

Open ROADM Network Model

Version [7.1.0](#)

December 16, 2020

Document Revision History

Date	Revision	Description
July 14, 2016	1.0	Initial issuance
July 21, 2016	1.1	Document updated to incorporate comments from Fujitsu
March 30, 2018	2.2	Updated to reflect V2.2 Open ROADM data models
December 7, 2020	7.1.0	Document updated to have 7.1.0 model support

Table of Content

DOCUMENT REVISION HISTORY	2
1 OPEN ROADM NETWORK INFORMATION MODEL.....	5
1.1 NETWORK MODEL I2RS ENHANCEMENTS	5
1.2 CLLI-NETWORK LAYER	9
1.3 OPENROADM-NETWORK LAYER.....	10
1.4 OPENROADM-TOPOLOGY LAYER.....	11
1.4.1 Direction/Degree.....	12
1.4.2 Add/Drop Group / SRG	16
1.4.3 Logical Connectivity Links	20
1.4.4 Add/Drop Wavelength Representation	27
1.5 OTN TOPOLOGY LAYER:	30
1.5.1 Xponder	33
1.5.2 External Pluggable.....	34
1.6 TAIL CONCEPT AND SERVICE MODEL LINK.....	35
1.6.1 Tail	35
1.6.2 Service/Circuit.....	38
2 CAPACITY AND EQUIPMENT PLANNING.....	42
2.1 DIRECTION/DEGREE	42
2.2 ADD/DROP GROUP AND SRG	43
2.3 TRANSPONDER	43
2.4 EXTERNAL PLUGGABLE.....	43
2.5 TAIL	43
3 PATH COMPUTATION	43
4 INFORMATION CONSOLIDATION BETWEEN NETWORK MODEL AND DEVICE MODEL	45
4.1 ROADM.....	46
4.2 TRANSPONDER	48
4.3 PLUGGABLE MODULE	49

List of Figures

FIGURE 1-1. A GENERIC REPRESENTATION OF AN M -DEGREE ROADM WITH N ADD/DROP GROUPS (SRGs) ...	12
FIGURE 1-2. NETWORK REPRESENTATION OF A ROADM DEGREE.....	12
FIGURE 1-3. CONNECTIONS BETWEEN TWO ROADM NODES.	13
FIGURE 1-4. MULTI-WAVELENGTH TTP AND CTP IN THE DIRECTION/DEGREE CONSTRUCT.....	15
FIGURE 1-5. WAVELENGTH #4 (λ_4) IS ASSIGNED TO A SERVICE SUPPORTED BY DIR-1 OF A ROADM.	16
FIGURE 1-6. THREE ADD/DROP GROUPS CORRESPOND TO THREE SRGS.	17
FIGURE 1-7. (A) A PAIR OF CONNECTION POINTS (CPs) IS ASSIGNED TO EACH SRG IN AN ADD/DROP GROUP CONSTRUCT THAT CONTAINS THREE SRGS. (B) A "TAIL" FACILITY IS CREATED VIA THE 2 ND SRG IN A 3-SRG ADD/DROP GROUP.	18
FIGURE 1-8. (A) UNIQUE WAVELENGTHS ARE ENFORCED BY PCE AT THE CP'S OF C/D SRG (B) DUPLICATED WAVELENGTHS ARE ALLOWED AT THE CP'S OF C/D/C SRG.	19
FIGURE 1-9. LOGICAL EXPRESSLINKS REPRESENT CONNECTIVITY BETWEEN ROADM DEGREES.	21
FIGURE 1-10. LOGICAL DROP LINKS REPRESENT CONNECTIVITY BETWEEN ROADM DEGREES AND SRG.	22
FIGURE 1-11. LOGICAL ADD LINKS REPRESENT CONNECTIVITY BETWEEN ROADM DEGREES AND SRG.....	23

FIGURE 1-12. LOGICAL LINKS REPRESENT CONNECTIONS BETWEEN TWO DEGREES OF ROADM FOR EXPRESS-THROUGH TRAFFIC.	26
FIGURE 1-13. A SERVICE EXPRESS THROUGH DIR-1 AND DIR-2 USING WAVELENGTH #4 (BOTH DEGREES ARE SHOWN).....	27
FIGURE 1-14. LOGICAL LINKS REPRESENTING SERVICE TRAFFIC BEING TRANSMITTED BETWEEN A DEGREE CONSTRUCT AND TWO SRG CONSTRUCTS.	28
FIGURE 1-15. LOGICAL LINKS BETWEEN TWO DEGREE CONSTRUCTS AND TWO SRG CONSTRUCTS.....	28
FIGURE 1-16. A SERVICE IS ADDED AND DROPPED BETWEEN DIR-1 AND SRG #1.....	29
FIGURE 1-17. A TRANSPONDER IS USED TO SUPPORT CONNECTION WITH ROUTER.	33
FIGURE 1-18. CONNECTION BETWEEN PLUGGABLE IN ROUTER AND ADD/DROP GROUP.	34
FIGURE 1-19. AN INTRA-OFFICE TAIL.	36
FIGURE 1-20. CLIENT TAIL AND NETWORK TAIL IN METRO.	37
FIGURE 1-21. A SERVICE SUPPORTED BY THREE OPEN ROADM NODES.	39
FIGURE 3-1. TOPOLOGY OF A 4-NODE ROADM NETWORK.....	44
FIGURE 3-2. TAILS ARE PRE-DEPLOYED IN THE ROADM NETWORK.	44
FIGURE 3-3. TWO DIVERSE SERVICES ROUTED IN THE ROADM NETWORK.	45
FIGURE 4-1. INTERNAL LINKS INSIDE A WSS.....	47

List of Tables

TABLE 1-3. ATTRIBUTES ASSOCIATED TO A ROADM DEGREE.....	13
TABLE 1-4. ATTRIBUTES ASSOCIATED TO AN SRG.	19
TABLE 1-9 ATTRIBUTES OF OTN TOPOLOGY NODE.	30
TABLE 1-10. ATTRIBUTES OF OTN TOPOLOGY TERMINATION POINT.....	31
TABLE 1-11. ATTRIBUTES OF OTN LINKS.....	32
TABLE 1-6. ATTRIBUTES ASSOCIATED TO AN XPONDER.	33
TABLE 1-7. EQUIPMENT STATES ASSIGNED BY ROADM CONTROLLER.	33
TABLE 1-8. ATTRIBUTES ASSOCIATED TO A PLUGGABLE IN PACKET BOX.	35
TABLE 1-12. ATTRIBUTES ASSOCIATED TO A TAIL FACILITY.	38
TABLE 1-13. PARAMETERS PROVIDED BY THE SDN-C IN A SERVICE/CIRCUIT REQUEST.	39
TABLE 1-14. A-TO-Z LAYOUT OF A ROADM FACILITY MAINTAINED IN THE NETWORK LEVEL.	40
TABLE 1-15. EXAMPLE OF AN A-TO-Z LAYOUT OF A ROADM FACILITY IN THE NETWORK LEVEL.	40
TABLE 1-16. Z-TO-A LAYOUT OF A SERVICE MAINTAINED IN THE NETWORK LEVEL.....	41
TABLE 1-17. EXAMPLE OF AN Z-TO-A LAYOUT OF A ROADM FACILITY IN THE NETWORK LEVEL.	41
TABLE 1-18. EXAMPLE OF A TAIL FACILITY.....	42

The data collected in the Inventory Database in the Open ROADM Control Layer depends on how the equipment's information models are defined.

- The information model at the network level should be vendor-agnostic. It is used by the Open ROADM Control Layer to identify resources that are needed for creating services and the relationships of the network resources to each other.
- The information model at the device level is vendor specific. Inventory data collected based on the device model is specific to vendors' equipment and configurations.

1 Open ROADM Network Information Model

1.1 Network Model I2RS enhancements

The Network model from release 4.x onwards is based on [RFC-8345](#) and uses [ietf-network@2018-02-26.yang](#) and [ietf-network-topology@2018-02-26.yang](#) as base models. The Open ROADM Network model provides augmentations to these models. The augmentations contain attributes specific to the network elements and links of DWDM and OTN layer.

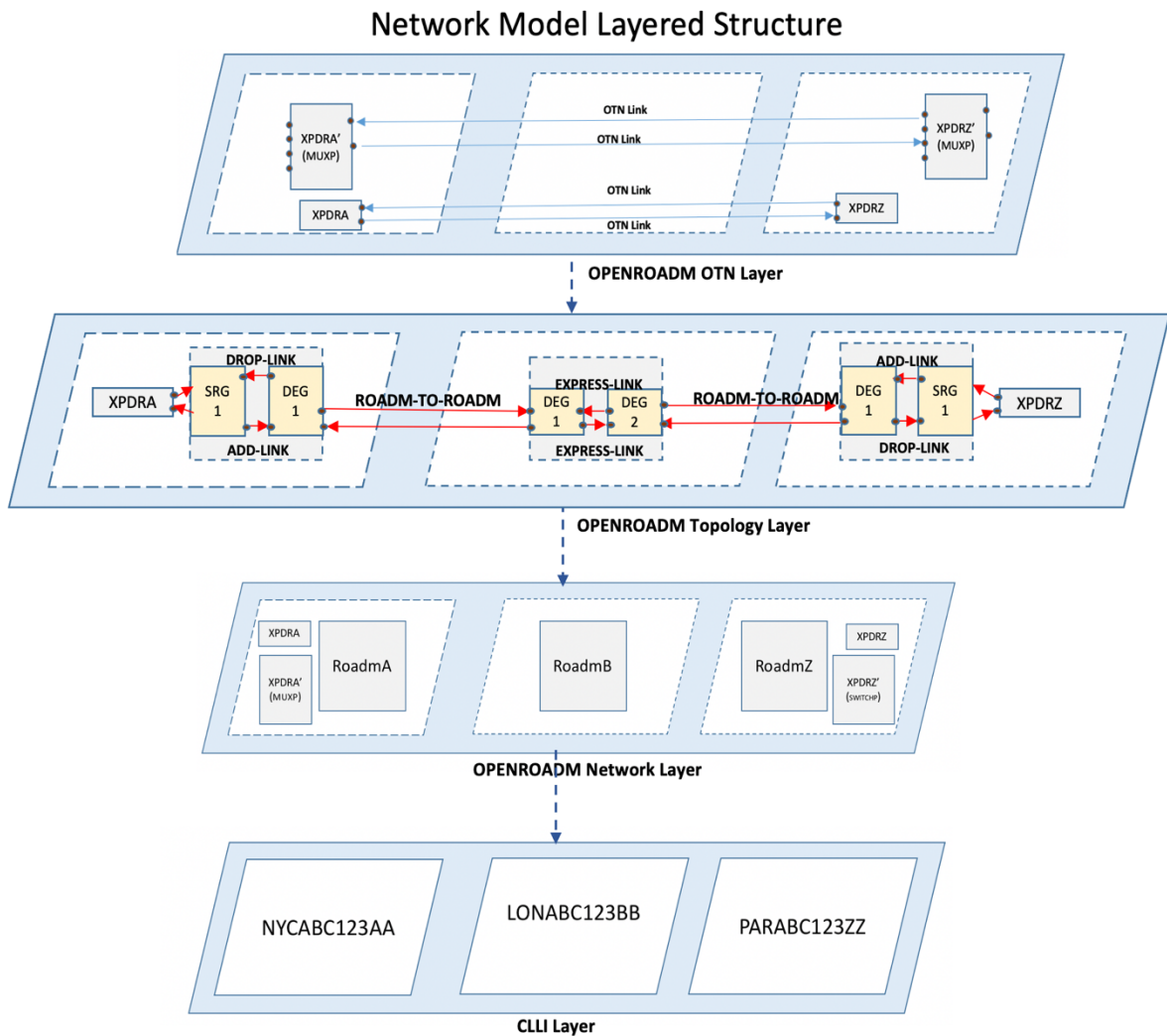


Figure 1-0. Three layered architecture for DWDM network

The DWDM network is divided into 3 layers to simplify network monitoring and management. The OTN network is modelled as an additional layer that builds on top of the DWDM OPENROADM topology layer. Each layer is uniquely identified in the network based on the attribute “network-id” and has its own set of nodes and optionally termination points and links. A node in a layer is uniquely identified with the attribute “node-id” and within the entire network based on combination of the network-id and node-id. A link in a layer is uniquely identified based on the “link-id” attribute and within the entire network using combination of network-id and link-id. The attributes “network-ref”, “node-ref” and “link-ref” hold the network-id, node-id and link-id of their respective parents (supporting-nodes).

The naming convention for “network-id” is as follows:

- **cli-network**

The cli-network layer holds the list of all the office locations where the OpenROADM equipment (ROADM, transponder, Muxponder etc.) can be planned or deployed. Nodes in the layer are office locations. Termination points for this layer can be ROADMs, transponders or other OpenROADM equipment located in the office. Links and termination points may be optionally added into CLI layer. The value of CLI (office) in this layer is based on preference of the service provider.

- **openroadm-network**

This layer holds equipment management level information such as vendor, IP, plan due date, maintenance schedule, shelf, model, software version etc. The “network-ref” for this layer is openroadm-network . The network-ref of its supporting network (or parent) is cli-network and all the nodes within same CLI (office) will point to the same CLI node in the cli-network. The openroadm-network layer is an underlay to the cli layer. This layer can have termination points and links depending on service provider’s preference. It inventories all the OpenROADM equipment planned or deployed in the network.

Openroadm-network layer can have following node types:

1. ROADM
2. XPONDER
3. EXT-PLUGGABLE

- **openroadm-topology**

The openroadm-topology layer holds the disaggregated view (degree and SRG for ROADM, multiple transponder card within an xponder) of the OpenROADM equipment. Information in this layer can be used by applications such as PCE (path computation engine), provisioning, power control etc. Each node in this layer is expected to have a number of “termination-points” that map directly to the attribute “logical-connection-point” in the device model. Spectrum availability or usage for each termination point should be reflected using avail-freq-maps/used-wavelengths. Spectrum usage should be updated after every service turn-up/turn-down to reflect the available spectrum.

Openroadm-topology layer can have following node types:

1. DEGREE

A degree node will have following termination point types if ports are bi-directional:

- a. DEGREE-TXRX-TTP
- b. DEGREE-TXRX-CTP

And the following if ports are unidirectional:

- a. DEGREE-TX-TTP
- b. DEGREE-RX-TTP
- c. DEGREE-TX-CTP
- d. DEGREE-RX-CTP

2. SRG

A SRG node will have following termination point types if ports are bi-directional:

- a. SRG-TXRX-CP
- b. SRG-TXRX-PPn (count based on device)

And the following if ports are unidirectional:

- a. SRG-TX-CP
- b. SRG-TX-PPn (count based on device model)
- c. SRG-RX-CP
- d. SRG-RX-PPn (count based on device model)

3. TPDR or MUXPDR or SWITCH

A transponder/Muxponder or OTN switch, based on the device manufacturer can have following set of termination point types:

- a. XPONDER-NETWORK (count based on device model)
- b. XPONDER-CLIENT (count based on device model)

4. REGEN or REGEN-UNI

A bidirectional or unidirectional REGEN node can have following termination points types:

- a. XPONDER-NETWORK (count based on device model)
- b. XPONDER-CLIENT (count based on device model)

With release 2.x the devices model supports flexible grid capability for DWDM systems. In release 1.x, the fixed grid model was supported. Under the fixed grid OpenROADM systems, the wavelengths were uniquely identified with an attribute “wavelength-number” that ranged from 1 to 96 and each number had a predefined center frequency and wavelength. The mapping from wavelength number to center frequency and width was found in the file “org-openroadm-wavelength-map.txt”. However, in release 2.x the fixed grid model is replaced with the flex grid model. In flex grid systems, the mapping is no longer fixed. In order to support this capability in the network model each wavelength is referred based on arbitrary index that holds the frequency and width information for the signal (at nodes Degree, SRG, XPONDER etc.). The “index” attribute is used to store the grid less wavelengths within a node and may or may not be unique in the network based on controller implementation. Starting from network model release 5.0, available frequency maps are added into openroadm-topology layer, which represents 96 bytes of binary information and can describe the spectrum occupation (at Degree and SRG nodes). Frequency is the center frequency for the wave and is expressed in THz and width is expressed in GHz.

