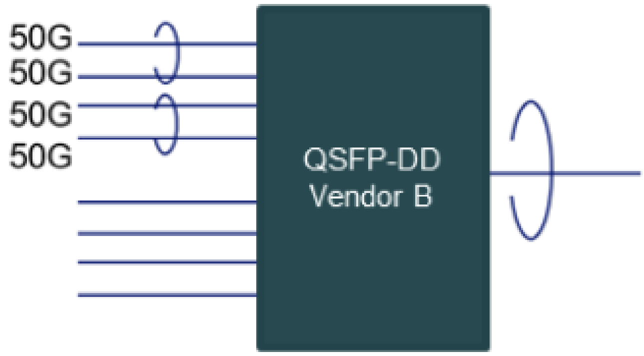

Figure 3 100GAUI-2 C2M (Annex 135G) over ZR200-OFEC-QPSK media interface.

Here one wrong implementation observed was:

AppSelCode	Name	Value	Description
0011b	HostInterfaceID	0Bh	100GAUI-2 C2M (Annex 135G)
	MediaInterfaceID	48h	ZR200-OFEC-QPSK
	HostLaneCount	4	Here it was assumed the number represents the total number of host lanes for the Host Interface.
	MediaLaneCount	1	
	HostLaneAssignmentOptions	11h	
	MediaLaneAssignmentOptions	01h	

While the correct implementation as an application descriptor in CMIS should be:

AppSelCode	Name	Value	Description
0011b	HostInterfaceID	0Bh	100GAUI-2 C2M (Annex 135G)
	MediaInterfaceID	48h	ZR200-OFEC-QPSK
	HostLaneCount	2	Here it was assumed the number represents the number of host lanes per the application defined in the Host Interface ID
	MediaLaneCount	1	
	HostLaneAssignmentOptions	11h	
	MediaLaneAssignmentOptions	01h	

In conclusion, the analysis revealed is very important for the next steps on the definition of the target set of requirements of plug-and-play coherent pluggable modules management.

2.1.3.2 FEC configurations in CMIS 5.0

To achieve traffic communication, the FEC should be appropriately configured.

11	B	CAUI-4 C2M (Annex 83E)[1]	103.13	4	25.78125	NRZ	1
65	41	CAUI-4 C2M (Annex 83E) without FEC	103.13	4	25.78125	NRZ	1
66	42	CAUI-4 C2M (Annex 83E) with RS (528,514) FEC	103.13	4	25.78125	NRZ	1

Figure 4 CAUI-4 C2M (Annex 83E) Host-Electrical-Interface-IDs in SFF8024

If the transceiver vendor would like to use CAUI-4 C2M (Annex 83E) in their transceiver they should use host-electrical-interface ID65 or ID66 (not ID11) as the latest SFF 8024 announces.

2.2 NETCONF OpenConfig router's management interface analysis

A good understanding of the basic technologies of DWDM, OTN and layer 3 IP networks is necessary to effectively leverage their capabilities and the benefits of IPoDWDM to build a high-capacity, efficient, and future-proof connectivity service provider network. This understanding must start by identifying the potential for interworking between IPoDWDM-ready routers. See the diagram below.

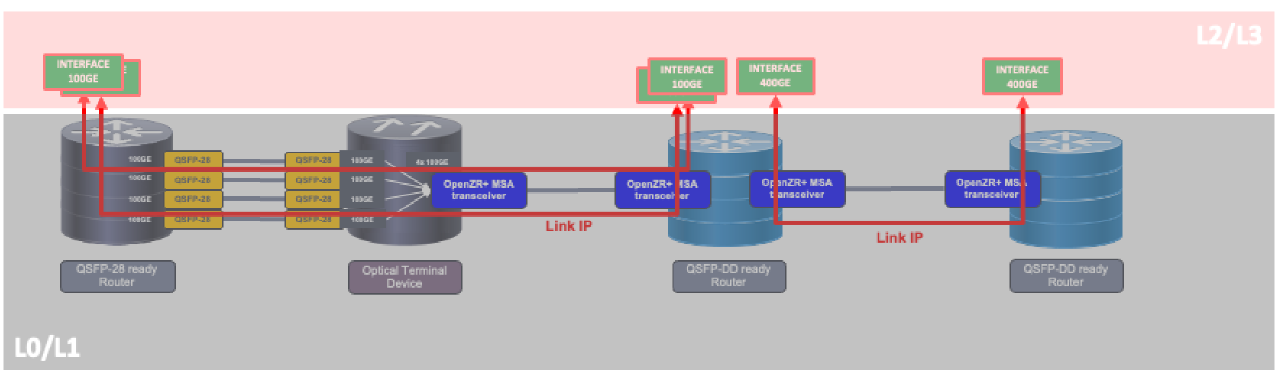

Figure 5 Potential internetworking for IPoDWDM

2.2.1 OpenConfig logical inventory representation

The proposed solution by the MANTRA subgroup for IPoDWDM relies on the OpenConfig YANG models for the data model representation of the coherent pluggable transceiver modules management and control capabilities. A logical diagram of the different models and objects defined in OpenConfig illustrates a possible logical representation of two different transmission schemas widely used in ZR+ based coherent pluggables: 1x400G and 4x100G client to line mappings.

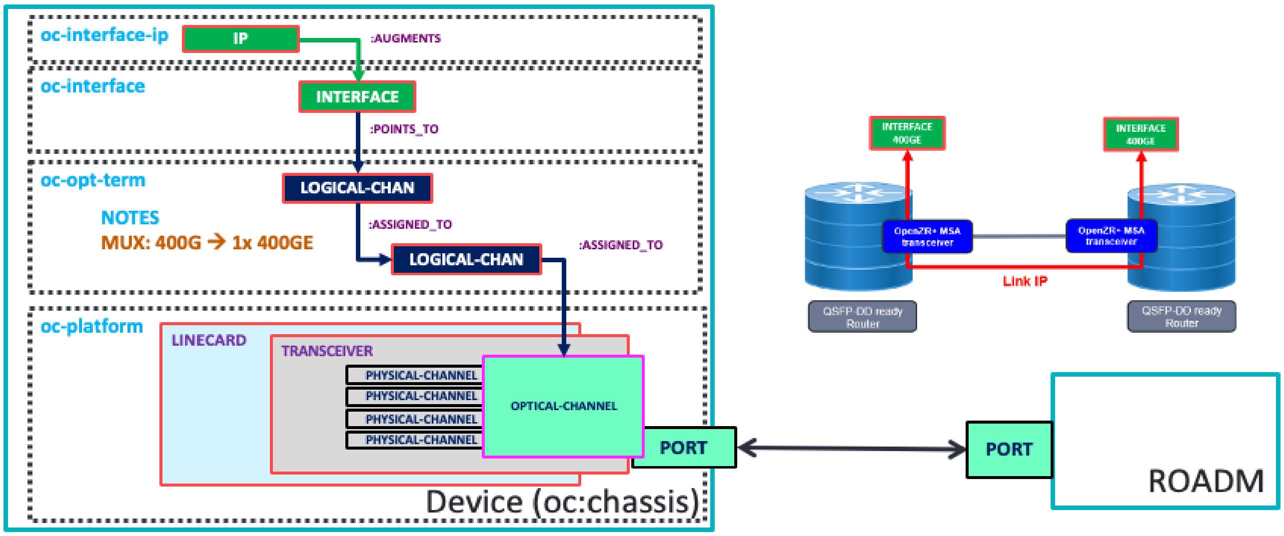

Figure 6 400G optical line port / 1x 400GE client

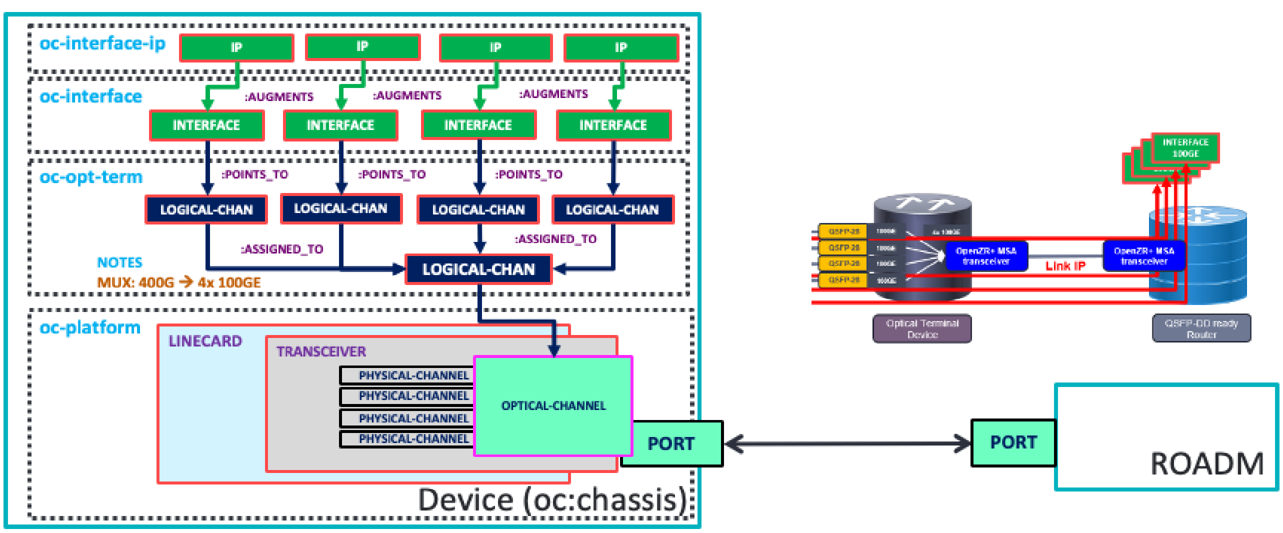

Figure 7 400G optical line port / 4x 100GE client

The hierarchy starts with interfaces (oc-interfaces), which are mapped to mux/demux signals (oc-terminal-device/logical-channel) transporting 1x400GE or 4x100GE client signals that in turn will be mapped to 400G line signal.

The multiplexed 400G line signal is mapped to the Optical Channel object (defined in oc-terminal-device which augments oc-platform model), supported by the Coherent Pluggable Module (oc-platform-transceiver). The Transceiver module attributes have a port (oc-platform-port) as a child object, which serves as a connection resource.

2.2.2 OpenConfig physical inventory representation

The inventory representation in OpenConfig is implemented through the openconfig-platform.yang model and all its augmentations for specific hardware component types such as Transceiver, Linecard, PSU, FAN and others.