The Openroadm-topology layer also holds the information related to links external to a node, which can be of the following types:

- a. EXPRESS-LINK
- b. ADD-LINK
- c. DROP-LINK
- d. ROADM-TO-ROADM
- e. XPONDER-INPUT
- f. XPONDER-OUTPUT

Since all the disaggregated elements within a ROADM may not be fully connected (e.g. Degree N not connected to Degree N+1) the data for express, add and drop link can be derived from the physical or internal links or connection-map in the device model or a planning application that is aware of such restrictions. The data for ROADM-TO-ROADM links can be discovered by the controller based on the Link Layer Discovery Protocol (LLDP) information reported under the “protocols” subtree in the device model and validated against the planned state.

- **otn-topology**

The OTN network is modelled using OTN topology layer. It holds network information for OTN elements including Muxponders, OTN switches/switchponders, Transponders and Regens. OTN topology layer is built on top of openroadm-topology. This layer is consisting of nodes, termination points and links

The nodes in this layer are as follows:

- SWITCH
- MUXPDR
- TPDR
- REGEN
- REGEN-UNI

Since OpenROADM MSA release 3.0.0, a new layer has been added to the Network models. This layer is named '**openroadm-common-network**'. It does not modify the existing layers hierarchy of the Network model and will not show up in the logically abstracted view shown in [Figure 1-0](#).

Openroadm-common-network layers is added to simplify the manageability of the yang code. The common parameters that were earlier defined multiple times in different files are now put in the single file org-openroadm-common-network.yang and it augments into I2RS node, termination point and link directly.

The attributes that have been moved into openroadm-common-network are defined in Table 1-1, 1-2 and 1-3.

Table 1-1. Augments associated to I2RS node.

<i>Attribute</i>	<i>Description</i>	<i>Note</i>
<i>node-type</i>	Specification of the type of the node, ROADM, DEGREE, SRG, XPONDER, EXT-PLUGGABLE, TPDR, MUXPDR, REGEN, REGEN-UNI, SWITCH..	Data from planning
<i>lifecycle-state</i>	Life cycle state of a node (planned, deployed or maintenance)	
<i>operational-state</i>	Operational state of the node	Set by SDN controller
<i>administrative-state</i>	Administrative state of the node	Set by SDN controller

Table 1-2. Augments associated to I2RS Termination Point.

<i>Attribute</i>	<i>Description</i>	<i>Note</i>
<i>tp-type</i>	Type of termination point e.g TTP, CTP,...	
<i>physical-tp</i>	True when the termination point maps to ports of an existing circuit-pack, False, when mapped to a slot (pluggable optics Holder) --> virtual tp	Applies to Termination Points that map to physical ports or slots on circuit packs. This attribute is not present for other Termination Points.
<i>associated-connection-map-tp</i>	Used to identify relationships between client and network ports in transponders and uni-directional regens. Provides the list of tps the tp is connected to, as defined in the device connection map.	

<i>Attribute</i>	<i>Description</i>	<i>Note</i>
<i>eqpt-srg-id</i>	Shared Risk Group identifier for the termination point.	All ports in a circuit-pack will have same srg-id
<i>lifecycle-state</i>	Life cycle state of a termination point (planned, deployed or maintenance)	Set by SDN controller
<i>operational-state</i>	Operational state of the tp	Set by SDN controller
<i>administrative-state</i>	Administrative state of the tp	Set by SDN controller

Table 1-3. Augments associated to I2RS link.

<i>Attribute</i>	<i>Description</i>	<i>Note</i>
<i>link-type</i>	Link type e.g. EXPRESS-LINK, ADD-LINK, DROP-LINK, OTN-LINK etc.	Add, Drop and Express links can be auto detected based on connection map from the device. ROADM-TO-ROADM can be detected using LLDP subtree from the device model. Xponder-input, Xponder-output Links data from planning. OTN-link created by controller if an OTN service exists between endpoints
<i>clfi</i>	Unique identifier of the link	Data from planning
<i>opposite-link</i>	Identifier of the link carrying traffic in opposite direction	
<i>link-length</i>	Link-length in kilometers	Data from planning
<i>link-latency</i>	Latency of link milliseconds	Data from planning
<i>TE-metric</i>	Traffic engineering metric which could be used for any type of link	
<i>Link-concatenation</i> <ul style="list-style-type: none"> <i>SRLG-ID</i> <i>SRLG-length</i> 		Data from planning
	Unique identifier for SRLG	
	Fiber length in meters	
<i>administrative-group?</i>	Defined in RFC 3630 section 2.5.9. Corresponds to the value of one or more administrative groups the links belongs to.	Data from planning
<i>Operational-state</i>	Operational state of the link	Set by SDN controller
<i>Administrative-state</i>	Administrative state of the link	Set by SDN controller
<i>lifecycle-state</i>	Life cycle state of a termination point (planned, deployed or maintenance)	Set by SDN controller

1.2 CLLI-network layer

The clii-network layer holds the list of all the office locations where the OpenROADM equipment (ROADM, transponder etc.) can be planned or deployed. Nodes in the layer are office locations. The value of node-id/clii,

termination points and links in this layer can be based on preference of the service provider. A node attributes for this layer are listed in table 1-4.

Table 1-4 Attributes associated to a CLLI Layer node.

<i>Attribute</i>	<i>Description</i>	<i>Note</i>
<i>cli</i> <i>node-id</i>	Location CLLI where ROADM resides	Data from planning
	Network-wide unique identifier for an openroadm node (ietf-network attribute)	office CLLI

1.3 Openroadm-network layer

This layer holds equipment management level information such as vendor, IP, plan due date, maintenance schedule, shelf, model, software version. The “network-ref” of the parent/supporting layer is cli-network and all the nodes within same CLLI (office) will point to the same CLLI node in the cli-network. The openroadm-network layer is an underlay to the cli layer. It inventories all the OpenROADM equipment planned or deployed in the network.

Nodes in this layer are as follows:

1. ROADM
2. XPONDER
3. EXT-PLUGGABLE

Node attributes for openroadm-network layer are listed below in table 1-5:

Table 1-5 Attributes associated to a OpenRoadm Network Layer node.

<i>Attribute</i>	<i>Description</i>	<i>Note</i>
<i>node-id</i>	Network-wide unique identifier for an openroadm node	Constructed by concatenating office identifier, bay identifier, shelf identifier
<i>supporting-node</i> <ul style="list-style-type: none"> • <i>network-ref</i> • <i>node-ref</i> 	Reference to supporting network and node with in supporting network layer	Set by SDN controller
<i>software-version</i>	Vendor software version	Data obtained from device
<i>openroadm-version</i>	OpenROADM yang model release version	Data obtained from device
<i>vendor</i>	Identifier of the supplier for the openroadm equipment	Data from planning, if life cycle state is planned
<i>model</i>	Identifier of the supplier’s equipment	Data from planning, if life cycle state is planned
<i>domain-subnetwork</i>	Specific Domain-Subnetwork in which the openroadm devices resides	Data from planning, if life cycle state is planned
<i>ip</i>	IP address assigned to the openroadm node	Data from equipment engineering, if life cycle state is planned
<i>relay-rack</i>	Frame Identification Code (FIC)	Data from equipment engineering, if life cycle state is planned

<i>shelf</i>	Shelf in which the NE controller is equipped	Data from equipment engineering, if life cycle state is planned
<i>node-connection-status</i>	Status of connection between Device and Controller. Possible values are: CONNECTED, CONNECTING, UNABLE-TO-CONNECT	Set by SDN controller
<i>roadm-attributes</i> <ul style="list-style-type: none"> • <i>max-degrees</i> • <i>max-srgs</i> • <i>current-degrees</i> • <i>current-srgs</i> 	Roadm information like max and current number of degrees and SRGs.	Data obtained from device
<i>xpdr-attributes</i> <ul style="list-style-type: none"> • <i>customer-code</i> 	Xponder attributes like customer code.	Data obtained from device
<i>pluggable-attributes</i> <ul style="list-style-type: none"> • <i>pluggable-id</i> • <i>customer-code</i> • <i>tail</i> <ul style="list-style-type: none"> – <i>client-equipment</i> – <i>client-equipment-id</i> – <i>clfi</i> 	Pluggable attributes like customer code and tail.	Data obtained from device
<i>plan-due-dates</i> <ul style="list-style-type: none"> • <i>due-dates</i> <ul style="list-style-type: none"> – <i>id</i> – <i>start-date</i> – <i>end-date</i> 	Start and End dates for planned node	Data from planning
<i>node-maintenance-schedule</i> <ul style="list-style-type: none"> • <i>due-dates</i> <ul style="list-style-type: none"> – <i>id</i> – <i>start-date</i> – <i>end-date</i> 	Maintenance schedule for the node	Data from planning

Please review network data models for more details on attributes and their enumeration values.

1.4 Openroadm-topology layer

The openroadm-topology layer holds the disaggregated view (degree and SRG for ROADM, multiple transponder card within an xponder) of the OpenROADM equipment.

Every ROADM is composed of a number of directions/degrees and a number of add/drop groups, as illustrated in [Figure 1-1](#). Thus, “direction/degree” and “add/drop group” are the two basic building blocks for a ROADM. In document we use add/drop group and SRG in the same context,

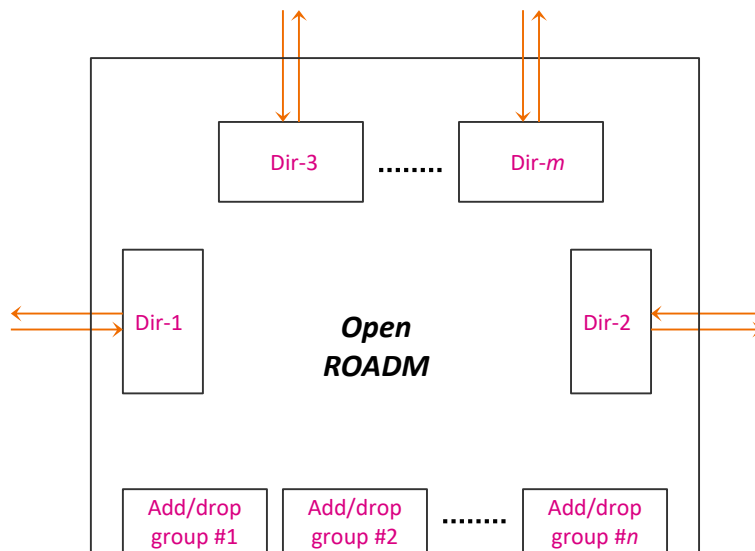


Figure 1-1. A generic representation of an m -degree ROADM with n add/drop groups (SRGs).

For colorless/directionless (C/D) ROADM or colorless/directionless/contentionless (C/D/C) ROADM, the directions/degrees and add/drop groups can be planned and deployed separately and independently.

1.4.1 Direction/Degree

At the network level, a degree of ROADM can be plainly made to have just external connections that are connected to another ROADM in an adjacent office and internal connections to support express and add/drop traffic. Thus, a direction/degree building block (or construct) can be represented by a pair of TTP's (trail termination points) and a pair of CTP's (connection termination points), as shown in [Figure 1-2](#).

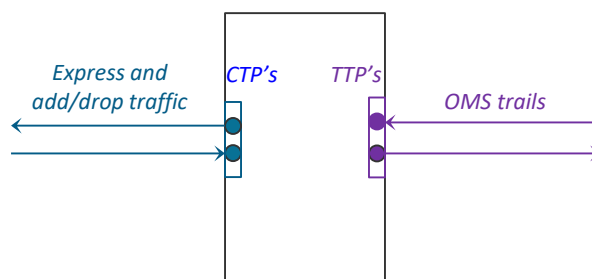


Figure 1-2. Network representation of a ROADM degree.

The two TTP's correspond to the incoming port of the pre-amp amplifier and the outgoing port of the booster amplifier in a direction/degree. The two physical ports supporting the TTPs are connected to another direction/degree of another ROADM in a neighboring office via outside plant (OSP) fiber. Inter-office OSP fiber is terminated on high-speed (HS) LGX in central offices. Thus, the two unidirectional links between the directions/degrees of two connected ROADM nodes are through HS LXs and OSP fiber, as shown in [Figure 1-3](#).

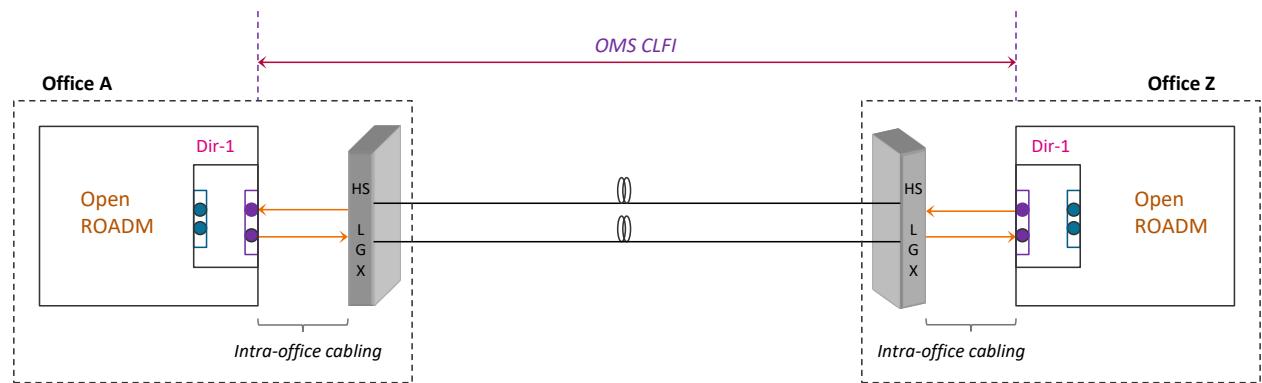


Figure 1-3. Connections between two ROADM nodes.

The HS LGX jack #s through which the ROADM's optical amplifiers are connected to outside plant fiber are identified manually through planning and equipment engineering process. The information can be transparent to the Network Model, but the information needs to be tracked in the Inventory Database in the Open ROADM Controller, i.e., the intra-office cabling shown in

[Figure 1-3](#) must be explicitly inventoried. LGX data is not yet part of OpenRoadm models.

The two CTP's correspond to multiple physical ports in the ROADM device where signals of express channels from other directions/degrees and signals of add/drop channels from different add/drop groups are received and transmitted. At the network level, those physical ports are combined into a transmit (Tx) CTP and a receive (Rx) CTP. The attributes associated to each degree of a ROADM are specified in Table 1-6:

Table 1-6. Attributes associated to a ROADM degree.

<i>Attribute</i>	<i>Description</i>	<i>Note</i>
<i>degree-number</i>	Identifier for each direction/degree	Data from planning
<i>max-wavelengths (N)</i>	Max number of wavelengths supported by a degree in fixed grid model	Data obtained from device
<i>ingress-span-loss-aging-margin</i>	Span-loss margin extracted from corresponding device OTS interface container, optional	Data obtained from device
<i>eol-max-load-pIn</i>	End Of Life Total input power at maximum load extracted from corresponding device OTS interface container	Derived from device
<i>egress-average-channel-power</i>	Total max power across the 4.8 THz passband	Set by SDN controller
<i>avail-freq-maps</i> <ul style="list-style-type: none"> <i>map-name</i> <i>start-edge-freq</i> <i>freq-map-granularity</i> <i>effective-bits</i> <i>freq-map</i> 	The spectrum occupation is defined by a list of available frequency maps. One map corresponds to one band (OpenROADM specifications only address C-Band at that time, so that only one map will be populated). For each map we define the start frequency, the map granularity which is derived from the device (it depends on the WSS technology and is provided in the device mc-capabilities), the number of effective bits used in the binary to cover all the spectrum (one bit corresponds to one elementary slot of the spectrum), and the freq-map, a binary, for which	Derived from the device and updated by SDN controller (freq-map)

<i>Attribute</i>	Description	Note
	the number of bits is defined by “effective-bits”. An available elementary slot will correspond to a 1. A used slot will correspond to a 0.	
<i>type-variety</i>	Equipment type variety defined by the Open ROADM MSA or by the vendor for bookending applications	

The TTP's and CTP's are logical ports. They are created to assist modeling of signal flow between devices. If each degree can support maximum of 96 wavelengths (i.e., the N in Table 1-6 equals to 96) in case of fixed grid, the TTP's are then modeled with 96 termination points in the transmit (Tx) direction and 96 termination points in the receive (Rx) direction. Similarly, the CTP's are modeled with 96 connection points in the transmit (Tx) direction and 96 connection points in the receive (Rx) direction. In the flex-grid model, the number of supported channels may vary according to their spectral-width. The CTP's are points associated to a specific degree where traffic inside a ROADM is aggregated from other degrees and from local add/drop groups of the ROADM. The TTP's are also points associated to a specific degree, however the traffic at those point is going to and coming from another ROADM that is connected through outside plant fiber.

[Figure 1-4](#) illustrates the multi-wavelength TTP's and CTP's in fixed grid model, where the incoming OMS trail is terminated at OMS-TTP-Rx. Using maximum of 96 wavelengths as the example, 96 termination points are

fanned out from OMS-TTP-Rx; each one can be assigned to a wavelength-level service. Similarly, 96 termination points are fanned out for the OMS-TTP-Tx in

[Figure 1-4](#) so that 96 wavelengths can be used for services to ride on the OMS trail to the other ROADM node. The CTP's are modeled the same way as TTP's. 96 wavelengths can be the input to the CTP-Rx in

[Figure 1-4](#), and, in the opposite direction, 96 wavelengths can be the output from the CTP-Tx.

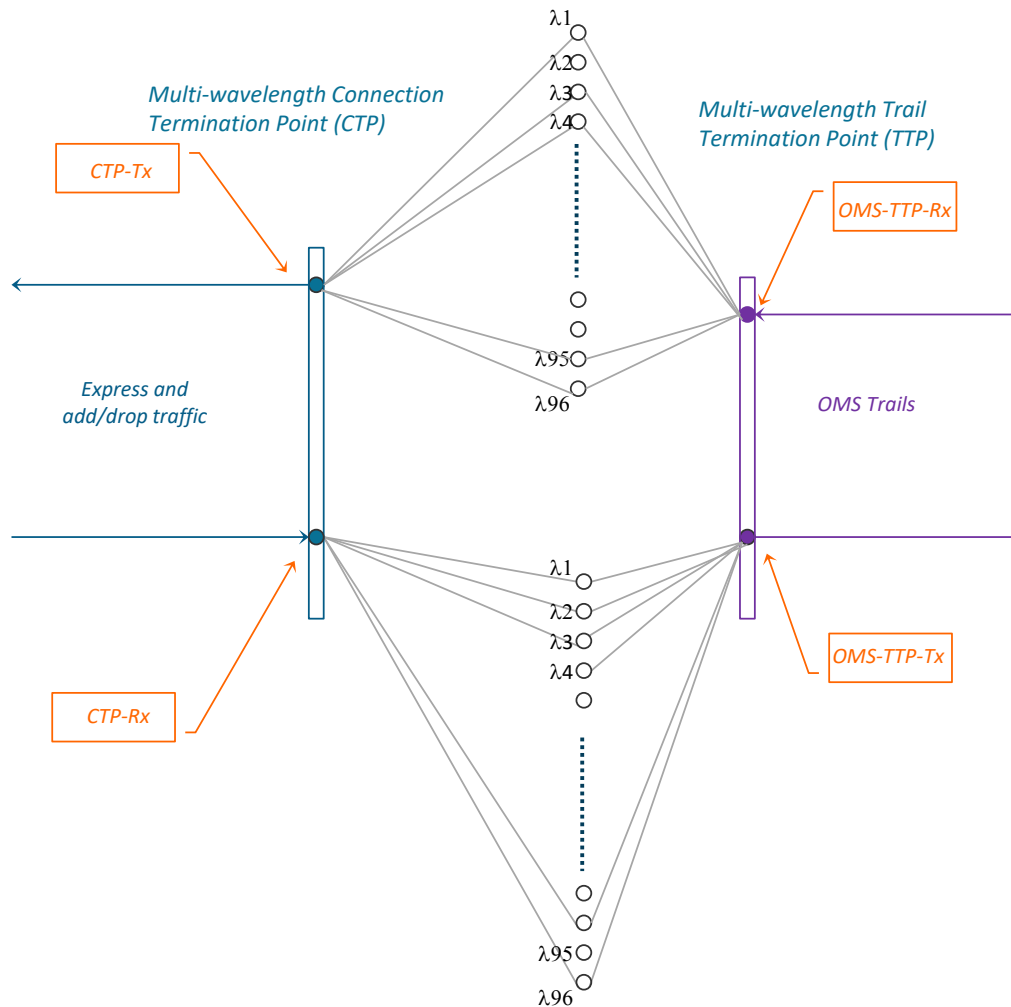


Figure 1-4. Multi-wavelength TTP and CTP in the Direction/Degree construct.

A service/circuit coming in one of a ROADM degree is received at its external OMS-TTP-Rx with a specific wavelength. The connection point of the same wavelength in the internal CTP is used to direct the signal to other part of the ROADM, e.g., in [Figure 1-5](#), λ_4 in CTP-Tx is matched to λ_4 in OMS-TTP-Rx. In the reverse direction, the same service received at CTP-Rx will be transmitted out to another ROADM via OMS-TTP-Tx. Therefore, the 96 connection termination points in CTP-Tx are one-to-one connected to the 96 trail termination points in OMS-TTP-Rx. The 96 connection termination points in CTP-Rx are one-to-one connected to the 96 trail termination points in OMS-TTP-Tx.

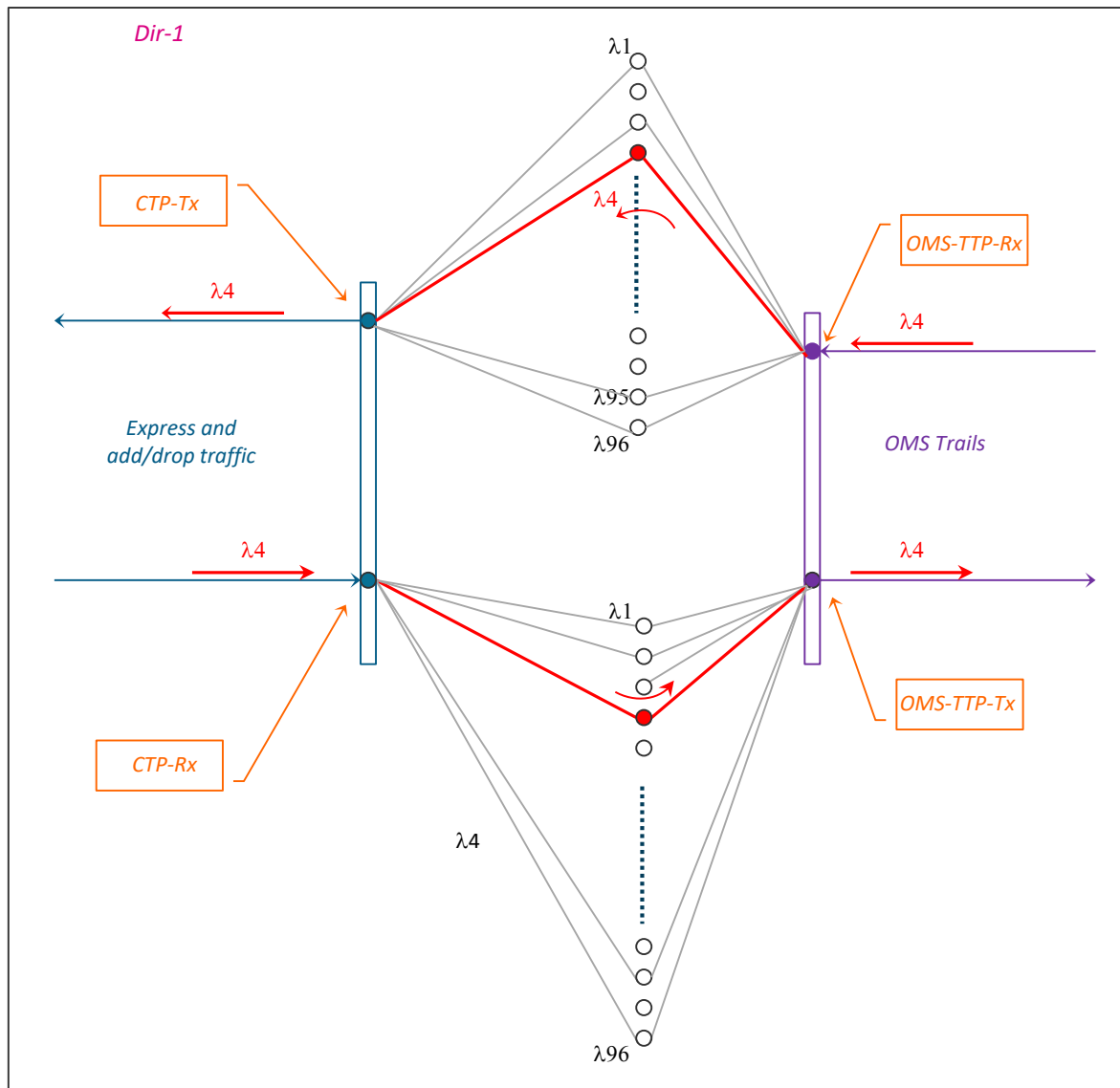


Figure 1-5. Wavelength #4 (λ_4) is assigned to a service supported by Dir-1 of a ROADM.

Since the OMS trails are terminated on the TTPs, tracking services that are routed on a particular OMS trail can be accomplished through the TTP associated to the OMS trail.

Starting release 5.0 available frequency maps are added as degree attribute to capture available spectrum information for roadms supporting flexible grid capability. Available frequency map has information regarding, starting edge frequency of the spectrum, frequency map granularity supported by the roadm, frequency map and number of effective bits in frequency map. Bits in the frequency map is decided by slot width granularity supported by roadm. For example, if a flex-grid roadm has 6.25 GHz of slot width granularity and 191,325 -196,125 THz of spectrum range then spectrum availability can be captured using 768 bits. Setting the value of the binary bit to 1 indicates that the corresponding spectrum is available and setting to 0 indicates the corresponding spectrum is unavailable. For more information on frequency map please refer to [RFC 8363](#)

1.4.2 Add/Drop Group / SRG

Each add/drop group (SRG) is equipped with a number of port pairs to support local add/drop traffic. Within each port pair (pp), there is one transmit (Tx) or OUT port and one receive (Rx) or IN port. Those Tx/Rx port pairs in an add/drop group may be supported by the same group of circuit packs or by different groups of circuit packs.

The equipment in a group shares the same risk and is considered a Shared Risk Group (SRG). Thus, the three add/drop groups shown in

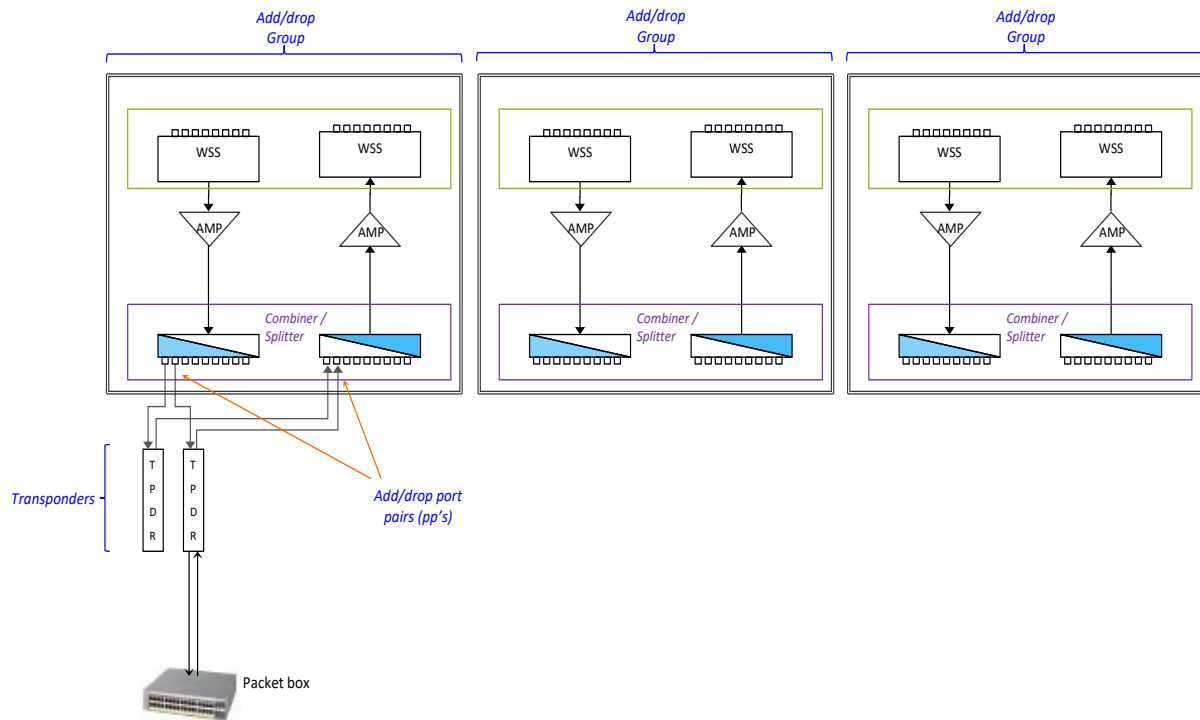


Figure 1-6. Three add/drop groups correspond to three SRGs.

The number of SRG's in an add/drop group varies depending on vendor's equipment configuration. Since the Open ROADM Controller needs the information to assign wavelength numbers for new services and select equipment SRGs to assign new services for add/drop, an add/drop group construct can be modeled at the network level to consist of a vendor specific number of SRGs, where each SRG is made up of

- A pair of CP's (Connection Points), one Tx CP and one Rx CP
- A vendor specific number of add/drop port pairs (pp's)

The add/drop port pairs are connected to transponders/muxponders to transport local traffic. The traffic is then directed to ROADM directions/degrees via the CP's.

[Figure 1-7](#)(a) depicts n add/drop groups with three SRGs within each add/drop group¹. A pair of CP's (Connection Points) is included each SRG. Applying the model to the add/drop example shown in [Figure 1-6](#), the configuration is simplified with three pairs of CP's and a "tail", as shown in [Figure 1-7](#)(b). The "tail" contains the packet box equipment and transponder that are pre-cabled together with the transponder being connected to an add/drop port pair (#4) in the 2nd SRG.

¹ Note: The OpenROADM v2.x models only support a 1:1 relationship between an add-drop group and SRGs.