A possible reference model that fits with the implementation observed during the PoC is illustrated in Figure .

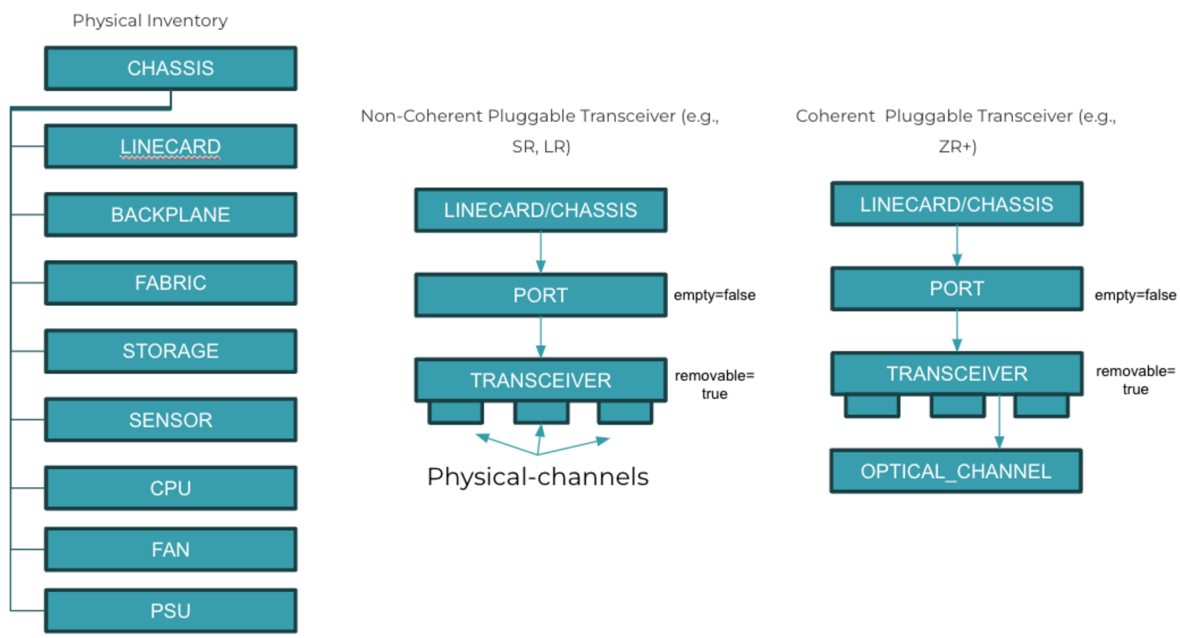

Figure 8 OpenConfig physical inventory reference model

The first open point to discuss for a future reference implementation is that there is a debate on whether the CHASSIS itself should be hosting the PORT components or if there should be component type in between, such as LINECARD, BACKPLANE or FABRIC components. In the case of pizza box type of device where no multiple linecards are allowed, whether a single LINECARD representing the router's forwarding ASIC and motherboard or if the CHASSIS component is enough to represent this type of hardware, is one of the target questions to resolve.

It is important to remark that in the implementation analyzed were found two elements that are not currently mappable to OpenConfig component types which are RAM and an EDFA which is part of the high power coherent pluggable solutions. The right representation of these components shall be analyzed in more detail.

Last, the representation of coherent and non-coherent transceiver pluggable modules is illustrated also in the figure. Right now the openconfig-transport-line-common.yang model contains an augmentation of component type PORT, named "optical-port" which contains an attribute named "optical-port-type" which allows two different port types definitions: TERMINAL_CLIENT, TERMINAL_LINE. Although this augmentation has been used in the past in transponder/muxponder Open Optical Terminals representations, in the case of ZR+ transceivers the host and media interfaces are collapsed in a single module and thus this duality between terminal client and line does not fit well. Thus the usage of this augmentation for ZR+ transceiver modules representation shall be deprecated.

2.2.3 Analysis of the change of operational mode (400G to 200G) and the client mapping mode from 4x100GE to 1x400GE (Use cases 3.2 and 3.3)

In the below diagram, it depicts the transition from a 400GE transmission over ZR400-OFEC-16QAM to a 200GE over ZR200-OFEC-QPSK through a change of the operational mode of Optical Channel OCH 0/0 and as second step, the reconfiguration of the breakout configuration at the client (host lane) port level from 1x200GE interface to 2x100GE.

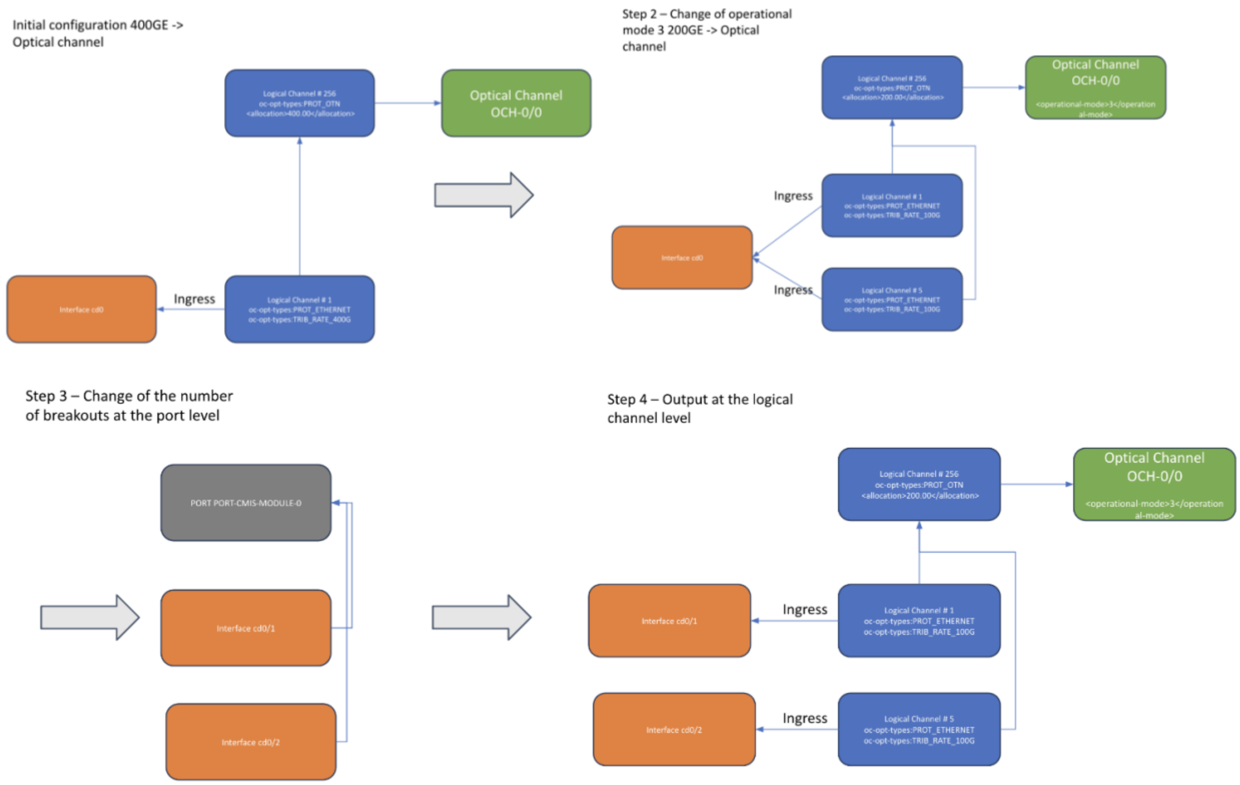

Figure 9 OpenConfig analysis of the change of operational mode (400G to 200G) and the client mapping mode from 1x200GE to 2x100GE (Use cases 3.2 and 3.3)

The analysis carried out is divided into the discovery and provisioning perspectives:

- From the **discovery** function perspective few key assessments are listed here:
  - The relationship between the Optical Channel component (openconfig-terminal-device.yang) and the L2 interfaces (openconfig-interfaces.yang model) is correctly discoverable through the implementation of the logical interfaces defined at the openconfig-terminal-device.yang model.
  - In the simplest case analyzed (400GE over 400ZR+ over optical channel), this is represented by two logical channels at the ETHERNET (host-lane) and OTN (media-lane) assigned to an optical-channel component (representing the optical DWDM channel).
  - The modification of the operational mode (application code in CMIS) is correctly reflected in the representation of the logical-channel's rate (in the example analyzed the OTN channel is downgraded from 400G to 200G) and in the logical channel structure (once modified two host lane at 100G are

created).
    - The relationship with the L2 interfaces model is maintained throughout the process.
    - Once the breakout mode is configured, the L2 interface is subdivided into 2 logical interfaces which appear correctly linked to the Ethernet (host-lane) logical channels without manual intervention.

- From the **provisioning** function perspective:

    - One key aspect is that once the operational-mode of an optical-channel is changed the **reconfiguration of the logical channels is automatic.**

        - In the cases analyzed, when the transmission mode is changed from 1x400GE over 400ZR to 2x100GE over 200ZR, the number of logical channels attached to the optical-channel is modified from 2 to 3 (adding one additional 100GE logical-channel representing the new host lane interface).
        - The fact that this happens automatically is a key aspect to consider for standardization of a common behavior across routers implementing the same model logic, since it impacts the management logic to be implemented by the management systems or SDN controllers in charge of the device's management.

    - A second aspect to highlight is the **relationship between logical channels and L2 interfaces.**

        - Throughout the execution of Use Case 3.3, we observed that even though the host lanes were divided into 2x100G, the L2 interface remained a single one.
        - Once the breakout mode is configured at the PORT component level, the two sub-interfaces were created and included in the list (cd0/1 , cd0/2)
        - This step requires the configuration of the number of breakouts per port, the speed of each breakout, and the number of physical channels per breakout.

2.2.4 Outstanding conclusions and remarks of the technical analysis.

The analysis also revealed several gaps in the OpenConfig model or in implementation practices that require further discussion:

2.2.4.1 Ambiguity in Transmission Mode (Media Interface) Protocol Encapsulation Representation

The first transmission mode analyzed involved a 400GE (400GBASE-R) host lane over a media lane using ZR400-OFEC-16QAM.