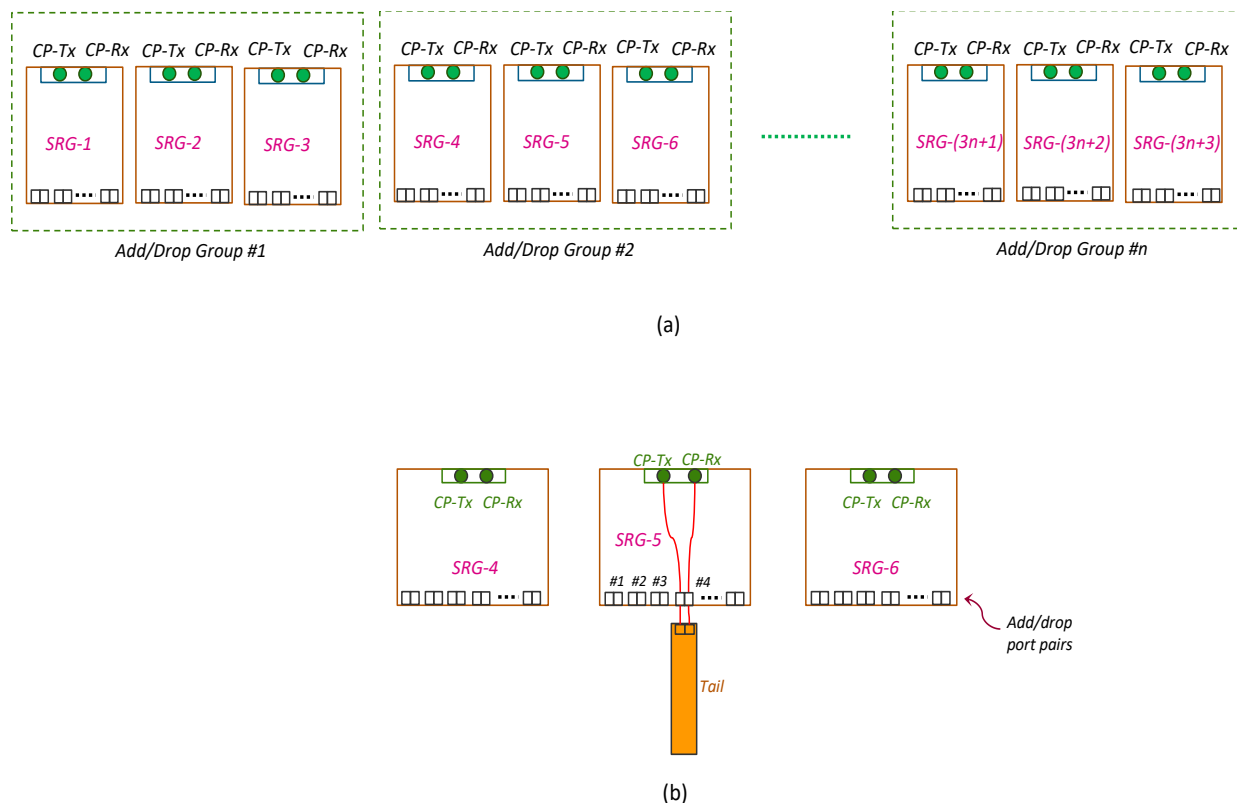


Figure 1-7. (a) A pair of Connection Points (CPs) is assigned to each SRG in an Add/drop group construct that contains three SRGs. (b) A “tail” facility is created via the 2nd SRG in a 3-SRG add/drop group.

The number of port pairs in an add/drop group or in an SRG is vendor specific. All those ports are used for intra-office connections between the ROADM and client equipment. The connections, also known as “tails”, may be direct interfaces with client equipment or may go through transponders or muxponders and intermediate LGXs (refer to Section 1.6 for tail equipment configurations).

SRGs are critical to the ROADM Controller to perform network functions, e.g., assigning services to equipment taking diversity routing constraint into consideration, due to the following:

- A C/D add/drop group will fail to function if there is an equipment problem in the group; hence the whole add/drop group is considered as one SRG.
- A C/D/C add/drop group is comprised of multiple SRGs. Equipment failure in one of the SRGs will bring down only one SRG; the other SRGs in the same add/drop group remain functional.

Thus, add/drop group construct is not required for the Network Model. Add/drop groups can be used for equipment planning and ordering but add/drop groups need to be converted to SRGs and included in the Network Model, e.g., the add/drop group numbers, i.e., 1, 2, ..., n, in Figure 1-7(a) can be transparent to the Network Model but the SRG numbers i.e., 1, 2, 3, 4, 5, 6, ..., 3n+1, 3n+2, 3n+3, in Figure 1-7(a) must be included in the Network Model.

Traffic routed through the CP's require wavelength assignment. The PCE in the ROADM Controller assigns wavelengths to services when services are first created. The CP's of C/D/C SRG support wavelength duplication, whereas the CP's of C/D SRG do not. This distinction is illustrated in

Figure 1-8(a) and

Figure 1-8(b).

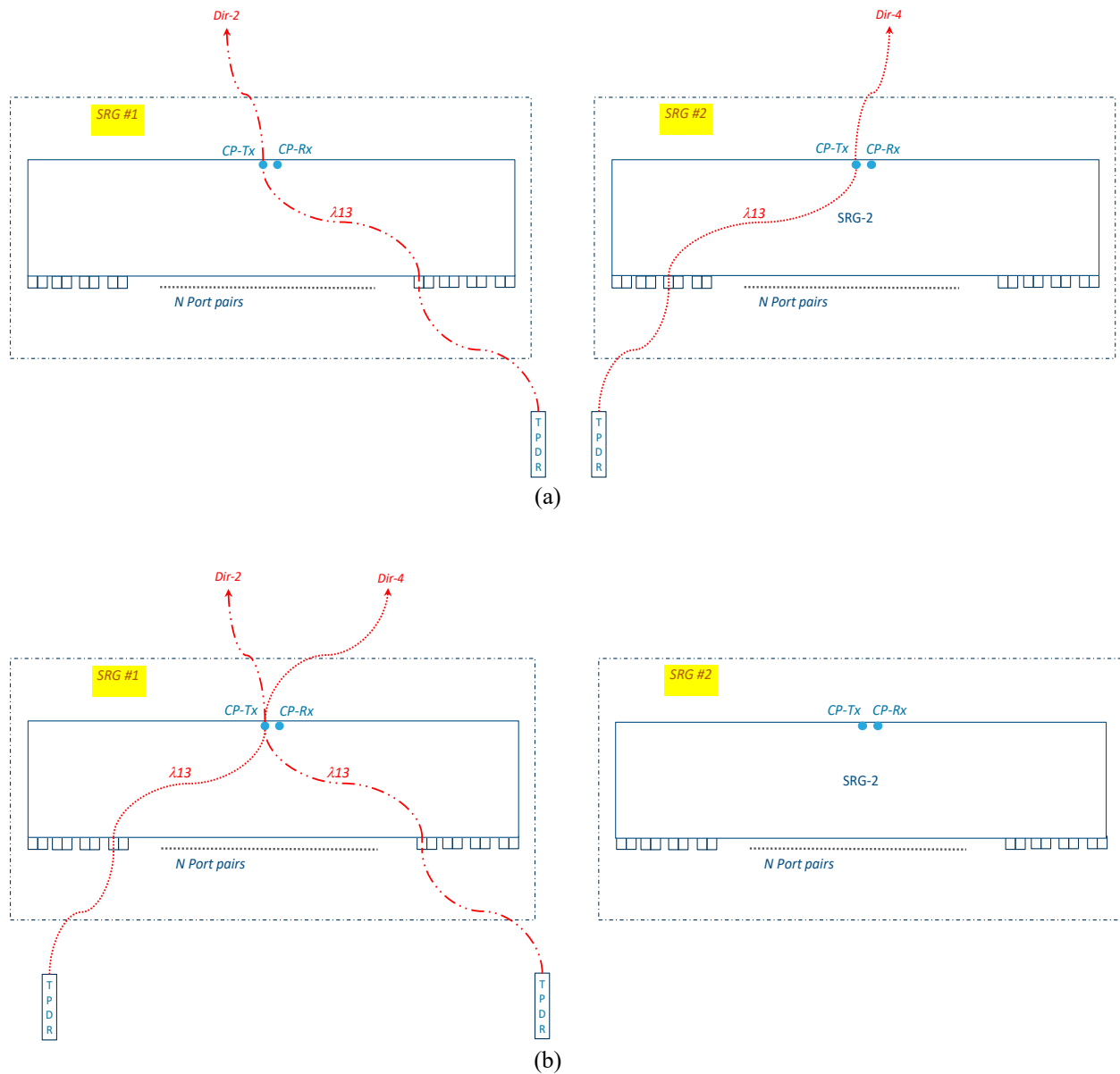


Figure 1-8. (a) Unique wavelengths are enforced by PCE at the CP's of C/D SRG (b) Duplicated wavelengths are allowed at the CP's of C/D/C SRG.

The information associated to each SRG of a ROADM contains the attributes specified in [Table 1-7](#):

Table 1-7. Attributes associated to an SRG.

<i>Attribute</i>	<i>Description</i>	<i>Note</i>
<i>srg-number</i>	Identifier for each SRG	Data from planning
<i>max-pp (N_{pp})</i>	Maximum number of add/drop port pairs in an SRG	Data from device Model

<i>Attribute</i>	<i>Description</i>	<i>Note</i>
<i>current-provisioned-pp</i>	Currently provisioned number of port pair in a given SRG	Data obtained from device
<i>Wavelength Duplication</i>	Enumerated value: <ul style="list-style-type: none"> • 1 – one per SRG • 2 – one per Degree 	Data from planning <ul style="list-style-type: none"> • “One per SRG” is applied for C/D add/drop group • “One per Degree” is applied for C/D/C add/drop group
<i>avail-freq-maps</i> <ul style="list-style-type: none"> • <i>map-name</i> • <i>start-edge-freq</i> • <i>freq-map-granularity</i> • <i>effective-bits</i> • <i>freq-map</i> 	The spectrum occupation is defined by a list of available frequency maps.	Derived from device and updated by SDN controller (freq-map)

Note:

The number of port pairs (pp's) in an SRG can be determined by one of the following approaches:

- Discovered from the network, i.e., via an API (e.g., getAllEquipment) that is provided by vendor's Device Model
- Provided by vendor's static meta-data as part of their Device Model that says “for an SRG of hardware pack type X, N_{pp} ports”.

1.4.3 Logical Connectivity Links

Connectivity between degrees and between degrees and SRGs within a ROADM is represented by logical links that connect the logical points in ROADM degrees, i.e., TTPs and CTPs, and the logical points in SRGs, i.e., CPs.

The naming convention of the logical connectivity links is as follows:

- **ExpressLinkmn**

This unidirectional logical link represents connectivity between two degrees of a ROADM, where number m is the degree # of the FROM degree (i.e., CTP-Tx logical port), number n is the degree # of the TO degree (i.e., CTP-Rx logical port). This is just a demonstration of naming convention, but it can be different based on service providers preference for example (ExpressLink-DEG1-CTP-TX-DEG3-CTP-RX). [Figure 1-9](#) illustrates the three pairs of ExpressLinks between the three degrees of a ROADM node.

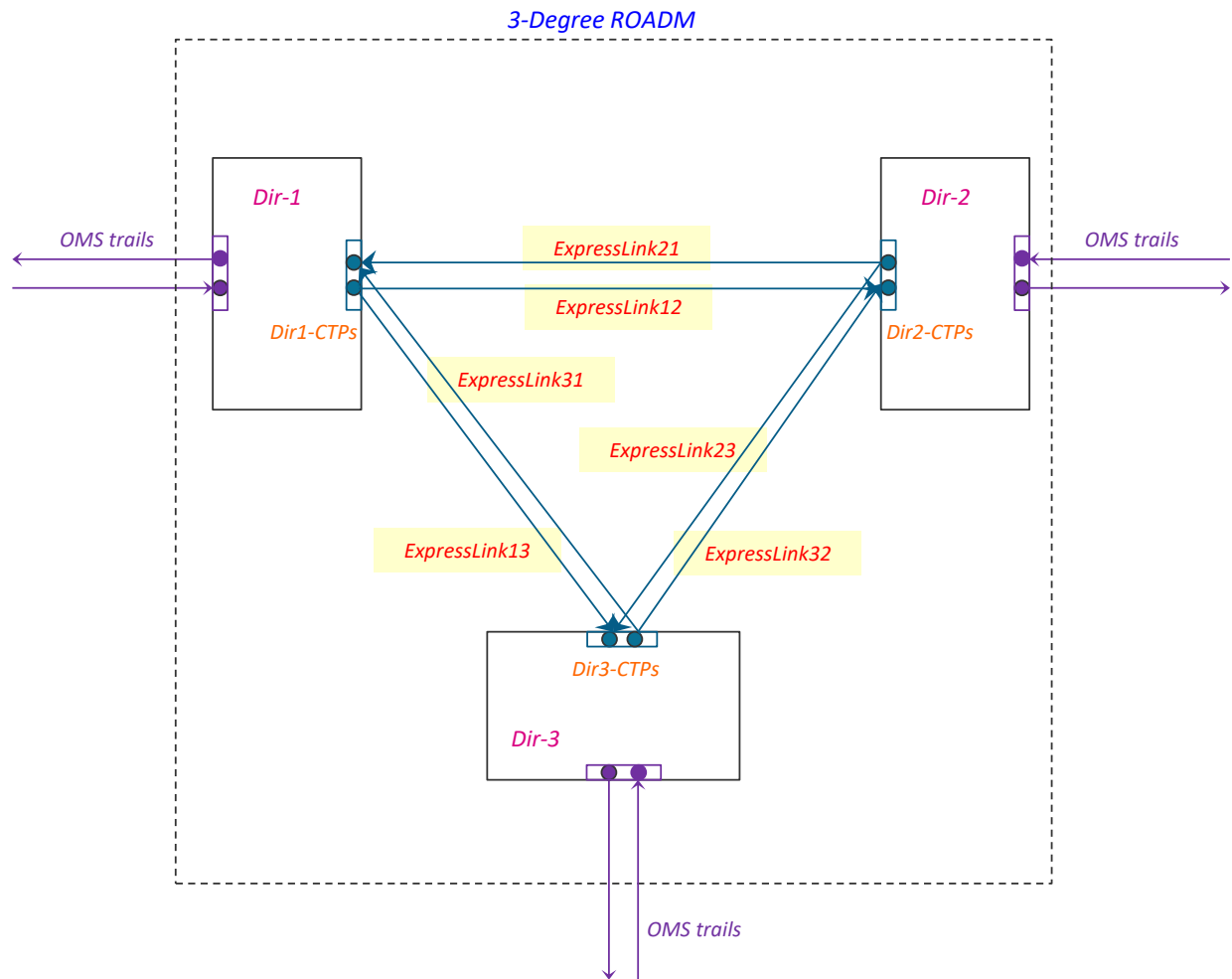


Figure 1-9. Logical ExpressLinks represent connectivity between ROADM degrees.

- **DropLinkxy**

This unidirectional logical link represents connectivity between a degree and an SRG of a ROADM in the direction of traffic being dropped from the degree, where number x is the degree # where the traffic is coming FROM (i.e., CTP-Tx logical port), y is the SRG # where the traffic is going TO be dropped (i.e., CP-Rx logical port). This is just a demonstration of naming convention but it can be different based on service providers preference for example (DropLink-DEG1-CTP-TX-SRG1-CP-RX).

[Figure 1-10](#) illustrates the six DropLinks between the three degrees and two SRGs of a ROADM node.

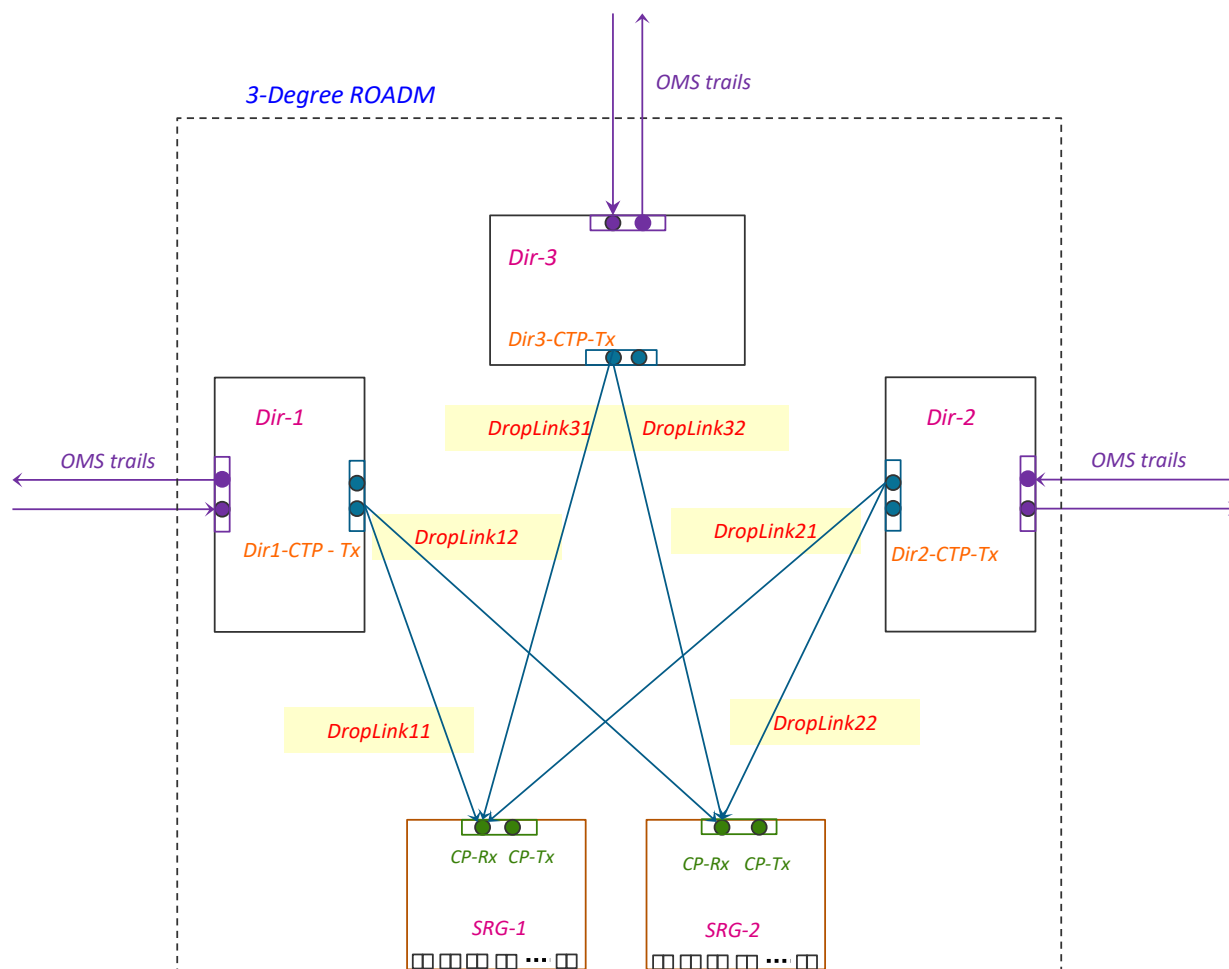


Figure 1-10. Logical drop links represent connectivity between ROADM degrees and SRG.

- **AddLinkyx**

This unidirectional logical link represents connectivity between a degree and an SRG of a ROADM in the direction of traffic being added from the SRG to the degree, where y is the SRG # where the traffic is coming FROM (i.e., CP-Tx logical port) and number x is the degree # where the traffic is going TO be added (i.e., CTP-Rx logical port). This is just a demonstration of naming convention but it can be different based on service providers preference for example (AddLink-SRG1-CP-TX-DEG1-CTP-RX).

[Figure 1-11](#) illustrates the six AddLinks between the three degrees and two SRGs of a ROADM node.

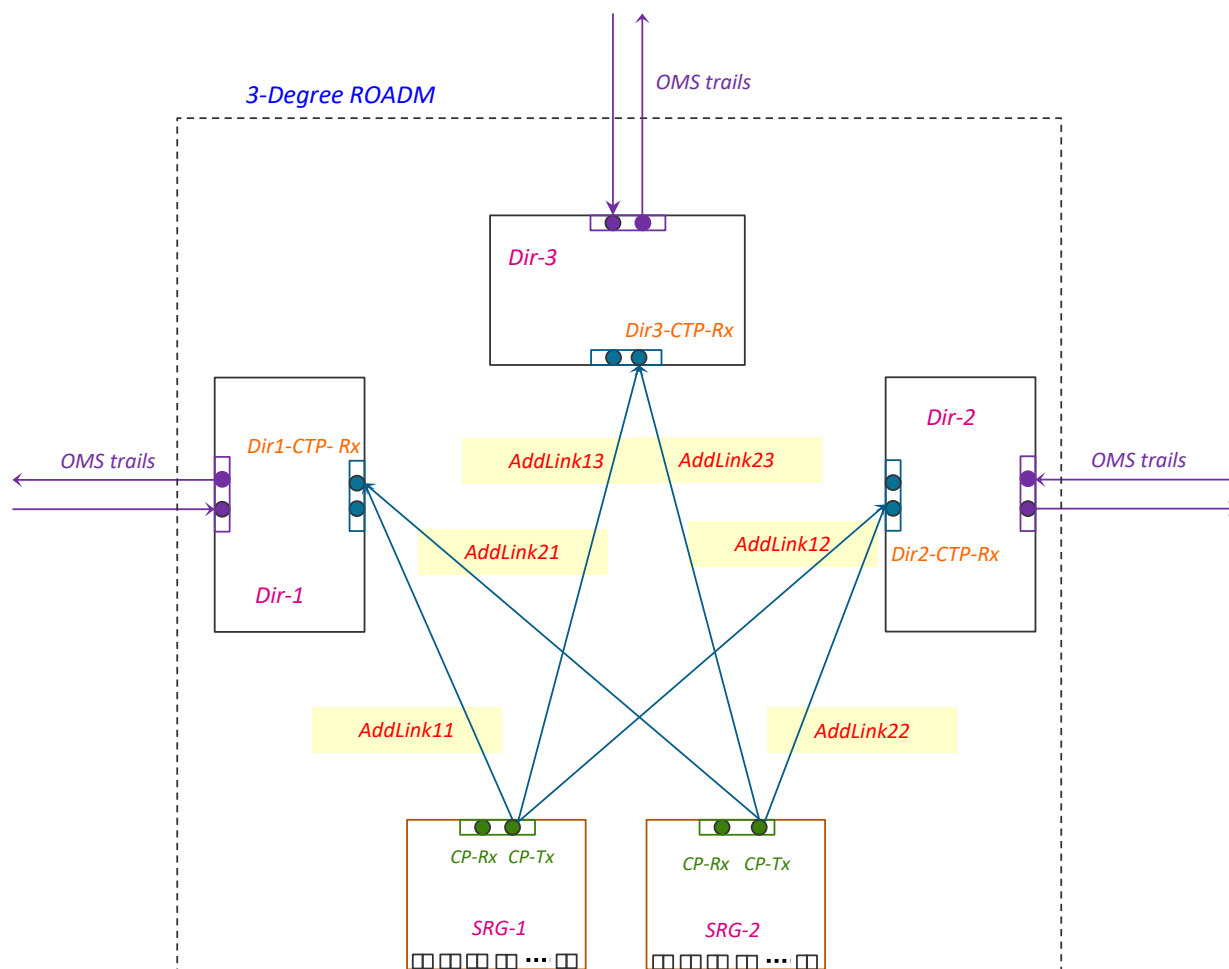


Figure 1-11. Logical add links represent connectivity between ROADM degrees and SRG.

- **Roadm-To-Roadm:**

This unidirectional logical link represents connectivity between two Roadms. The data for ROADM-TO-ROADM links can be discovered by the controller based on the Link Layer Discovery Protocol (LLDP) information reported under the “protocols” subtree in the device model or can be an input from external planning system during planning phase.

- **Xponderlinks:**

OpenRoadm topology layer will have Transponder to Roadm links and Roadm to Transponder links represented by following link types:

- XPONDER-INPUT
- XPONDER_OUTPUT

Link should appear when a physical fiber connection is made between Roadm and transponder.

The logical connectivity links are specified in a Connectivity Map in the ROADM Network Model based on input from planning. Logical links are included in the Connectivity Map of device model if and only if physical connections are planned in a node, e.g., logical express links between two degrees are not created if the two degrees are not fibered to support through traffic between them. Add link, drop link and express links are derived from device's physical links/internal links or connection map into network model. In case the link-type is ROADM-TO-ROADM, the conditional subtree called OMS-attributes appears with under the links tree. Starting from version 4.x the common attributes associated with a link such as link-type, link-length, link-latency, TE-metric, opposite links and clfi have been moved to module org-openroadm-common-network. Attributes of the links in network model are described in [Table 1-8](#).

Table 1-8. OpenROADM network model augmentation associated to a link

<i>Attribute</i>	<i>Description</i>	<i>Note</i>
<i>amplified</i>	Defines whether a ROADM-TO-ROADM Link includes line amplifiers or not	
<i>OMS-attributes</i>	OMS-attributes is optional subtree which appears only for Roadm-to-Roadm links	

The attributes for OMS-attribute subtree are displayed in the [Table 1-9](#).

Table 1-9. OMS link attributes

Attribute		Description	Note	
span		This subtree appears when the ROADM-TO-ROADM link is not amplified	Data from planning	
	auto-spanloss	Flag to enable/disable automatic span loss measurement, default it set to ‘True’	Data from planning	
	spanloss-base	Span loss measured when Degree is turned up for the first time.	Set by SDN controller	
	spanloss-current	Current measured, updated periodically if auto-spanloss is enabled.	Set by SDN controller	
	spanloss-last-measured	Last measured ROADM span loss	Set by SDN controller	
	engineered-spanloss	Reference span loss used for the initial design	Data from external system	
	link-concatenation	Lists of shared risk link groups	Data from planning	
		SRLG-Id	Identifier for the srlg	Data from planning
		fiber-type	Type of underlying fiber	Data from planning
		SRLG-length	Fiber length in meters	Data from planning
		pmd	Polarization mode dispersion expressed in ps/km(1/2)	Data from external system
amplified-link		This subtree appears when the ROADM-TO-ROADM link is amplified. Contains lists of section elements part which are part of the amplified links.		

			Section elements can either be an inline amplifier (ILA) or a span.	
		<i>section-elt-number</i>	Identifier for the section element.	
		<i>section-element</i>	Define whether a section element contains span or ila	
		<i>ila</i>		
		<i>amp-type</i>	Amplifier type	Data from device
		<i>amp-gain-range</i>	Gain range for the device between 1 and 4.	Data from device
		<i>ingress-span-loss-aging-margin</i>	Span-loss margin used to set optical amplifier gain and output-voa. Corresponds to operator specific engineering rules. Transferred by Controller to device in device OTS interface container, so that the device can set optical amplifiers parameters accordingly. Optional since it concerns only line facing amp.	Data from planning
		<i>gain</i>	Overall Amplifier Signal gain, excluding ASE, including VOA attenuation.	retrieved from operational value (PM)
		<i>initially-planned-gain</i>	Overall Amplifier Signal gain, excluding ASE, including VOA attenuation. Used as a reference to track deviations out of the initial design settings, and trig warning when the settings goes out of the authorized range (Line shall be re-designed)	Data from planning tool initial design
		<i>tilt</i>	Tilt of smart EDFA	Data from retrieved from operational value (PM)
		<i>initially-planned-tilt</i>	Initially planned Tilt of smart EDFA: used as a reference to keep a trace of the setting that came out of the initial design.	Data from planning tool initial design
		<i>out-voa-att</i>	output VOA attenuation	
		<i>eol-max-load-pln</i>	End Of Life Total input power at maximum load used for amplifier and VOA setting. Transferred by Controller to device in device OTS interface container	Data from planning tool initial design
		<i>egress-average-channel-power</i>		
		<i>type-variety</i>		
		<i>span</i>	Span subtree defined in Table 1-9 .	

1.4.3.1 Express Wavelength Representation

The CTPs in a degree construct are used to manage services/circuits routed through a ROADM. Physical connections between two degrees can be represented by two logical links between the CTPs. Traffic traverses through the two directions/degrees can be described using those logical links, which are depicted in [Figure 1-12](#) where two unidirectional links between the CTPs in Dir-1 and Dir-2 are shown to carry express traffic.

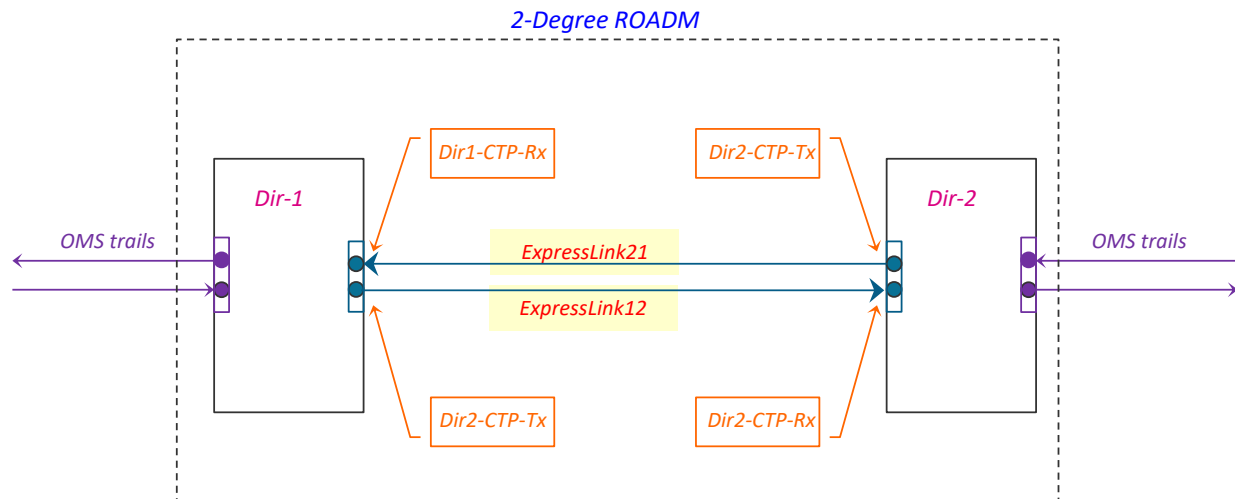


Figure 1-12. Logical links represent connections between two degrees of ROADM for express-through traffic.

At each of the four connected CTP's, the wavelength assigned to a circuit/service that uses the logical links is mapped to one of the connection points that are fanned out from the CTP. This is illustrated in [Figure 1-13](#) using 96 as the maximum number of wavelengths, where wavelength #4 is assigned to a wavelength-level service that is express through between Dir-1 and Dir-2.

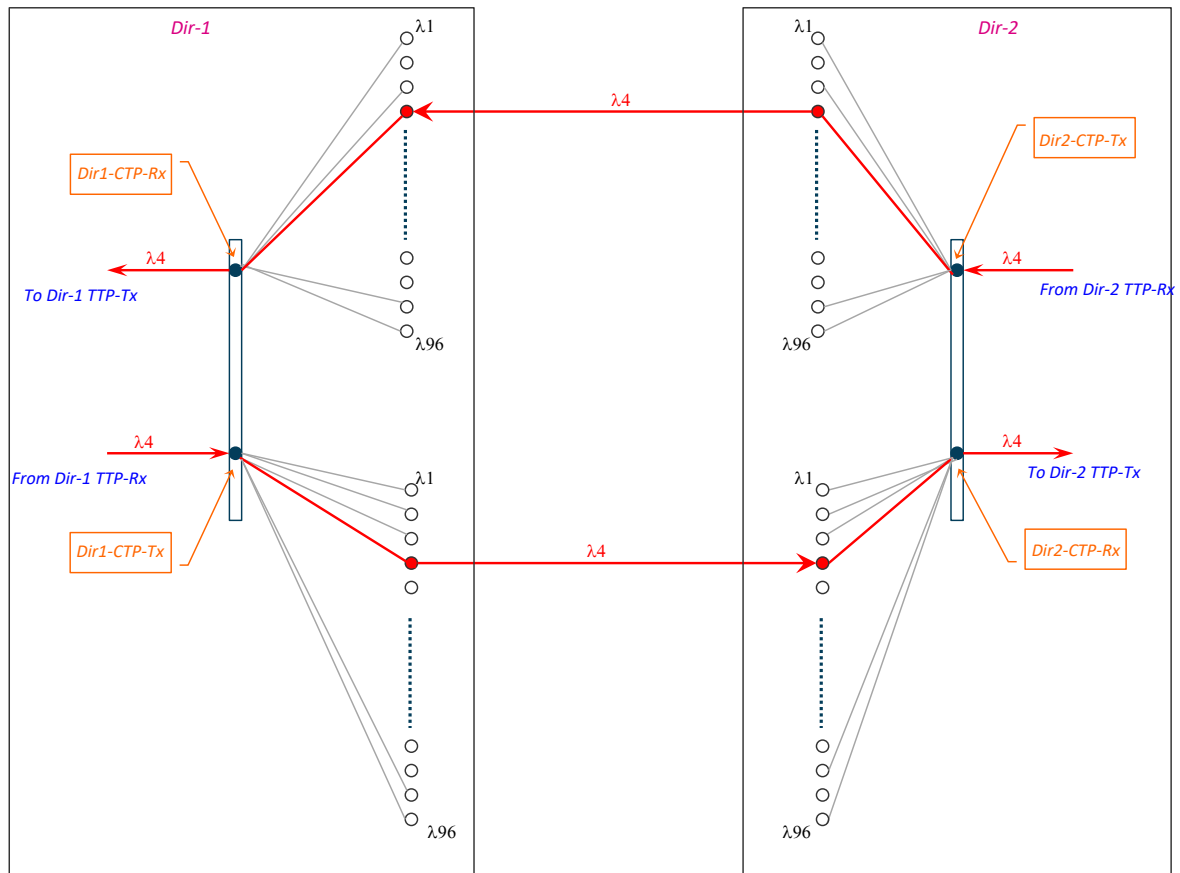


Figure 1-13. An express server through Dir-1 and Dir-2 using wavelength #4 (both degrees are shown).