The implementation correctly used a logical-channel to represent the media lane, but the <logical-channel-type> was set to PROT_OTN. However, since OTN framing is not used (ZR+ framing is the standard), it is unclear how this should be represented within OpenConfig. Currently, OpenConfig only allows OTN or ETHERNET for logical-channel types. The PROT_OTN was used here simply because no better option exists. A new identity ref in OpenConfig would be more accurate and is anticipated for future updates.

2.2.4.2 Host-Side Transmission Representation in OpenConfig

The representation of the host side of the transmission in OpenConfig is still unclear due to the incomplete implementation of physical channels at the transceiver component.

Assuming a CAUI-4 over ZR200-OFEC-QPSK operational mode illustrated in section 2.1.3.1 (Figure) the expected OpenConfig representation would be:

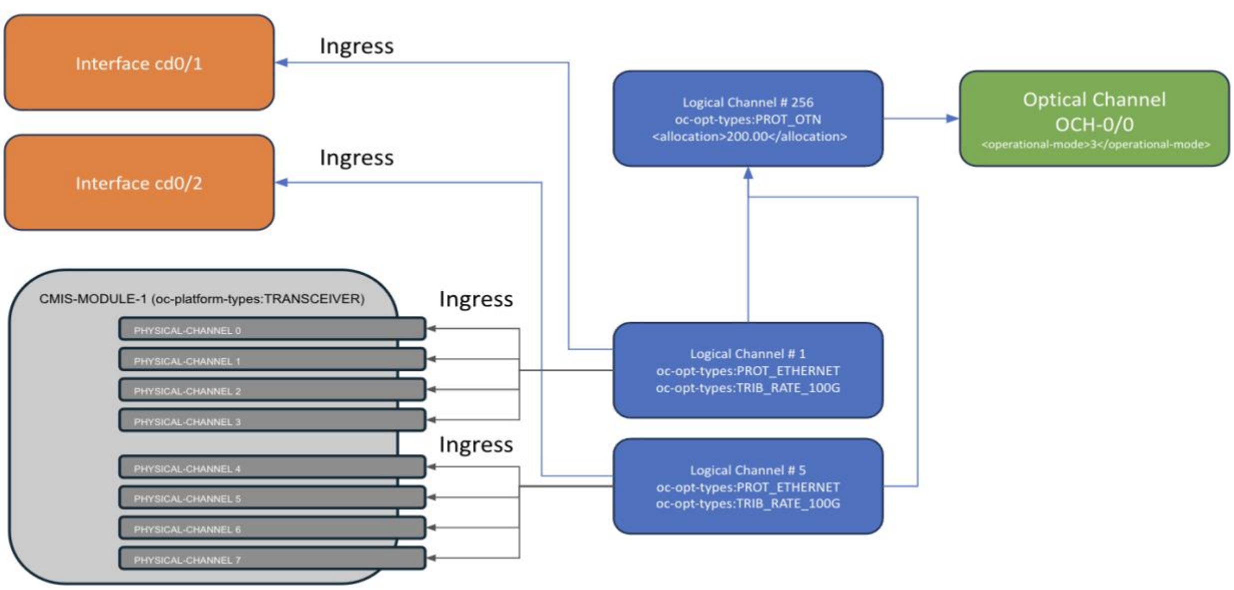

Figure 10 OpenConfig representation of Host Interface

However, the implementation observed shows that the TRANSCEIVER CMIS-MODULE-0, includes only one physical channel listed, and this count does not change when the operational mode changes or when breakout mode is configured.

The clarifications provided by the vendor are that in the current implementation, transceiver channels on the OcNOS model represent the line side of the transceiver and thus the transceiver's physical channels represent only one lane (instead of the eight host lanes, 4 per each host interface). Clarifying this reference implementation guidelines is important to avoid future different interpretations from different vendor implementations.

3

Functional and operational analysis

This section presents the functional and operational evaluation of the use cases proposed.

3. Functional and operational analysis

This section presents the functional and operational evaluation of the use cases proposed.

3.1 Use Case 1.1 - Coherent pluggable integration and discovery

In the initial phase, discussions primarily focused on the integration of coherent pluggable modules through the OIF-IA-CMIS-5.x and the lifecycle management of the discovery process by the router.

3.1.1 Hot and Cold Insertion Scenarios

The team tested the system's response to both hot and cold insertion scenarios. These tests were crucial for understanding how the system managed modules that were inserted or removed while the system was active versus when it was powered down. The discussions highlighted that while the system performed adequately, there were some delays and inconsistencies in updating the inventory status, particularly in hot insertion scenarios.

After clarifications with IP Infusion, it was confirmed that delays noted in the hot insertion scenarios were mainly due to the transitory phase from the coherent modules (clearly indicated in their datasheets) to reach their final state. As a consequence, the conclusions are twofold:

- Both in cold and hot insertion scenarios the final stage is the same with the same information reported for the coherent module
- In the hot insertion scenario, some transitory stages are reported that cannot be seen in the cold insertion scenario hidden by the host start-up process

It is still under investigation whether there could be a notification process after the pluggable configuration process is finalized, so that no transitory states are reported to the host showing only partial information. Only final coherent pluggable configuration stage should be reported to the host.

3.1.2 Discussion about default values

There was a detailed examination on how default operational parameters, such as central frequency, output power, and operational mode, were handled in the CMIS interface. The team evaluated how the pluggable modules deal with the information stored in the CMIS registers through the process of plug-in and plug-out process.

It is considered critical by operators to have the same kind of commissioning process independently on the deployment scenarios (e.g. coherent pluggables over P2P dedicated fiber between routers versus over meshed ROADM network). It was found during the POC that some factory default parameters may vary from one manufacturer to another. These considerations imply at least three main requirements for coherent pluggables' default parameters handling:

- The set of coherent pluggable pre-configured default parameters shall be overwritten through the configuration information stored in the host router, which might have been set in a previous step either through CLI or through management/SDN controller. This default configuration information, determined by the operator, shall always have precedence over any default configuration of the coherent pluggable.
- In case of any reset of the coherent pluggable (due to port reset/linecard reset or NE reboot etc.) the coherent pluggable shall always reload the last working configuration defined by the Operator. The factory default parameters shall only be loaded in the absence of any Operator-defined configuration.
- The set of coherent pluggable pre-configured default parameters shall include at least (but not restricted only to those):
    - nominal_central_frequency (e.g. channel identifier seen in the tests)
    - launched power
    - application-code ID
    - admin-status enabled
    - laser_status disabled (while in the tests laser_status was enabled by default)
- To avoid any negative impact over any existing optical channels already implemented over the DWDM network, the Operator will have to explicitly enable the laser_status of each pluggable after having checked the minimum set of required default parameters for that coherent pluggable.

3.2 Use Case 1.2 - Physical Inventory discovery.

3.2.1 ZR+ Coherent pluggable modules' available hardware inventory information

The CMIS implementation of the pluggable vendors was analyzed by matching the target OpenConfig physical inventory model to the CMIS registers. This analysis is detailed in Appendix A –Table 1 and Table . This analysis was focused on the transceiver's physical inventory.

Here is a list of further attributes included in OpenConfig models that have not been analyzed in this PoC and are left for further study:

- /components/component/oc-transceiver:transceiver/oc-transceiver:state/oc-transceiver:ethernet-pmd
- /components/component/oc-transceiver:transceiver/oc-transceiver:state/oc-transceiver:fec-mode
- /components/component/oc-transceiver:transceiver/oc-transceiver:state/oc-transceiver:vendor-rev
- /components/component/oc-transceiver:transceiver/oc-transceiver:state/oc-transceiver:module-functional-type
- /components/component/oc-transceiver:transceiver/oc-transceiver:state/oc-transceiver:date-code
- /components/component/state/clei-code

3.2.2 Hardware location and inventory management by the router

It is important that the router reports its hierarchy of components and is able to properly identify the physical position in which a component is located.

In the PoC, the router was a monolithic device. The hierarchy that was presented started from the chassis and the ports directly rooted from it. Under the port, the pluggable modules were hooked. Despite the hierarchy being correct, it lacked a proper identification of the location within the chassis.

In this regard, OpenConfig has recently deprecated the location attribute, which was completely at vendors' discretion to fill and without any standard format, and include two new attributes, install-position and install-component. Hence, the port will be identified with these two attributes. Note that install-component does not necessarily be the parent component (even though it will be the general case that the parent component is used as the reference). This way, it is feasible to identify the position of an element (transceiver, port, card) in a vendor agnostic fashion.

The operators found also some potential enhancements regarding the information exposed by the router. In order to be able to improve the planning, the router could report the capabilities of a given port in terms of maximum power supported, and operational modes accepted. This way, a controller/planning tool can decide among the possible operational modes with more accurate information. Now, such information must be incorporated to the planning tool / controller as data-sheet like information, which could be outdated upon firmware updates. Also, it is advisable to report the capabilities at card / chassis level in terms of maximum aggregated power consumption. These enhancements will require the relevant extensions in openconfig and the router to be able to report them.

3.2.3 Operational and administrative status of the pluggable transceiver

In section 2.1.2 a first analysis of the mapping between of the operational and administrative status to CMIS FirmwareStatus information was presented. While the information regarding the Firmware images is important, it is not the target use case defined by the MANTRA subgroup, which is now summarized as follows:

1. Being able to turn the transceiver power (**administrative state**) on and off. Observing OpenConfig model, this feature is modeled as:

    - **OpenConfig Xpath**: /oc-platform:components/component/oc-transceiver:transceiver/oc-transceiver:state/oc-transceiver:enabled
    - **Description:** *"Turns power on / off to the transceiver -- provides a means to power on/off the transceiver (in the case of SFP, SFP+, QSFP,...) or enable high-power mode (in the case of CFP, CFP2, CFP4) and is optionally supported (device can choose to always enable). True = power on / high power, False = powered off".*
    - **Analysis/Conclusion:** So far this feature has not been identified in CMIS during the PoC and it is left for further study. We welcome CMIS experts reading this document to provide feedback about this point.

2. Being able to discover the current **operational state** of the transceiver.

- **OpenConfig Xpath** : /oc-platform:components/component/state/oper-status
- **Description**: "If applicable, this reports the current operational status of the component".
- **Analysis/Conclusion:** The current definition of the oper-status attribute in OpenConfig is a bit vague and needs to be clarified. The analysis done so far is that the FirmwareStatus (0100h:9Fh:136) is found to be the most direct mapping from the vendor's perspective, however, in CMIS the "ModuleState" in 00h:3:3-1 could also be a valid parameter. Moreover, another alternative would be to use the "data path state" 11h: 128-131 which shows if traffic can be carried. There is a gap on the definition of the use case itself which shall be addressed by the TIP MANTRA subgroup as next step.