The path of the service/circuit going through between the two degrees can be represented using the two logical links depicted in [Figure 1-12](#) marked as “ExpressLink12” and “ExpressLink21”.

1.4.4 Add/Drop Wavelength Representation

Adding and dropping wavelength-level services by a ROADM involve both direction/degree construct and SRG construct. The CTP-Tx in the direction/degree construct, which receives incoming signals from the OMS trail and feeds express channels to other directions/degrees, can also feed add/drop wavelengths to an add/drop SRG. The CTP-Rx in the direction/degree construct, which sends outgoing signals to the OMS trail and receives express channels from other directions/degrees, can also receive add/drop wavelengths from an add/drop SRG. Thus, logical links can be created between the CTPs of the direction/degree construct and the CPs of the SRG construct to support add/drop wavelengths. This is illustrated in [Figure 1-14](#) where two pairs of logical links are used to represent two services supported between Dir-1 and two different SRGs. Each of the two SRGs is represented by a pair of CPs.

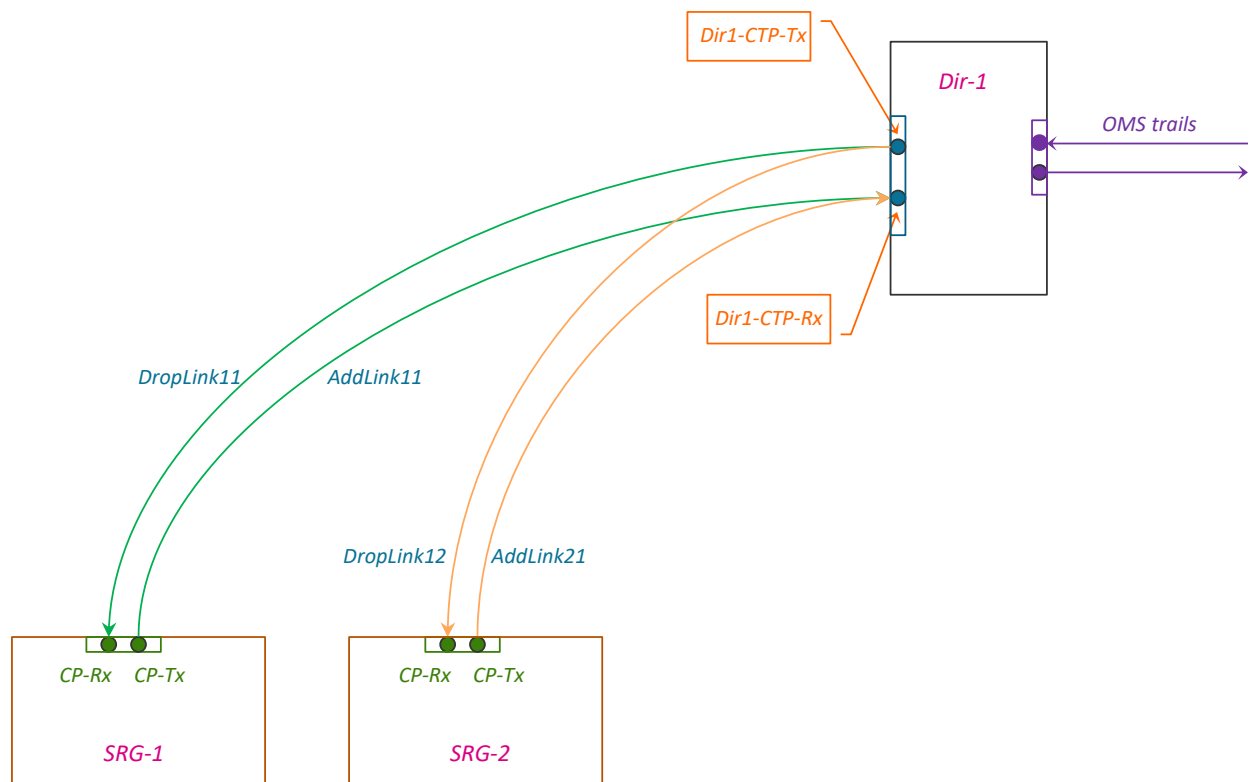


Figure 1-14. Logical links representing service traffic being transmitted between a Degree construct and two SRG constructs.

Each pair of CPs in an SRG construct can be logically linked to all degree constructs, e.g., the two CP pairs, representing two SRGs in [Figure 1-15](#), are connected simultaneously to two separate degrees.

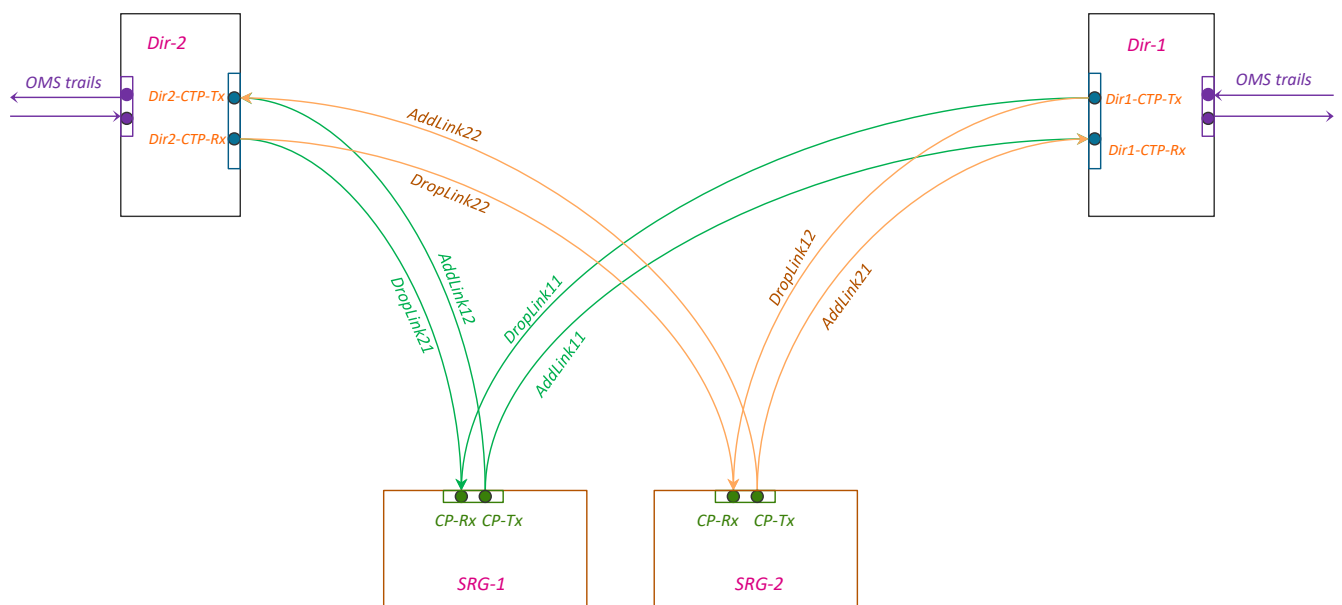


Figure 1-15. Logical links between two Degree constructs and two SRG constructs.

Wavelengths/Spectrum supported by a CP pair must be unique if the SRG is C/D equipment configuration, duplications are allowed if the SRG is C/D/C equipment configuration. The PCE in the Open ROADM Control Layer will enforce the rules while performing wavelength assignments.

The port pairs in an SRG that are used to connect to external devices, i.e., transponders, LGXs, pluggable units, can be pictured to be fan-out points of the CPs. Since the number of port pairs in an SRG is specific to vendor's equipment configuration, the number of fan-out points needs to be identified in vendor's Device Model.

When a pair of ports in an SRG is connected to a transponder, LGX jacks, or a pluggable unit, the corresponding fan-out points in the CPs needs to reflect the connections. This way, the information on which port pair is connected to an external device is associated to the CPs and the information can be used by the PCE to determine whether there are spare add/drop ports in an SRG to support new service demands.

[Figure 1-16](#) shows a transponder, which is embedded in the tail construct and cabled to the 2nd port pair (IN2 and OUT2) in the SRG #1, is used for a service/circuit in degree Dir-1.

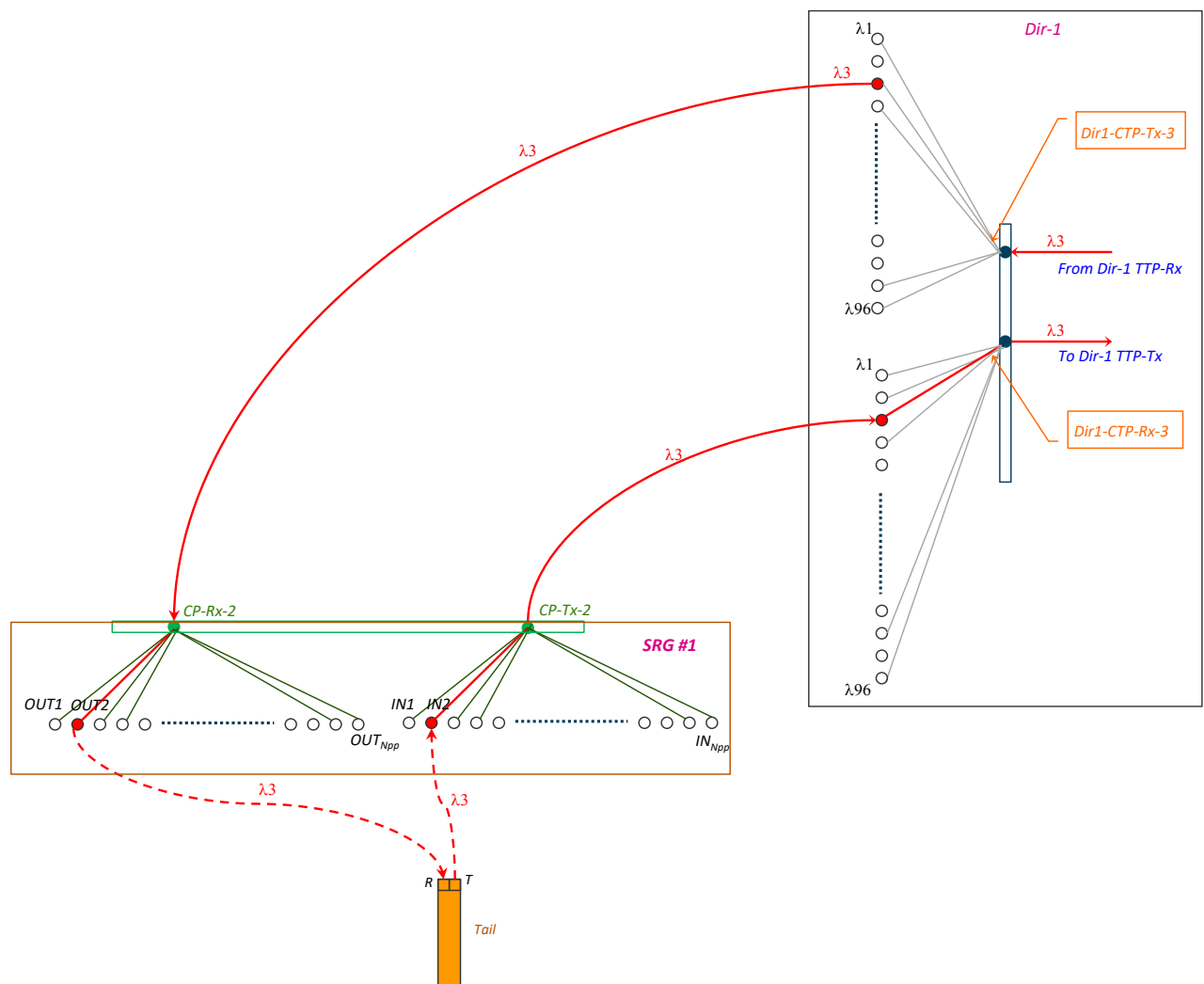


Figure 1-16. A service is added and dropped between Dir-1 and SRG #1.

When a service/circuit is added/dropped through an SRG, the wavelength information (λ_3 in [Figure 1-16](#)) is tracked by the corresponding CTPs in the degree construct (Dir1-CTP-Tx-3 and Dir1-CTP-Rx-3 in [Figure 1-16](#)) and the add/drop port information (port pair #2 in [Figure 1-16](#)) is tracked by the CPs in the SRG construct.

1.5 OTN Topology Layer:

OTN topology layer in I2RS network model holds Network information for OTN elements including Muxponders, OTN switches/switchponders, Transponder and Regens. This layer is consisting of nodes, termination points and links.

OTN Node can be either a transponder, regen, muxponder, switchponder or OTN-switch. Within a single physical node or shelf, there can be more than one OTN element. OTN's supporting network is openroadm-network and openroadm-topology layers. Openroadm-network layer will have node level information for the whole OTN device as described in the openroadm-network layer. Openroadm-topology layer will hold supporting links for OTN-links. OTN topology layer will only have nodes of type TPDR, REGEN, REGEN-UNI, MUXPDR or SWITCH. Each node in OTN layer will have attributes described in table 1-10.

Table 1-10 Attributes of OTN topology Node

Attribute			Description	Note		
tp-bandwidth-sharing			Defines whether a ROADM-TO-ROADM Link includes line amplifiers or not	Data from device		
	tp-sharing-id		Unique Id to identify sharing group	Data from device		
	tp-list		List of termination points which are sharing B/W	Data from device		
	shared-bandwidth		Total B/W shared among list of termination points in Gbps	Data from device		
	possible-tp-config		Identifies the supported combinations of possible tp configuration	Data from device		
		config-id		Unique id for tp config		
		tp-if-type-config				
			tp-name		Termination point name	
			tp-if-type		Supported interface capability	
			otsi-rate		Optical Tributary Signal (OTSi) rate in Gbps	
switching-pools						
odu-switching-pools				Data from device		
	switching-pool-number		Unique identifier for each switching pool from the list	Data from device		
	switching-pool-type		Blocking (added constrains due to switching fabric) or Non-blocking (any port can be connected to any port)	Data from device		
	non-blocking-list			Data from device		
		nbl-number		Unique identifier for non blocking list	Data from device	
		interconnect-bandwidth-unit		Granularity of switch fabric	Data from device	
		capable-interconnect-bandwidth		Interconnect B/W supported by switching fabric	Data from device	
		available-interconnect-bandwidth		Available B/W for non-blocking elements	Data from device	

	<i>tp-list</i>	List of termination points which can be interconnected	Data from device
<i>xpdr-attributes</i>			
	<i>xpdr-number</i>	Unique Id to identify Xpdr with in a shelf	Data from device

One OTN Node can have multiple client and network ports. A termination point in OTN topology layer can have following attributes listed in [table 1-11](#)

Table 1-11. Attributes of OTN topology termination point.

<i>Attribute</i>		<i>Description</i>	<i>Note</i>
<i>tp-supported-interfaces</i>		List of interfaces supported by termination point like 100GE, 40GE, ODU1, ODU2	Data from device
	<i>supported-interface-capability</i>		Data from device
	<i>if-cap-type</i>	Supported interface capability on the tp	Data from device
<i>xpdr-tp-port-connection-attributes</i>			
	<i>rate</i>	Rate identity of the ODU	Data from device
	<i>odtu-tpn-pool</i>		Data from device
	<i>odtu-type</i>	ODTU type, part of the MSI (Multiplex Structure Identifier)	Data from device
	<i>tpn-pool</i>	List of available Tributary Port Number (0-based), part of the MSI	Data from device
	<i>ts-pool</i>	List of available Tributary Slots for tp	Data from device
	<i>wavelength</i>	Attribute to be used when OTN link is using a WDM lambda.	
	<i>frequency</i>	Central frequency	
	<i>width</i>	Slot width	
	<i>tail-equipment</i>	Type of equipment connected to the tail for example packet box	Data from planning
	<i>tail-equipment-id</i>	Identifier of equipment connected to the tail for example client equipment ID	Data from planning
	<i>tail-clfi</i>	Tail CLFI is available	Data from planning
	<i>tail-id</i>	Termination point id	Set by SDN controller
	<i>network-ref</i>	Reference to the network layer	Set by SDN controller
	<i>node-ref</i>	Reference to the node in the network layer	Set by SDN controller
	<i>supported-client-services</i>		

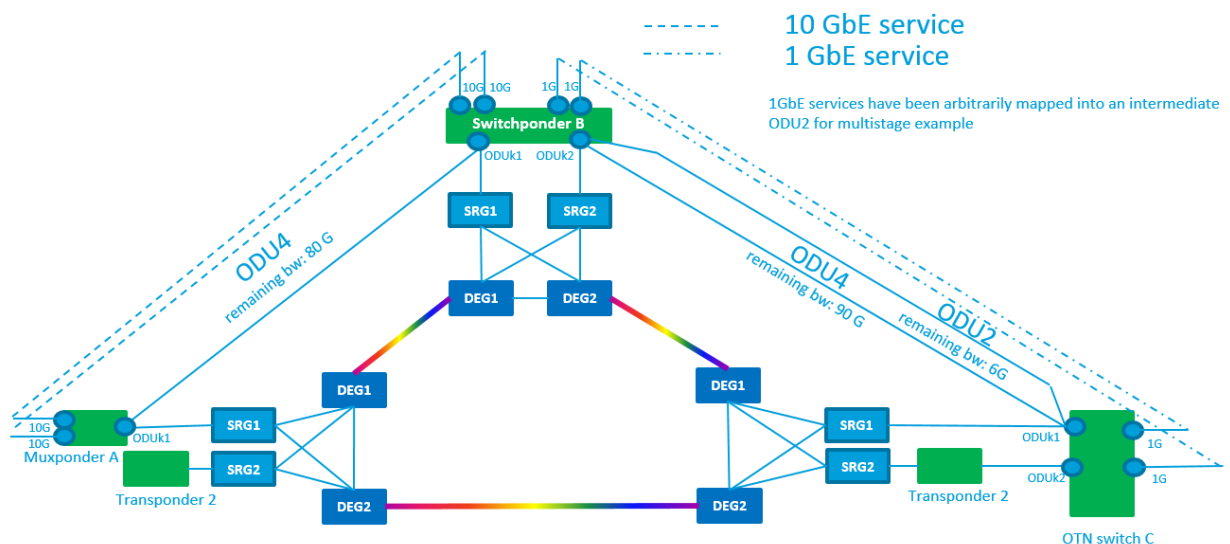
	<i>service-format</i>	Format of the requested service: Ethernet, OTU, etc	
	<i>service-rate</i>	Rate of the requested service in GBps. Not used when service-format=other	
	<i>other-service-format-and-rate</i>	Used when service-format is set to other in the bookend xponder use case	

OTN Nodes typically would be connected to each other through underlying DWDM network, although direct connections are also supported (to address, as an example, the use case where 2 switches located in the same office must be interconnected). OTN topology has OTN-links which are logical links supported by openroadm-topology layer links with following attributes:

Table 1-12. Attributes of OTN links

<i>Attribute</i>	Description	Note
<i>available-bandwidth</i>	Available B/W for the link	Set by SDN controller
<i>used-bandwidth</i>	Total used B/W for the link	Set by SDN controller
<i>ODU-protected</i>	ODU protection flag	Set by SDN controller

When a service request comes between two OTN nodes, path computation might involve setting up a service into DWDM layer. Below is the example of OTN network with existing ODU services.



OTN path computation will first validate reachability using OTN nodes and OTN links. If a path (OTN continuity) is found, the Controller shall check that the available bandwidth on the path allows the required bandwidth to be provided. If this is the case, OTN client and network ports can be set-up since DWDM network continuity already exists. If there is no path returned at the OTN layer, the Path Computation Engine (PCE) can identify connected DWDM elements using OTN tail information. PCE will need to find optimal path within DWDM network, possibly considering specific constraints in a first step. Once a WDM path is retrieved, a 100G service will be

created between OTN elements to support OTN based services. This 100G service will appear as a single OTN link in the OTN layer.

1.5.1 Xponder

The line side of an Xponder (transponder or muxponder) is connected to an SRG of a ROADM and the client side of the Xponder is connected to switch/router equipment through intra-office LGXs. Xponders and switch/router equipment are usually fibered to the back of LGX panels. Connections between them are then completed through jumpers inserted on the front of the LGX panels.

[Figure 1-17](#) shows the line-side and client-side connections of a transponder.

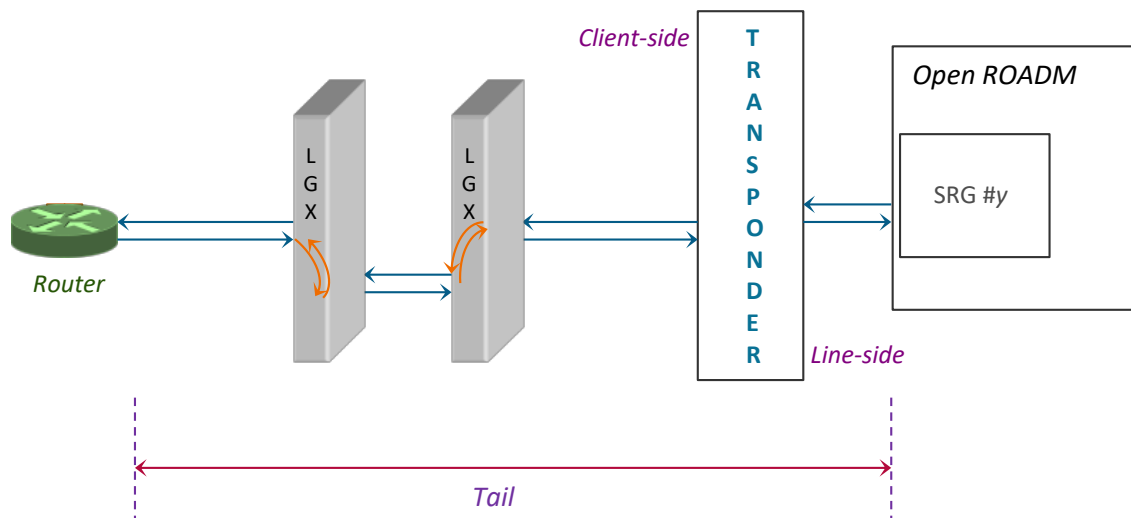


Figure 1-17. A transponder is used to support connection with router.

Xponder in openroadm-topology represents transponders which can have client and network port as termination point. The information associated to an Xponder in topology layer is described in [Table 1-13](#).

Table 1-13. Attributes associated to an Xponder.

<i>Attribute</i>	<i>Description</i>	<i>Note</i>
Xponder number	Unique identifier for a transponder with in a Node	Data obtained from vendor's device

Table 1-14. Equipment states assigned by ROADM Controller.

<i>reserved-for-facility-planned</i>	Equipment is planned for use by a service
<i>not-reserved-planned</i>	Equipment is planned by not reserved for any purpose
<i>reserved-for-maintenance-planned</i>	Equipment is planned for use as a maintenance spare
<i>reserved-for-facility-unvalidated</i>	Equipment is reserved for use by a service but not validated against planned equipment
<i>not-reserved-unvalidated</i>	Equipment is not reserved for any purpose and not validated against planned equipment

<i>unknown-unvalidated</i>	Unknown equipment not validated against planned equipment
<i>reserved-for-maintenance-unvalidated</i>	Equipment is to be used for use as a maintenance spare but not validated against planned equipment
<i>reserved-for-facility-available</i>	Reserved for use by a service and available
<i>not-reserved-available</i>	Not reserved for use by a service and available
<i>reserved-for-maintenance-available</i>	Reserved as a maintenance spare and available
<i>reserved-for-reversion-inuse</i>	Equipment that is reserved as part of a home path for a service that has been temporarily re-routed
<i>not-reserved-inuse</i>	Equipment in use for a service
<i>reserved-for-maintenance-inuse</i>	Maintenance spare equipment that is in use as a maintenance spare

1.5.2 External Pluggable

Transponder is not always required between packet box equipment and ROADM. The external pluggable can be part of OTN layer as well as OpenRoadm topology layer where physically connected to SRG port. Pluggable modules can be used in packet boxes to connect to add/drop groups directly, as shown in

[Figure 1-18](#).

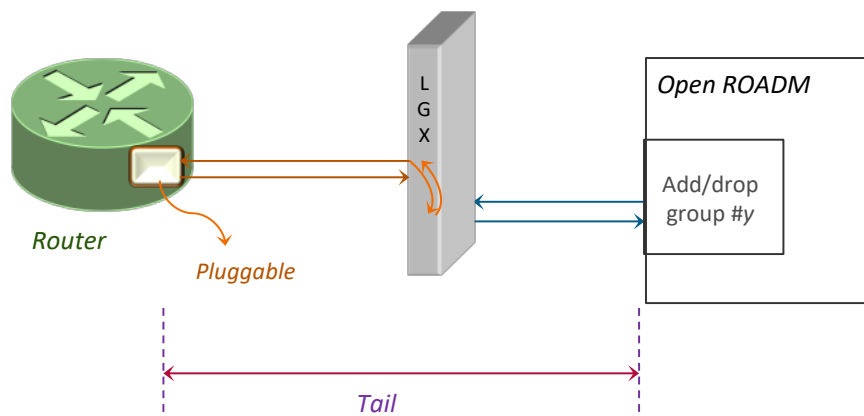


Figure 1-18. Connection between pluggable in router and add/drop group.

A pluggable installed in packet box equipment to interconnect with ROADM will be managed through the packet box. However, the information associated to the pluggable and described in [Table 1-15](#) is made known to the Open ROADM Controller:

Table 1-15. Attributes associated to a pluggable in packet box.

<i>Attribute</i>		<i>Description</i>	<i>Note</i>
<i>Office</i>		Location CLLI where the pluggable unit resides	Data from planning
<i>Node Type</i>		Specification of the type of the node, “PLG”.	Data from planning
<i>Pluggable Number</i>		Identifier of the pluggable unit in a given office, i.e., 1, 2, ..., N_P	Data from planning
<i>Pluggable ID</i>		Network-wide unique identifier for a pluggable	<i>Constructed by concatenating office CLLI, FIC, and shelf #?</i>
<i>Vendor</i>		Identifier of the pluggable unit’s supplier	Data from planning
<i>Customer Code</i>		Owner of the pluggable unit	Data from planning
<i>External connection</i>	<i>ROADM node ID</i>		Data from planning
	<i>SRG #</i>		Data from planning
	<i>Port Pair #</i>		Data from planning
	<i>Rate</i>		
	<i>Signal Format</i>		
	<i>Reach</i>		
	<i>Gray/color</i>		
	<i>State</i>	Pluggable module in the port can be in one of the equipment state in Table 1- .	
<i>Tail</i>	<i>Client equipment</i>		From SDN-C
	<i>Client equipment ID</i>		From SDN-C
	<i>CLFI</i>		From SDN-C

1.6 Tail concept and Service model link

1.6.1 Tail

In

[Figure 1-17](#), a tail facility is used to represent the connection between the port pair in an add/drop group and the router including the intermediate LGXs and transponder. This is an example which could be different for service providers. [Figure 1-19](#) shows another intra-office tail in an example office.

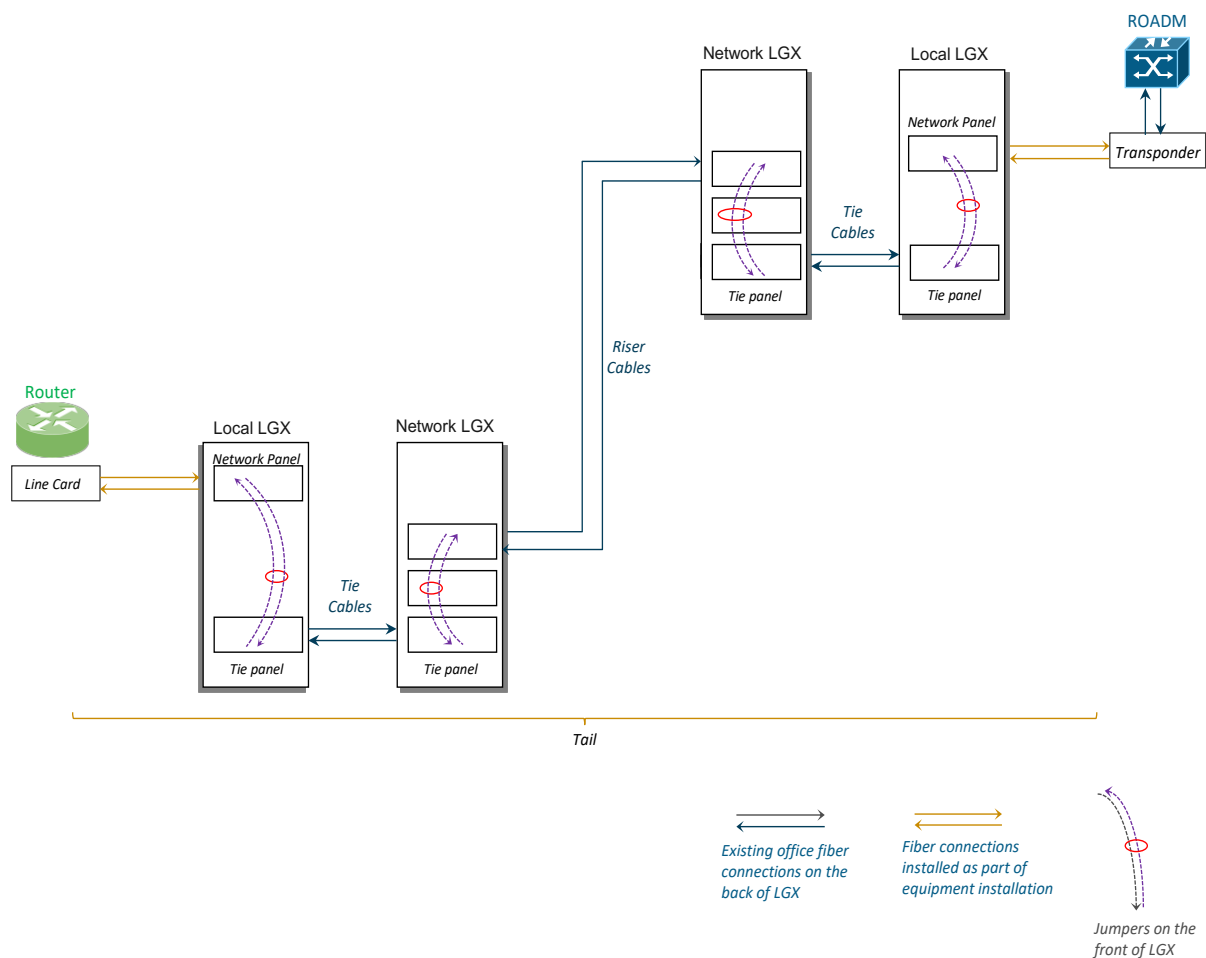


Figure 1-19. An intra-office tail.