3. **Laser transmission status**.

- **OpenConfig Xpath:** /components/component/oc-transceiver:transceiver/oc-transceiver:physical-channels/oc-transceiver:channel/oc-transceiver:config/oc-transceiver:tx-laser
- **Description:** *"Enable (true) or disable (false) the transmit label for the channel".*

- **Analysis/Conclusions:** The mapping between OpenConfig and CMIS in this case is not clear. CMIS (Section "8.10 Banked Page 12h (Tunable Laser Control and Status)" of CMIS 5.0.) proposed mappings identified during the PoC:

    - **TuningInProgressTx** - Bool: Status indication for tuning in progress on media lane =1-8, 0b/1b: Tuning not in progress/in progress. Tuning is in progress when the laser is tuning to an ongrid channel, or fine-tuning to a frequency offset, or tuning to target output power.
    - **WavelengthUnlockStatusTx** - Bool: Unlocked status indication for laser wavelength on media lane =1-8 0b/1b: Wavelength locked/unlocked

In this case, the CMIS interface provides richer laser status information with the two identified attributes.

3.3 Use Case 1.3 - ZR+ coherent transceiver pluggable discovery logical inventory.

3.3.1 Discovery of the application codes in the transceiver module

Observing the CMIS implementation of the Application Descriptor Advertising, the whole application including Host Interface, Media Interface, Host Lane Count, Media Lane Count and Host and Lane Assignment options is advertised through a single AppSelCode identifier.

Byte	Bits	AppSel Code	Name	Value	Description
85	7-0	N/A	Module Type encoding		
00h:86	7-0	0001b	HostInterfaceID	11	400GAUI-8 C2M
87	7-0		MediaInterfaceID	3E	400G-ZR
88	7-4		HostLaneCount	8	Host Lane Count: 8
	3-0		MediaLaneCount	1	Media Lane Count: 1
89	7-0		HostLaneAssignmentOptions	01	Permissable First Host Lane for Application: Lane 1
01h:176	7-0		MediaLaneAssignmentOptions	01	MediaLaneAssignmentOptions App1

Table 1: Discovery of the application descriptors in CMIS.

Through the implementation of the AppSelCodes in Staged Control Sets, the coherent transceiver manufacturer can automate the configuration of the applications they support.

One interoperability concern here is that each manufacturer is implementing their AppSelCodes without any specific guidelines, and therefore even if two different manufacturers are advertising the same application (same Host and Media Interface values), their corresponding AppSelCodes can be different, thus introducing the need for the Router host operating system to develop a custom mapping for each of them. It has been observed in the PoC that the result in the management interface is that the same application available in the two vendors' implementation analyzed is finally advertised through a different ID value in the Router's Management Interface (OpenConfig).

If we compare the Application Descriptor Advertising mechanism in CMIS with the approach defined in OpenConfig, the approach is very similar. In OpenConfig the operational-mode concept is used to configure the target media interface configuration through a single mode-id parameter. The main difference is that the OpenConfig operational-mode targets the characterization of the media interface only, while the model introduces various degrees of flexibility on how to configure the client to line mapping and multiplexing.

Please continue reading Section 3.5 for further details about this analysis.

3.3.2 ZR+ coherent transceiver pluggable logical inventory implementation in OpenConfig

Please check the previous Section 2.2.1 with the detailed analysis of the logical inventory representation in OpenConfig as the outcome of this use case.

3.3.3 Correlation Between Optical and IP Layers

It is key to verify the relationship between the logical L2 interface and the hardware port component. The openconfig-interfaces.yang model contains the oc-port:hardware-port attribute at:

- /oc-if:interfaces/oc-if:interface/oc-if:state/oc-port:hardware-port
- /oc-if:interfaces/oc-if:interface/oc-if:state/oc-transceiver:transceiver
- /oc-if:interfaces/oc-if:interface/oc-if:state/oc-transceiver:physical-channels

which shall be implemented to correctly map L2 interfaces to the hardware components.

Then the L2 interface status:

- /interfaces/interface/state/admin-status
- /interfaces/interface/state/oper-status

Shall be correlated to the transceiver component “enabled” and its physical-channels “laser-tx” transmission status at:

- /components/component/oc-transceiver:transceiver/oc-transceiver:state/oc-transceiver:enabled
- /components/component/oc-transceiver:transceiver/oc-transceiver:physical-channels/oc-transceiver:channel/oc-transceiver:config/oc-transceiver:tx-laser

The correlation between the different combinations of these attributes to the status at the L2 interfaces object is identified as key for aligning different implementations to a reference implementation agreement.

3.4 Use Case 2 - DWDM network planning (including physical impairment validation) for IPoDWDM-based services.

The scope of planning connections over DWDM networks differs depending on whether the network is a) non-amplified point-to-point or b) amplified optical line system. To secure the connection quality for the first case, a less advanced verification can be done, in second case impairment validation is preferably carried out where more network and transceiver data is taken into account in a more advanced analysis. In both cases, transceiver data is required, and to build an on-line DWDM network planning function it is necessary to retrieve the transceiver data from the pluggable optics in routers via the CMIS interface and then through OpenConfig.

In this regard, the TIP MUST subgroup coordinated the development of OpenConfig Terminal Device Manifest files. The second release of these models are already available in OpenConfig public repository:

- https://github.com/openconfig/public/tree/master/release/models/devices-manifest

3.4.1 Discovery of optical-channel capabilities.

The target set of data to be exposed by the router/pluggable optics for DWDM planning use case is based on the referenced OpenConfig Terminal Device manifest. For the discovery of optical-channel capabilities, see Table 2, column – Optical connection capabilities to be discovered.

	Optical connection capabilities to be discovered, defined in use case 2	Discovered in PoC
Operational modes and their characteristics available	Bit rate	Yes
	Baud Rate	Yes
	Modulation Format	Yes
	FEC coding	No
	minOSNR	No

Physical Rx tolerances	minRxPower	Partially, see Annex A
	maxCD	No
	maxPDL	No
	maxDGD	No
Optical channel configuration constraints	min/maxTxOutputPower	Yes
	min/maxCentralFrequency	Yes
	frequency grid	Yes
	adjustment granularity	Yes
	available modes	No

Table 2: Discovery of optical-channel capabilities for DWDM network planning.

The data available in the PoC for the discovery of the specification of physical tolerances for the interface was limited as shown in the Table 2, column – Discovered in PoC. Data was in general available to discover monitoring of actual performance, warnings and alarms trigged by default levels. Actual performance and alarms were available for FEC, RxPower, OSNR, CD, PDL and DGD. See Figure 1 for the example for RxPower where actual value and High and Low level alarms are available. I.e. the parameters that we are interested in are available but not as specifications of physical tolerance values.

```
Port Number                   : 0
-------------------------------------------------------------------------------------------------------
       Monitors         | Lane |  Value       |  High Alarm  | High Warning | Low Warning  |  Low Alarm   |  Unit  |
-------------------------------------------------------------------------------------------------------
Rx Optical Power        |  1   |  -9.97       |  8.00        |  6.00        |  -16.02      |  -17.96      |  dBm   |
```

Figure 11 Example of parameter that is available for discovery for actual value and alarm levels.

The values for the defined parameters must be discoverable as specifications of physical tolerances for a clear implementation and adoption. The target data to be discovered is described in OpenConfig Terminal Device Properties v0.2.0 section “channel-config-value-constraints” and “operational-mode-descriptors”.

3.5 Use Case 3 - Creation/Deletion of an IP link over an Ethernet transport service over a ZR+ OTSi optical channel over WDM

This use case was evaluated through the provisioning of a 400G line transmission mapped into a 1x400GE host lane on the client side.

The provisioning function was done by first retrieving the tunning capabilities of the coherent transceiver, checking the status of the port (whether the tunning of the laser's frequency is in progress and the administrative state of the port is enabled) and then proceeding with the setting of the optical channel transmission parameters:

- Laser frequency
- Target output power
- Application code

The use case was validated correctly without major findings.

During phase 2 of the PoC, the use case evaluation was repeated by using the OpenConfig-based management interface for the configuration. Again, no major observations from the operational perspective have been obtained through the evaluation of this use case.

3.5.1 Change of the operational mode (different bit rate) and discovery of the correlation with the IP layer

Another significant area, where the PoC put the focus on, was the process of changing operational modes, specifically transitioning from one bit rate to another (e.g., from 400G to 200G). The team discussed the necessary steps to document these changes and ensure proper correlation between the optical and IP layers. The participants emphasized the importance of capturing the before-and-after states of the system to understand the impact of these changes.

The discussion delved into how changes in operational modes affect the terminal device configuration and the open configuration interfaces. The team sought to ensure that these changes were accurately reflected in the system, particularly in terms of how Layer 2 interfaces were mapped to the optical channels. This examination was crucial for verifying that the system could adapt to different configurations without errors or misrepresentations.

The key operational question to answer for this use case is: How to define the configuration workflow for the reconfiguration of the line transmission mode?, in this regard, as detailed in section 2.2.3, the automatic reconfiguration of the client-to-line mapping when changing the operational mode of the optical channel (media interface) is very interesting since reduce the operational complexity and also reduce the potential configuration mismatches that can be introduced during the configuration of the interface.

3.5.2 Change the client mapping mode from 4x100GE to 1x400GE

In this use case, the main observation is that while the CMIS configuration of the application descriptor (AppSelCode) in CMIS characterizes the host and media interfaces in one shot, the operational workflow in an OpenConfig-based management interface, may allow to configure the line/media interface (e.g., ZR400-OFEC-16QAM through the selection of the operational-mode) and host/client interface mapping (e.g., 1x400G or 4x100G modes) separately. In OpenConfig, this is possible through the configuration of the “client-mapping-mode” attribute within the logical-channel object representing the line side of the transmission (i.e., the logical-channel object connected directly to the Optical-Channel component).

- /terminal-device/logical-channels/channel/config/client-mapping-mode

Through the analysis presented in Section 2.2.3, we observed that in the implementation analyzed, this option is not allowed. The logical channels representing the client side (host lanes) were automatically reconfigured when the operational mode was set.

This behavior infers the conclusion that the current observed implementation maps the application descriptor (AppSelCode) of CMIS to the operational mode, determining the configuration of the host and media interfaces in one shot, also in OpenConfig.

Last, the execution of this use case also covered the analysis of the PORT component breakout mode functionality. The result observed is that the number of breakouts correlates to the number of L2 interfaces and the bit rate of each of them. In this regard, taking the example illustrated as a reference where the media interface was configured as ZR200-OFEC-QPSK and the host lanes were CAUI-4 C2M, the resulting L2 interface was 200 Gigabit Ethernet and it was required to breakout these two 2x100GE in a second step.

3.6 Use Case 4 - E2E Ethernet interface and OTSi service performance monitoring through streaming telemetry (gNMI subscription)

The final topic discussed in Phase 2 of the PoC focused on streaming telemetry. The team examined the gNMI capabilities and the parameters that could be collected using this interface.

Regarding gNMI features, it was observed that the devices support both dial-in and dial-out, complying with MUST IP dTRD requirements for routers [8]. The devices support JSON, JSON_IETF, and protobuf encoding.

During a detailed examination of the implementation of this use case, some limitations in the maximum number of streaming telemetry channels allowed by the system were advertised. In gNMI the configuration of a streaming interface is done by creating a sensor group grouping the set of xpaths (or sensor paths) from where the streaming telemetry system will be advertising changes or periodically stream the values. The current system analyzed in this PoC limits the number of sensor paths and sensor groups supported by the device. These limitations are attributed to the CPU and memory availability of the router.

Moreover, the system also introduces some limitations to the xpaths that can be selected as sensor paths. A sample list of potential xpaths of interest to be streamed is detailed in the following table, highlighting which ones are currently supported and which are not. It is worth mentioning that the objective of this PoC is not to determine whether the current implementation is right or wrong but to highlight potential areas of interest to look at in later projects. In this case, the conclusion so far is that the streaming telemetry use cases of interest from the operators shall be further characterized in terms of minimum required performance and also in terms of scope (i.e., it would be interesting to reach out agreements for common practices on how to stream the performance data of the router's coherent pluggable transceivers based on OpenConfig models, acknowledging there might be different flavors depending on the granularity of the data per streaming interface targeted per use case).

Target sensor xpath	Discovered in PoC
/oc-platform:components/	No
/oc-platform:components/component[name=xyz]	Yes
/oc-platform:components/component[name=xyz]/state	Yes
/oc-platform:components/component[name=xyz]/config	No
/oc-platform:components/component[name=xyz]/optical-channel	No
/oc-platform:components/component[name=xyz]/optical-channel/state	No
/oc-platform:components/component[name=xyz]/optical-channel/config	No
/oc-platform:components/component[name=xyz]/transceiver	Yes
/oc-platform:components/component[name=xyz]/transceiver/state	Yes
/oc-platform:components/component[name=xyz]/transceiver/config	No
/oc-opt-term:terminal-device/logical-channels/	No
/oc-opt-term:terminal-device/logical-channels/channel[index=1234]	No
/oc-opt-term:terminal-device/logical-channels/channel[index=1234]/state	No
/oc-opt-term:terminal-device/logical-channels/channel[index=1234]/config	No
/oc-sys:system/alarms/	No
/oc-sys:system/alarms/alarm[id=xyz]/state/	No

Regarding gNMI modes, the analyzed streaming mode in the PoC was STREAM. Other modes such ONCE and POLL were left for further study. Under STREAM mode, the only available option was SAMPLE, other STREAM capabilities defined in gNMI protocol such as ON-CHANGE or TARGET-DEFINED are also of interest to the operators.

Once the configuration was finalized, examples of subscriptions to gather device information from a server were demonstrated. Both dial-in and dial-out were tested successfully. It was also shown that dynamic subscriptions could be configured. The parameters that could be collected for PM data were related to the Ethernet interface. However, it was not possible to retrieve PM data from the optical channel.

In summary, the gNMI capabilities were successfully demonstrated during the session. Further refinement is needed to fully meet the E2E Ethernet interface and OTSi service performance monitoring requirements.

3.7 Use Case 5 - E2E Ethernet+Optical fault management troubleshooting with events/alarms correlation

On the given routing software (OcNOS), the ZR/ZR+ transceiver events are not integrated into the Fault Management System (FMS). This prevents the alarm indications from being properly displayed on the OpenConfig platform model (/oc-platform:components/oc-platform:component/oc-platform:state/oc-alarms:equipment-failure). The OpenConfig alarms list (/oc-sys:system/oc-sys:alarms) is also impacted and does not show any ZR/ZR+ related alarm.

In this particular PoC, the events considered have been notified using Netconf notifications based on the IP Infusion proprietary.

In the first step we disabled one of the transceivers using the CLI command "service-disable". At the other end of the connection, alarm notifications related to media side of the transceiver were observed: Rx-Optical-Power, Rx-LOS, Rx-CDR-LOL, Rx-Demodulator-Loss-of-Lock, Rx-Loss-of-Multiframe, Rx-Loss-of-Frame, eSNR-Input, Pre-FEC-BER-Current-Sample-Input, OSNR, eSNR, EVM-Modem, Rx-Total-Power, Rx-Signal-Power, and MER.

The host-side alarms were observed: Rx-Output (for each host lane), Tx-Remote-Fault, Rx-Local-Fault (transitory), and Rx-Remote-Fault(transitory).

Also, link-state-change notification related to the Ethernet interface associated with the transceiver was observed, indicating a link-down event. After restoring the transceivers status, we noted that all alarms are cleared.

In the second step we changed the threshold configuration to simulate an Optical signal degradation. Specific notification alarms were observed for each threshold changed: Rx-Total-Power and Rx-Signal-Power.

4

Insights and Conclusions

The TIP OOPT MANTRA IPoDWDM PoC successfully demonstrated the feasibility of integrating IP over DWDM in an SDN-controlled environment. The project met its primary objectives, including validating the management of coherent pluggable transceivers across multi-vendor platforms and implementing critical use cases that reflect real-world deployment scenarios.

4. Insights and Conclusions

The TIP OOPT MANTRA IPoDWDM PoC successfully demonstrated the feasibility of integrating IP over DWDM in an SDN-controlled environment. The project met its primary objectives, including validating the management of coherent pluggable transceivers across multi-vendor platforms and implementing critical use cases that reflect real-world deployment scenarios.

The PoC and this report present a comprehensive analysis of the implementation of IPoDWDM solutions based on OIF-IA-CMIS-5.0 and OpenConfig. It illustrates the correspondence or mapping between the two interfaces at different levels, including 1:1 parameter comparison but also model logic differences and key architectural considerations for future definition of a reference implementation guidelines for this type of solution.

The vendor reports and discussions about OIF-IA-CMIS-5.0 and OIF-Coherent CMIS 1.3, revealed that while the standards provided a solid foundation for integration, they were not always sufficient to ensure full plug-and-play integration of multi-vendor coherent pluggable in the routers. The need for ad-oc customizations per vendor to discover its VDM monitoring capabilities is a perfect example that illustrates this statement.

From the OpenConfig modeling perspective, the solution analyzed allows to derive a first reference model for the representation of OpenZR+ transceiver modules logical and physical inventory discovery. One of the most interesting conclusions reached is the need for a simple and automatic reconfiguration of the data path’s logical representation (from the host/client interface to the media/line) similar to the CMIS application selection mechanism, which allows a full data path reconfiguration through the selection of a unique Application Selection Codes (AppSelCodes).

Thus, even if the OpenConfig models allow further degrees of flexibility (such as the selection of the media/line interface transmission mode through the operational mode, and the line-to-client mapping mode (e.g., 1x400GE or 4x100GE) independently) in the case of ZR/ZR+ transceiver management, the simplified approach described in this whitepaper might be considered an effective solution. The general ambition expressed by the MANTRA subgroup, participating in this PoC, is to minimize the configuration required from the client application as a general premise.

The reports also emphasized the importance of scalability in performance monitoring. As networks grow and become more complex, the ability to monitor performance across a wide range of metrics will be critical. The current limitations observed in sensor-path handling suggest that further work is needed to identify the minimum streaming telemetry capabilities for commercial solutions.

Key Achievements

- The successful integration of two different 400G ZR+ coherent pluggable modules into the route platform through standard OIF-IA-CMIS 5.0 and C-CMIS 1.3 was demonstrated.
- A comprehensive detailed data analysis of the mapping between CMIS and OpenConfig data models has been obtained and presented in this whitepaper for further study.
- The first OpenConfig reference implementation designs of ZR+ coherent pluggable solutions are included in this whitepaper and will pave the way for a detail implementation agreement definition as the next step.

Areas for Improvement

- The analysis presented does not cover extensively the analysis of how to manage data plane interoperability through ZR+ standard applications descriptors in non-bookended scenarios. Here, the mapping between SFF-8024 module management reference codes used in CMIS's Application Descriptors and the encoding of those in OpenConfig's operational-mode descriptors would be an interesting area to explore.
- The mapping analysis between OpenConfig models and OIF-CMIS-5.0 was not exhaustive and shall be completed in future work. Moreover, the analysis shall be extended to newer versions of CMIS such as 5.2.
- The platform's limitations in handling extensive telemetry monitoring need to be addressed to improve scalability.

Future Work

The results of this PoC provide a strong foundation for further exploration and refinement of IPoDWDM technologies. Future efforts should focus on addressing the identified areas for improvement, particularly in standardization and scalability, and expanding the use cases to more complex and large-scale network scenarios.

A

Detailed comparison between OpenConfig and CMIS 5.0 data models

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Appendix A – Detailed comparison between OpenConfig and CMIS 5.0 data models

In this section, we are including the detailed analysis done during the PoC comparing the OpenConfig data model attributes identified per use case, with the data available through the CMIS interface version 5.0.

In a nutshell, each attribute identified in OpenConfig includes a potential mapping identified by the optical coherent transceiver's vendors participating the PoC. The analysis of the suitability of this mapping and the alignment between the vendors on it, is included in the column "Conclusions and Remarks".

The color coding shall be interpreted as follows:

- Green highlighted cells, indicate a 1:1 mapping and alignment between vendors on the appointed CMIS field and register page/byte/bit included in the cell.

- Yellow highlighted cells, indicate partial mapping exists (since at least a candidate CMIS Field has been identified) but there are either different interpretations of the standard from the vendors or an ambiguity on the OpenConfig attribute purpose which needs to be clarified.

- Red highlighted cells indicate the target attribute is not standardized in CMIS or a viable mapping has not been found.

Table 3: Use Case 1 - Inventory discovery and visualization of IPoDWDM routers after pluggable installation and network commissioning, without services deployed (Day 0).

OpenConfig Model Attribute	OpenConfig xpath	[redacted]	Minimum Available CMIS / C-CMIS Version	CMIS / C-CMIS Field Name	CMIS / C-CMIS Register (Page/Byte/Bits)	Alignment between vendors	Conclusions and remarks
Min-configurable-central-frequency	/oc-opt-term-properties:linecard-descriptors/linecard-descriptor/compatible-transceivers/compatible-transceiver/constrained-compatible-modes/constrained-compatible-mode/optical-channel-config-value-constraints/state/min-central-frequency	[redacted]	CMIS 5.0	Channel number ranges	04h:130-161	Yes	This attribute is defined in CMIS depending on the Grid supported, so there are multiple registers 04h:130-161 associated with the same value, as reported by both vendors. Ciena's field name includes the "Subject Area" which is the same for all the field names which are included in the range, but the actual Field Name is the one provided by NEC.
Max-configurable-central-frequency	/oc-opt-term-properties:linecard-descriptors/linecard-descriptor/compatible-transceivers/compatible-transceiver/constrained-compatible-modes/constrained-compatible-mode/optical-channel-config-value-constraints/state/max-central-frequency	[redacted]	CMIS 5.0	Channel number ranges	04h:130-161	Yes	same as previous comment.
Frequency Grid	/oc-opt-term-properties:linecard-descriptors/linecard-descriptor/compatible-transceivers/compatible-transceiver/constrained-compatible-modes/constrained-compatible-mode/optical-channel-config-value-constraints/state/grid-type	[redacted]	CMIS 5.0	Wavelength grids	04h:128	Yes	Valid register 04h:128 (bits from 7-0 depending on the Grid supported).
Min-channel-spacing (Adjusted granularity)	/oc-opt-term-properties:linecard-descriptors/linecard-descriptor/compatible-transceivers/compatible-transceiver/constrained-compatible-modes/constrained-compatible-mode/optical-channel-config-value-constraints/state/adjustment-granularity	[redacted]	CMIS 5.0	GridLowChannel3p125GHz / FineTuningResolution	04h:130-131:7-0 / 04h:190-191	Partial	Here both answers provided by the vendors are correct, since with the grid based approach supported by Ciena, the lowest granularity is 3.125 GHz spacing, NEC support a finer tunning resolution of m times 0.001 GHz.
Min-configurable-output-power	/oc-opt-term-properties:linecard-descriptors/linecard-descriptor/compatible-transceivers/compatible-transceiver/constrained-compatible-modes/constrained-compatible-mode/optical-channel-config-value-constraints/state/min-output-power	[redacted]	CMIS 5.0	ProgOutputPowerMin	04h:198-199:2	Yes	Alignment between vendors, no comments.
Max-configurable-output-power	/oc-opt-term-properties:linecard-descriptors/linecard-descriptor/compatible-transceivers/compatible-transceiver/constrained-compatible-modes/constrained-compatible-mode/optical-channel-config-value-constraints/state/max-output-power	[redacted]	CMIS 5.0	ProgOutputPowerMax	04h:200-201	Yes	Alignment between vendors, no comments.
List of available operational-modes (application-codes)	/oc-opt-term:terminal-device/operational-modes	[redacted]	CMIS 5.0	*Appsel codes*	00h:86-117 01h:223-250	Yes	Alignment between vendors, no comments.
Min-tolerable-input-power	/oc-opt-term-properties:operational-mode-descriptors/operational-modes/mode-descriptors/mode-descriptor/state/min-input-power	[redacted]	CMIS 5.0	Lane-specific monitor thresholds OpticalPowerRxLowAlarmThreshold	02h:176-199 02h:194-195	Partial	The alignment is that this attribute shall be mappable to the Lane-Related Monitor Thresholds (Page 02h) included in Table 8-55 of CMIS 5.0, in particular OpticalPowerRxLowAlarmThreshold was proposed by one of the vendors however it is observed that the mapping to OpenConfig is not 1:1, since the proposed mappable attributed in CMIS is a register that indicates an alarm threshold, not the required input sensitivity.

Table 4. Use Case 1.2 - Physical Inventory discovery. a. ZR+ coherent transceiver pluggable hardware inventory information discovery

OpenConfig Model Attribute	OpenConfig xpath	[redacted]	Minimun Available CMIS / C-CMIS Version	CMIS / C-CMIS Field Name	CMIS / C-CMIS Register (Page/Byte/Bits)	Alignment between vendors	Conclusions and remarks
Part Number	/oc-platform:components/component/state/part-no /components/component/oc-transceiver:transceiver/oc-transceiver:state/oc-transceiver:vendor-part	[redacted]	CMIS 5.0	VendorPN	00h:148-163:16	Yes	Alignment between vendors about CMIS implementation. There exist two different xpaths in OpenConfig which shall be filled with the same value extracted from CMIS.
Serial Number	/oc-platform:components/component/state/serial-no /components/component/oc-transceiver:transceiver/oc-transceiver:state/oc-transceiver:serial-no	[redacted]	CMIS 5.0	VendorSN	00h:166-181:16	Yes	Alignment between vendors about CMIS implementation. There exist two different xpaths in OpenConfig which shall be filled with the same value extracted from CMIS.
Manufacturer name	/oc-platform:components/component/state/mfg-name /components/component/oc-transceiver:transceiver/oc-transceiver:state/oc-transceiver:vendor	[redacted]	CMIS 5.0	VendorName	00h:129-144:16	Yes	Alignment between vendors about CMIS implementation. There exist two different xpaths in OpenConfig which shall be filled with the same value extracted from CMIS.
Software-version	/oc-platform:components/component/state/software-version	[redacted]				N/A	This attribute shall be skiped or mapped to the same value as the Firmware-version.
Firmware-version	/oc-platform:components/component/state/firmware-version	[redacted]	CMIS 5.0	ModuleActiveFirmwareMajorRevision / ModuleActiveFirmwareMinorRevision	00h:39 / 00h:40	Yes	Active (00h:39-40) and Inactive (01h:128-129) Firmware revision .
Connector Type	/components/component/oc-transceiver:transceiver/oc-transceiver:state/oc-transceiver:connector-type	[redacted]	CMIS 5.0	ConnectorType	00h:203	Yes	Values are specified in SFF-8024..

Form Factor	/components/component/oc-transceiver:transceiver/oc-transceiver:state/oc-transceiver:form-factor	[redacted]	CMIS 5.0	SFF8024Identifier	00h:128	Yes	Values are specified in SFF-8024.
Power-consumption	/oc-platform:components/component/state/used-power		CMIS 5.0	MaxPower	00h:201: 7-0	Yes	Alignment between vendors, no comments.
Temperature	/oc-platform:components/component/state/temperature /components/component/oc-transceiver:transceiver/:physical-channels/channel/state/laser-temperature/instant		CMIS 5.0	ModuleTempMax/ ModuleTempMin	01h:146-147:7-0	Yes	Alignment between vendors, no comments.
Admin-state	/oc-platform:components/component/oc-transceiver:transceiver/oc-transceiver:state/oc-transceiver:enabled		CMIS 5.0	FirmwareStatus	0100h:9Fh:136	No	"7.3.1.4 Firmware Administration and Status" CMIS 5.0 section. Agreed by both vendors.
Operational-state	/oc-platform:components/component/state/oper-status		CMIS 5.0	FirmwareStatus	0100h:9Fh:136	Yes	TIP to clarify what information is expected as the "operational state". While the FirmwareStatus (0100h:9Fh:136) was found the most direct mapping from the vendors perspective, the module state in 00h:3:3-1 could also be a valid parameter too. Moreover, another alternative would be to use the "data path state" 11h: 128-131 which shows if traffic can be carried.
Laser tx-status	/oc-platform:components/component/oc-transceiver:transceiver/physical-channels/channel/state/tx-laser		CMIS 5.0	TuningInProgressTx<n>	12h:222-229.1	Yes	The solution proposed is documented in "8.10 Banked Page 12h (Tunable Laser Control and Status)" CMIS 5.0 section. Both vendors agreed on this. There is another register called in CMIS "WavelengthUnlockStatus" which might be more appropriate to enable/disable the laser, to be discussed.

Table 5. Use Case 1.3 - ZR+ coherent transceiver pluggable discovery logical inventory.

OpenConfig Model Attribute	OpenConfig xpath	[redacted]	Minimun Available CMIS / C-CMIS Version	CMIS / C-CMIS Field Name	CMIS / C-CMIS Register (Page/Byte/Bits)	Alignment between vendors	Conclusions and remarks
Client mapping mode (1x400, 2x200G, 4x400G)	/terminal-device/logical-channels/channel/config/client-mapping-mode		CMIS 5.0	HostInterfaceIDAppxx	00h:86-117 01h:223-250	Yes	Documented as part of the Application Descriptors, This attribute can be inferred by the information provided in the HostInterfaceId..
Tributary Protocol (OTUcN, OTU4, 400GE, 100GE..)	/terminal-device/logical-channels/channel/state/trib-protocol		CMIS 5.0	HostInterfaceIDAppxx	00h:86-117 01h:223-250	Yes	Documented as part of the Application Descriptors, This attribute can be inferred by the information provided in the MediaInterfaceId.
OTN Frame Mapping (GFP-T, GFP-F, GMP, IMP…)	/terminal-device/logical-channels/channel/logical-channel-assignments/assignment/config/mapping		N/A			Yes	Seems to not be supported by the standard CMIS 5.0
Line Rate / Baud Rate	/terminal-device/logical-channels/channel/config/rate-class		CMIS 5.0	MediaInterfaceID	00h:86-117 01h:223-250	Yes	Documented as part of the Application Descriptors, This attribute can be inferred by the information provided in the MediaInterfaceId.

Table 6. Use Case 2 - DWDM network planning (including physical impairment validation) for IPoDWDM-based services.

OpenConfig Model Attribute	OpenConfig xpath	[redacted]	Minimun Available CMIS / C-CMIS Version	CMIS / C-CMIS Field Name	CMIS / C-CMIS Register (Page/Byte/Bits)	Alignment between vendors	Conclusions and remarks
mode-id	/operational-mode-descriptors/operational-modes/state/mode-id		CMIS 5.0	AppSelCode	00h:86-117 / 01h:223-250	Yes	This attribute is mappable to the MediaInterfaceId. Please review sections 3.3 and 3.5 for more details of the analysis done.
modulation-format	/operational-mode-descriptors/operational-modes/state/modulation-format		CMIS 5.0	Included in the Mediainterfaceid	00h:86-117 / 01h:223-250	Yes	Documented as part of the Application Codes, This attribute can be inferred by the information provided in the MediaInterfaceId.
bit-rate	/operational-mode-descriptors/operational-modes/state/bit-rate		CMIS 5.0	Included in the Mediainterfaceid	00h:86-117 / 01h:223-250	Yes	Documented as part of the Application Codes, This attribute can be inferred by the information provided in the MediaInterfaceId.
baud-rate	/operational-mode-descriptors/operational-modes/state/baud-rate		CMIS 5.0	Included in the Mediainterfaceid	00h:86-117 / 01h:223-250	Yes	Documented as part of the Application Codes, This attribute can be inferred by the information provided in the MediaInterfaceId.

optical-channel-spectrum-width	/operational-mode-descriptors/operational-modes/state/optical-channel-spectrum-width	N/A			Yes	Not defined by the standard
filter/state/pulse-shaping-type	/operational-mode-descriptors/operational-modes/filter/state/pulse-shaping-type	N/A			Yes	Not defined by the standard
filter/state/roll-off	/operational-mode-descriptors/operational-modes/filter/state/roll-off	N/A			Yes	Not defined by the standard
min-tx-osnr	/operational-mode-descriptors/operational-modes/mode-descriptors/mode-descriptor/state/min-tx-osnr	N/A			Yes	Not defined by the standard
min-rx-osnr	/operational-mode-descriptors/operational-modes/mode-descriptors/mode-descriptor/state/min-rx-osnr	CMIS 5.0	HighAlarmThreshold28OSNR	29h:216-217	No	The definition and the position of VDM sample depend on the vendor, this register indicates alarm threshold. (not the input sensitivity)
min-input-power	/operational-mode-descriptors/operational-modes/mode-descriptors/mode-descriptor/state/min-input-power	CMIS 5.0	LowAlarmThreshold43(Rx Total Power)	2Ah:210-211	No	The definition and the position of VDM sample depend on the vendor, this register indicates alarm threshold. (not the input sensitivity)
max-input-power	/operational-mode-descriptors/operational-modes/mode-descriptors/mode-descriptor/state/max-input-power	CMIS 5.0	HighAlarmThreshold33Rx Total Power	2Ah:128-129	No	The definition and the position of VDM sample depend on the vendor, this register indicates alarm threshold. (not the input sensitivity)
max-chromatic-dispersion	/operational-mode-descriptors/operational-modes/mode-descriptors/mode-descriptor/state/max-chromatic-dispersion	CMIS 5.0			No	The definition and the position of VDM sample depend on the vendor. In this case, none of the vendors supported this attribute in their current implementation.
max-differential-group-delay	/operational-mode-descriptors/operational-modes/mode-descriptors/mode-descriptor/state/max-differential-group-delay	CMIS 5.0	HighAlarmThreshold25DGD	29h:192-193	No	The definition and the position of VDM sample depend on the vendor, this register indicates alarm threshold. (not the input sensitivity)
max-polarization-dependent-loss	/operational-mode-descriptors/operational-modes/mode-descriptors/mode-descriptor/state/max-polarization-dependent-loss	CMIS 5.0	HighAlarmThreshold27PDL	29h:208-209	No	The definition and the position of VDM sample depend on the vendor, this register indicates alarm threshold. (not the input sensitivity)
pre-fec-ber-threshold	/operational-mode-descriptors/operational-modes/mode-descriptors/mode-descriptor/state/pre-fec-ber-threshold	CMIS 5.0	HighAlarmThreshold51Pre-FEC BER Maximum Media Input (Data Path)	2Bh:144-145	No	The definition and the position of VDM sample depend on the vendor, this register indicates alarm threshold. (not the input sensitivity)
penalties/penalty	/operational-mode-descriptors/operational-modes/mode-descriptors/mode-descriptor/penalties/penalty	N/A			Yes	Not defined by the standard
penalties/penalty/parameter-and-unit	/operational-mode-descriptors/operational-modes/mode-descriptors/mode-descriptor/penalties/penalty/parameter-and-unit	N/A			Yes	Not defined by the standard
penalties/penalty/up-to-boundary	/operational-mode-descriptors/operational-modes/mode-descriptors/mode-descriptor/penalties/penalty/up-to-boundary	N/A			Yes	Not defined by the standard
penalties/penalty/state/penalty-value	/operational-mode-descriptors/operational-modes/mode-descriptors/mode-descriptor/penalties/penalty/state/penalty-value	N/A			Yes	Not defined by the standard
fec/state/fec-coding	/operational-mode-descriptors/operational-modes/fec/state/fec-coding	N/A			Yes	Not defined by the standard
fec/state/coding-overhead	/operational-mode-descriptors/operational-modes/fec/state/coding-overhead	N/A			Yes	Not defined by the standard
fec/state/coding-gain	/operational-mode-descriptors/operational-modes/fec/state/coding-gain	N/A			Yes	Not defined by the standard

Table 7. Use Case 3.1 - Creation/Deletion of an IP link over an Ethernet transport service over a ZR+ OTSi optical channel over WDM.

OpenConfig Model Attribute	OpenConfig xpath	Minimun Available CMIS / C-CMIS Version	CMIS / C-CMIS Field Name	CMIS / C-CMIS Register (Page/Byte/Bits)	Alignment between vendors	Conclusions and remarks
Operational-central-frequency	/components/component/oc-opt-term:optical-channel/oc-opt-term:config/oc-opt-term:frequency	CMIS 5.0	Frequency setting based on: - GridSpacingTx1 - ChannelNumberTx1 - FineTuningOffsetTx1 Laser frequency reading: - CurrentLaserFrequencyTx1	Three sets of registers are used to provision the tx frequency: - 12h:128: GridSpacingTx1 - 12h:136-137: ChannelNumberTx1 - 12h:152-153: FineTuningOffsetTx1 Current laser frequency can be read back from the following register - 12:168-169: CurrentLaserFrequencyTx1	Yes	No issues here, both vendors reported in the same format.
Target-output-power	/components/component/oc-opt-term:optical-channel/oc-opt-term:config/oc-opt-term:target-output-power	CMIS 5.0	TargetOutputPowerTx1	12h:200-201	Yes	No issues here, both vendors reported in the same format.
Selected-Operational-mode	/components/component/oc-opt-term:optical-channel/oc-opt-term:config/oc-opt-term:operational-mode	CMIS 5.0	ApSelCodeLanex	11h:206-213	Yes	Here both vendors seems refers to the same attribute in CMIS (AppSelCodeLane). The Active state 11h.206-213 is showing what has been programmed.
Admin-state					N/A	Here there is not alignment between the vendors, TIP might clarify what is expected as an Admin state.

Table 8. Use Case 4 - E2E Ethernet interface and OTSi service performance monitoring through streaming telemetry (gNMI subscription).

Attribute	OpenConfig xpath	Minimun Available CMIS / C-CMIS Version	CMIS / C-CMIS Field Name	CMIS / C-CMIS Register (Page/Byte/Bits)	Alignment between vendors	Conclusions and remarks
in-pcs-bip-errors	/terminal-device/logical-channels/channel/ethernet/state/in-pcs-bip-errors	N/A			Yes	Not defined by the standard
in-pcs-errored-seconds	/terminal-device/logical-channels/channel/ethernet/state/in-pcs-errored-seconds	N/A			Yes	Not defined by the standard
in-pcs-severely-errored-seconds	/terminal-device/logical-channels/channel/ethernet/state/in-pcs-severely-errored-seconds	N/A			Yes	Not defined by the standard
in-pcs-unavailable-seconds	/terminal-device/logical-channels/channel/ethernet/state/in-pcs-unavailable-seconds	N/A			Yes	Not defined by the standard
out-pcs-bip-errors	/terminal-device/logical-channels/channel/ethernet/state/out-pcs-bip-errors	N/A			Yes	Not defined by the standard
out-crc-errors	/terminal-device/logical-channels/channel/ethernet/state/out-crc-errors	N/A			Yes	Not defined by the standard
out-block-errors	/terminal-device/logical-channels/channel/ethernet/state/out-block-errors	N/A			Yes	Not defined by the standard
errored-seconds	/terminal-device/logical-channels/channel/otn/state/errored-seconds	N/A			Yes	Not defined by the standard
severely-errored-seconds	/terminal-device/logical-channels/channel/otn/state/severely-errored-seconds	N/A			Yes	Not defined by the standard
unavailable seconds	/terminal-device/logical-channels/channel/otn/state/unavailable-seconds	N/A			Yes	Not defined by the standard
background-block-errors	/terminal-device/logical-channels/channel/otn/state/background-block-errors	N/A			Yes	Not defined by the standard
input-power	/components/component/port/oc-line-com:optical-port/oc-line-com:state/oc-line-com:input-power	CMIS 5.0	OpticalPowerRx1	11h:186-187	Yes	Both vendors are aligned on the agreed solution.
output-power	/components/component/port/oc-line-com:optical-port/oc-line-com:state/oc-line-com:output-power	CMIS 5.0	OpticalPowerTx1	11h:154-155	Yes	Both vendors are aligned on the agreed solution.
fec-corrected-bytes	/terminal-device/logical-channels/channel/otn/state/fec-corrected-bytes	N/A			Yes	Not defined by the standard

fec-corrected-bits	/terminal-device/logical-channels/channel/otn/state/fec-corrected-bits	CMIS 5.0	rxCorrBitsPm	Page 34h:144-51	Yes	No issues here, both vendors reported in the same format.
q-value instant	/terminal-device/logical-channels/channel/otn/state/q-value/instant	CMIS 5.0 / C-CMIS 1.3	VDMSample151	26h:150-151	No	VDMSample151 (Q-Factor) at 26h:173-174, as defined in C-CMIS-1.3 (defined in section 7.3 Versatile Diagnostics Monitor (VDM) Extensions) seems to be the right appropiate implementation for this attribute. According with CMIS 5.0, Table 8-123 Page 24h-27h VDM Real-Time Values, the right register for VDMSample151 shall be: 26h:173-174. One vendor accept this approach while the other provided a different VDM sample : VDMSample137.
q-value average	/terminal-device/logical-channels/channel/otn/state/q-value/avg	CMIS 5.0 / C-CMIS 1.3	rxAvgQFactorPm	35h:230-231	No	rxAvgQFactorPm at 35h:230-231, as defined in C-CMIS-1.3 (defined in section 7.4.8 Media Lane Link Performance Monitoring (page 35h)) seems to be the right appropiate implementation for this attribute. One vendor accept this implementation while the other provided a different register value (35h:250-251).
q-value min	/terminal-device/logical-channels/channel/otn/state/q-value/min	CMIS 5.0 / C-CMIS 1.3	rxMinQFactorPm	35h:232-233	Yes	Not defined by standard of "C-CMIS version 1.1" . rxMinQFactorPm (35h:232-233) has been added in C-CMIS 1.3 (defined in section 7.4.8 Media Lane Link Performance Monitoring (page 35h)).
q-value max	/terminal-device/logical-channels/channel/otn/state/q-value/max	CMIS 5.0 / C-CMIS 1.3	rxMaxPmQFactor	35h:234-235	Yes	Not defined by standard of "C-CMIS version 1.1". rxMaxPmQFactor (35h:234-235) has been added in C-CMIS 1.3 (defined in section 7.4.8 Media Lane Link Performance Monitoring (page 35h)).
esnr instant	/terminal-device/logical-channels/channel/otn/state/esnr/instant	CMIS 5.0 / C-CMIS 1.3	VDMSample140	26h:150-151	No	Both vendors accept VDMSample140 (eSNR), as defined in C-CMIS-1.3 (defined in section 7.3 Versatile Diagnostics Monitor (VDM) Extensions), as the correct implementation. According with CMIS 5.0, "Table 8-123 Page 24h-27h VDM Real-Time Values", the right register for VDMSample140 shall be: 26h:150-151. However, the register provided by one vendor differs to the theoretical calculation based on CMIS 5.0 , (24h:136-137)
esnr average	/terminal-device/logical-channels/channel/otn/state/esnr/avg	CMIS 5.0 / C-CMIS 1.3	rxAvgEsnrPm	Page 35h:164-165	Yes	Defined in C-CMIS 1.3 (defined in section 7.4.8 Media Lane Link Performance Monitoring (page 35h)). Vendors agree.
esnr min	/terminal-device/logical-channels/channel/otn/state/esnr/min	CMIS 5.0 / C-CMIS 1.3	rxMinEsnrPm	Page 35h:166-167	Yes	Defined in C-CMIS 1.3 (defined in section 7.4.8 Media Lane Link Performance Monitoring (page 35h)). Vendors agree.
esnr max	/terminal-device/logical-channels/channel/otn/state/esnr/max	CMIS 5.0 / C-CMIS 1.3	rxMaxEsnrPm	Page 35h:168-169	Yes	Defined in C-CMIS 1.3 (defined in section 7.4.8 Media Lane Link Performance Monitoring (page 35h)). Vendors agree.
pre-fec-ber instant	/terminal-device/logical-channels/channel/otn/state/pre-fec-ber/instant	CMIS 5.0	VDMSample15 Pre-FEC BER Current Value Media Input (Data Path)	24h:156-157	No	Both vendors report that VDMs can be available in different registers. Hosts need to implement a VDM engine and abstract the register locations out of this. However, in this specific case, the CMIS 5.0 TABLE 8-122 VDM Observable types (see tab VDM Identifiers) defines: - Pre-FEC BER Current Value Media Input (Data Path) as VDMSample15, which according to "Table 8-123 Page 24h-27h VDM Real-Time Values", the correct register should be Page 24h:156-157. However the one of the vendors identified this other register as a candidate mapping: - FERC Current Value Media Input (Data Path) as VDMSample23, which according to "Table 8-123 Page 24h-27h VDM Real-Time Values", the correct register should be Page 24h:172-173. It should be discussed which of the two VDM observable types is the right one according to pre-fec-ber/instant definition in OpenConfig.
pre-fec-ber average	/terminal-device/logical-channels/channel/otn/state/pre-fec-ber/avg	CMIS 5.0	VDMSample13 Pre-FEC BER Average Media Input (Data Path)	24h:152-153	No	Both vendors report that VDMs can be available in different registers. Hosts need to implement a VDM engine and abstract the register locations out of this. However, in this specific case, the CMIS 5.0 TABLE 8-122 VDM Observable types (see tab VDM Identifiers) defines: - Pre-FEC BER Average Media Input (Data Path) as VDMSample13, which according to "Table 8-123 Page 24h-27h VDM Real-Time Values", the correct register should be Page 24h:152-153. - FERC Average Media Input (Data Path) as VDMSample21, which according to "Table 8-123 Page 24h-27h VDM Real-Time Values", the correct register should be Page 24h:168-169. It should be discussed which of the two VDM observable types is the right one according to pre-fec-ber/avg definition in OpenConfig. In this case, one the vendors was reporting this value at VDMSample211 (27h:164-165)

pre-fec-ber min	/terminal-device/logical-channels/channel/otn/state/pre-fec-ber/min	CMIS 5.0	VDMSample9 Pre-FEC BER Minimum Media Input (Data Path)	24h:144-145	No	Both vendors report that VDMs can be available in different registers. Hosts need to implement a VDM engine and abstract the register locations out of this. However, in this specific case, the CMIS 5.0 TABLE 8-122 VDM Observable types (see tab VDM Identifiers) defines: - Pre-FEC BER Minimum Media Input (Data Path) as VDMSample9, which according to "Table 8-123 Page 24h-27h VDM Real-Time Values", the correct register should be Page 24h:144-145. - FERC Minimum Media Input (Data Path) as VDMSample17, which according to "Table 8-123 Page 24h-27h VDM Real-Time Values", the correct register should be Page 24h:160-161. It should be discussed which of the two VDM observable types is the right one according to pre-fec-ber/min definition in OpenConfig. In this case, one the vendors was reporting this value at VDMSample193 (27h:128-129)
pre-fec-ber max	/terminal-device/logical-channels/channel/otn/state/pre-fec-ber/max	CMIS 5.0	VDMSample11 Pre-FEC BER Maximum Media Input (Data Path)	24h:148-149	No	Both vendors report that VDMs can be available in different registers. Hosts need to implement a VDM engine and abstract the register locations out of this. However, in this specific case, the CMIS 5.0 TABLE 8-122 VDM Observable types (see tab VDM Identifiers) defines: - Pre-FEC BER Maximum Media Input (Data Path) as VDMSample11, which according to "Table 8-123 Page 24h-27h VDM Real-Time Values", the correct register should be Page 24h:148-149. - FERC Maximum Media Input (Data Path) as VDMSample19, which according to "Table 8-123 Page 24h-27h VDM Real-Time Values", the correct register should be Page 24h:164-165. It should be discussed which of the two VDM observable types is the right one according to pre-fec-ber/max definition in OpenConfig. In this case, one the vendors was reporting this value at VDMSample202 (27h:152-153)
post-fec-ber instant	/terminal-device/logical-channels/channel/otn/state/post-fec-ber/instant	N/A			Yes	Not defined by the standard
post-fec-ber average	/terminal-device/logical-channels/channel/otn/state/post-fec-ber/avg	N/A			Yes	Not defined by the standard
post-fec-ber min	/terminal-device/logical-channels/channel/otn/state/post-fec-ber/min	N/A			Yes	Not defined by the standard
post-fec-ber max	/terminal-device/logical-channels/channel/otn/state/post-fec-ber/max	N/A			Yes	Not defined by the standard
errored-seconds	/terminal-device/logical-channels/channel/otn/state/errored-seconds	N/A			Yes	Not defined by the standard
severely-errored-seconds	/terminal-device/logical-channels/channel/otn/state/severely-errored-seconds	N/A			Yes	Not defined by the standard
unavailable seconds	/terminal-device/logical-channels/channel/otn/state/unavailable-seconds	N/A			Yes	Not defined by the standard
background-block-errors	/terminal-device/logical-channels/channel/otn/state/background-block-errors	N/A			Yes	Not defined by the standard
Rx Optical Power Avg	/components/component[name=n]/transceiver/physical-channels/channel[index=y]/state/input-power/avg	CMIS 5.0	xAvgPowerPm	Page 35h:188-189	Yes	No issues here, both vendors reported in the same format.
Rx Optical Power instant	/components/component[name=n]/transceiver/physical-channels/channel[index=y]/state/input-power/instant		VDMSample129Rx Total Power	26h:128-129	No	VDMs can be available in different registers. Hosts need to implement a VDM engine and abstract the register locations out of this. Question to vendors: Is there any source for alignment here, such as the information included in CMIS 5.0 TABLE 8-122 VDM Observable types (see tab VDM Identifiers)
Tx Optical Power Avg	/components/component[name=n]/transceiver/physical-channels/channel[index=y]/state/output-power/avg	CMIS 5.0	txAvgPowerPm	Page 35h:182-183	Yes	No issues here, both vendors reported in the same format.
Tx Optical Power instant	/components/component[name=n]/transceiver/physical-channels/channel[index=y]/state/output-power/instant		VDMSample80Tx Power	25h:158-159	No	VDMs can be available in different registers. Hosts need to implement a VDM engine and abstract the register locations out of this. Question to vendors: Is there any source for alignment here, such as the information included in CMIS 5.0 TABLE 8-122 VDM Observable types (see tab VDM Identifiers)
Rx Channel Power Avg	/components/component[name=n]/optical-channel/state/input-power/avg	CMIS 5.0	rxAvgSigPowerPm	35h:194-195	Yes	No issues here, both vendors reported in the same format.

Rx Channel Power instant	/components/component[name=n]/optical-channel/state/input-power/instant		VDMSample130Rx Signal Power	26h:130-131	No	VDMs can be available in different registers. Hosts need to implement a VDM engine and abstract the register locations out of this. Question to vendors: Is there any source for alignment here, such as the information included in CMIS 5.0 TABLE 8-122 VDM Observable types (see tab VDM Identifiers)
Tx Channel Power Avg	/components/component[name=n]/optical-channel/state/output-power/avg	CMIS 5.0	txAvgPowerPm	35h:182-183	Yes	No issues here, both vendors reported in the same format.
Tx Channel Power instant	/components/component[name=n]/optical-channel/state/output-power/instan		VDMSample80Tx Power	25h:158-159	No	VDMs can be available in different registers. Hosts need to implement a VDM engine and abstract the register locations out of this. Question to vendors: Is there any source for alignment here, such as the information included in CMIS 5.0 TABLE 8-122 VDM Observable types (see tab VDM Identifiers)

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