An intra-office tail could be further divided into two portions:

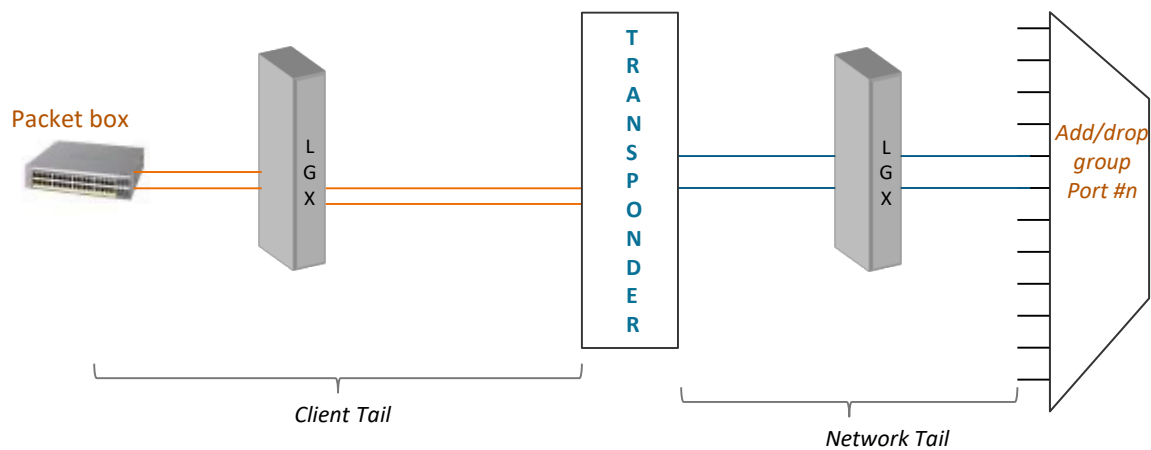
- **Client Tail**

When a transponder or a muxponder is used between client equipment (router, switch, POI/TDI) and add/drop ports in ROADM SRG, a Client tail includes the client equipment, the client ports in the transponder or muxponder, and intermediate LGXs between them. Refer to [Figure 1-20](#) (a) for an example.

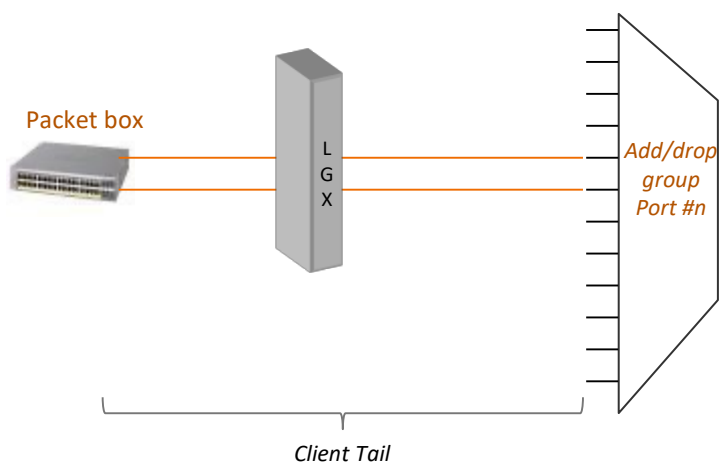
When no transponder or muxponder is used, a Client tail becomes the entire intra-office tail, which includes the client equipment, the add/drop ports in ROADM SRG, and intermediate LGXs between them. Refer to [Figure 1-20](#) (b) for an example.

- **Network Tail**

This tail exists only when a transponder or a muxponder is used between client equipment (router, switch, POI/TDI) and add/drop ports in ROADM SRG. It includes the line side of transponder or muxponder, the ports in ROADM add/drop group, and intermediate LGXs between them. Refer to [Figure 1-20](#) (a) for an example.



(a)



(b)

Figure 1-20. Client tail and Network tail in Metro.

Tail models are not part of Openroadm models yet, but information below will help understand tails. The information associated to a tail facility is shown in [Table 1-16](#):

Table 1-16. Attributes associated to a tail facility.

<i>Attribute</i>		<i>Description</i>	<i>Note</i>
<i>CLFI</i>	Facility identifier of the tail		Data from planning
<i>Time stamps</i>	<i>Start date</i>		Data from planning
	<i>End date</i>		Data from planning
<i>Layout</i>	<i>Client equipment</i>		From SDN-C
	<i>External pluggable</i>	optional	
	<i>List of intermediate LGXs (LGX ID + jack assignments)</i>	optional	
	<i>Transponder ID</i>		From SDN-C
	<i>List of intermediate LGXs (LGX ID + jack assignments)</i>	optional	
	<i>ROADM node ID</i>		From SDN-C
	<i>SRG #</i>		From SDN-C
	<i>Add/drop Port #</i>		From SDN-C

1.6.2 Service/Circuit

When tail facilities exist in the offices where a service is to be terminated, the PCE in the open ROADM controller can simply use the information provided by the Network Model to compute an optimal service path between the two tails. If tail facilities do not exist when a service request is made to the open ROADM controller, the PCE will not only compute an optimal path between two service-terminating ROADM nodes but also use the information provided by the Network Model to select proper SRGs in the ROADM nodes and, if transponders are present, identify transponders and the add/drop port pairs the transponders are connected to. The PCE can use the span loss information in the Network Model to find the shortest path for the service, use fiber span information to perform constrained routing, use the fan-out points in the TTPs and CTPs to make wavelength assignments, and use the fan-out points in the CPs to make add/drop SRG selections.

A service or circuit at wavelength-level consists of one or more OMS sections. The service is terminated on client equipment connected to ROADM nodes directly or through transponders. A service is represented using six facilities, assuming a transponder is present:

- A client tail facility and a network tail facility in service's A-end
- A client tail facility and a network tail facility in service's Z-end
- A "ROADM facility" between the add/drop ports including all of the OMS trails and cross-connects
- An overall service facility between the client equipment, which encompasses the four tail facilities and the ROADM facility

Figure 1-21 shows the six facilities related to a service supported by three ROADM nodes in offices A, B, and C.

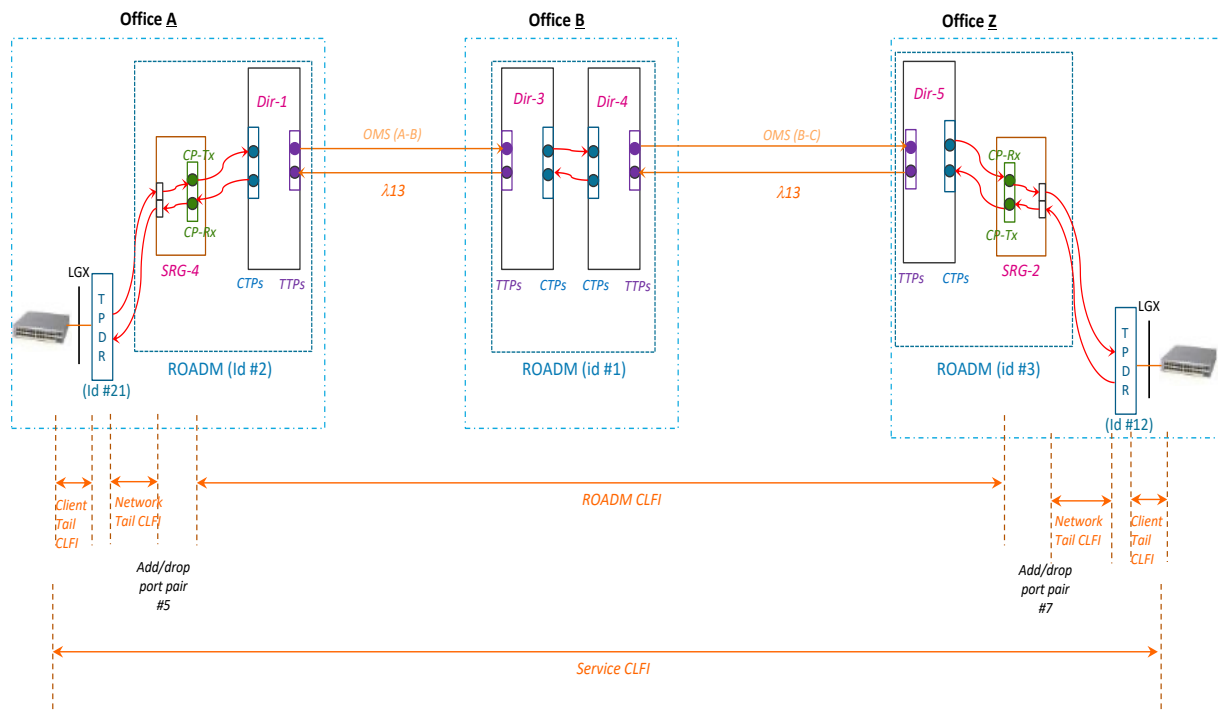


Figure 1-21. A service supported by three open ROADM nodes.

When tails are not pre-deployed, the information provided by the SDN Controller in the request to the Open ROADM Controller for a new service/circuit includes the attributes listed in Table 1-17 (not an exhaustive list):

Table 1-17. Parameters provided by the SDN-C in a service/circuit request.

Attribute	Description	Note
Facility CLFI	Identifier for the service/circuit	Data provided by SDN-C
A-end CLLI	Service's A-end office	
Z-end CLLI	Service's Z-end office	
Start date	Starting date of the service/circuit	
End date	End date of the service/circuit	
Routing constraints	diversity, exclude, include, co-routing, latency	

The 'Facility CLFI' in Table 1-17 is the 'Service CLFI' in Figure 1-21.

The PCE performs path computation using the network level information based on the Network Models to generate a ROADM Facility. The layout of the ROADM Facility is comprised of two ROADM nodes at the

service's termination locations, intermediate OMS trails, and zero or a number of express-through ROADM nodes.

- The wavelength # used by the ROADM Facility is assigned by the PCE. The PCE manages wavelength usages of each OMS section using the TTPs terminating the OMS trails.
- The PCE also manages port pair (PP) in an SRG:
 - A pre-deployed transponder is pre-cabled to a PP in an SRG. If the PCE selects the transponder for a requested service, the transponder's PP # is then associated to the SRG's CPs and included in the service's ROADM Facility.
 - If no transponder is available for the requested service, the PCE will select a PP from the SRG the PCE picked for the service, associates the PP # to the SRG's CPs and include them in the service's ROADM Facility.
 - The PPs in existing tail facilities are associated to their corresponding SRGs' CPs. If an existing tail facility is identified in the service request, the PCE will use the PP # in the tail in the service's ROADM Facility.

[Table 1-18](#) shows the layout in the ROADM Facility's A-to-Z direction.

Table 1-18. A-to-Z Layout of a ROADM Facility maintained in the Network level.

<i>Office A CLI</i>	Node ID + [SRG ID] + [CP-Tx]-[pp#]	
	Node ID + AddLink[SRG ID][Dir ID]	
	Node ID + [Dir ID] + [CTP-Rx]-[wavelength #]	
	Node ID + [Dir ID] + [TTP-Tx]-[wavelength #]	
[OMS Trail CLFI]		
<i>Office X CLI</i>	Node ID + [Dir ID ₁] + [TTP-Rx]-[wavelength #]	Zero or multiple express-thru ROADM
	Node ID + [Dir ID ₁] + [CTP-Tx]-[wavelength #]	
	Node ID + ExpressLink[Dir ID ₁][Dir ID ₂]	
	Node ID + [Dir ID ₂] + [CTP-Rx]-[wavelength #]	
	Node ID + [Dir ID ₂] + [TTP-Tx]-[wavelength #]	
[OMS Trail CLFI]		
<i>Office Z CLI</i>	Node ID + [Dir ID] + [TTP-Rx]-[wavelength #]	
	Node ID + [Dir ID] + [CTP-Tx]-[wavelength #]	
	Node ID + DropLink[Dir ID] [SRG ID]	
	Node ID + [SRG ID] + [CP-Rx]-[pp #]	

Using the service in

[Figure 1-21](#), [Table 1-19](#) shows the service's ROADM Facility layout in the A-to-Z direction.

Table 1-19. Example of an A-to-Z layout of a ROADM Facility in the Network level.

<i>Office A CLI</i>	Node #2 + SRG #4 + CP-Tx-5	
	Node #2 + AddLink41	
	Node #2 + Dir-1 + CTP-Rx-13	
	Node #2 + Dir-1 + TTP-Tx-13	

OMS (A-B)		
<i>Office B CLLI</i>	Node #1 + Dir-3 + TTP-Rx-13	Express-thru ROADM
	Node #1 + Dir-3 + CTP-Tx-13	
	Node #1 + ExpressLink34	
	Node #1 + Dir-4 + CTP-Rx-13	
	Node #1 + Dir-4 + TTP-Tx-13	
OMS (B-C)		
<i>Office Z CLLI</i>	Node #3 + Dir-5 + TTP-Rx-13	
	Node #3 + Dir-5 + CTP-Tx-13	
	Node #3 + DropLink52	
	Node #3 + SRG #2 + CP-Rx-7	

In the opposite transmission direction, i.e., Z-to-A, the layout of the ROADM Facility is described in [Table 1-20](#).

Table 1-20. Z-to-A Layout of a service maintained in the Network level.

<i>Office Z CLLI</i>	Node ID + [SRG ID] + [CP-Rx]-[pp #]	
	Node ID + DropLink[Dir ID][SRG ID]	
	Node ID + [Dir ID] + [CTP-Tx]-[wavelength #]	
	Node ID + [Dir ID] + [TTP-Rx]-[wavelength #]	
[OMS Tail CLFI]		
<i>Office X CLLI</i>	Node ID + [Dir ID ₁] + [TTP-Tx]-[wavelength #]	Zero or multiple express-thru ROADM
	Node ID + [Dir ID ₁] + [CTP-Rx]-[wavelength #]	
	Node ID + ExpressLink[Dir ID ₂][Dir ID ₁]	
	Node ID + [Dir ID ₂] + [CTP-Tx]-[wavelength #]	
	Node ID + [Dir ID ₂] + [TTP-Rx]-[wavelength #]	
[OMS Tail CLFI]		
<i>Office A CLLI</i>	Node ID + [Dir ID] + [TTP-Tx]-[wavelength #]	
	Node ID + [Dir ID] + [CTP-Rx]-[wavelength #]	
	Node ID + AddLink[SRG ID][Dir ID]	
	Node ID + [SRG ID] + [CP-Tx]-[pp #]	

Using the service in

[Figure 1-21](#), [Table 1-21](#) shows the service's ROADM Facility layout in the Z-to-A direction.

Table 1-21. Example of an Z-to-A layout of a ROADM Facility in the Network level.

<i>Office Z CLLI</i>	Node #3 + SRG #2 + CP-Rx-5	
	Node #3 + DropLink25	
	Node #3 + Dir-5 + CTP-Tx-13	
	Node #3 + Dir-5 + TTP-Rx-13	

OMS (B-A)		
<i>Office B CLLI</i>	Node #1 + Dir-4 + TTP-Tx-13	Express-thru ROADM
	Node #1 + Dir-4 + CTP-Rx-13	
	Node #1 + ExpressLink43	
	Node #1 + Dir-3 + CTP-Tx-13	
	Node #1 + Dir-3 + TTP-Rx-13	
OMS (C-B)		
<i>Office A CLLI</i>	Node #2 + Dir-1 + TTP-Tx-13	
	Node #2 + Dir-1 + CTP-Rx-13	
	Node #2 + AddLink14	
	Node #2 + SRG #4 + CP-Rx-7	

Using the service in [Figure 1-21](#), [Table 1-22](#) shows the tail facility in Office A.

Table 1-22. Example of a tail facility.

<i>CLFI</i>	<i>Tail facility CLFI</i>
<i>Start date</i>	<i>November 1, 2016</i>
<i>End date</i>	<i>January 1, 9999</i>
<i>Packet box</i>	<i>#1</i>
<i>Transponder ID</i>	<i>#21</i>
<i>LGX frame 3-1-36</i>	<i>LGX frame 3-1-36</i>
<i>ROADM ID #2</i>	<i>ROADM ID #2</i>
<i>SRG #4</i>	<i>SRG #4</i>
<i>Port pair #5</i>	<i>Port pair #5</i>

2 Capacity and Equipment Planning

2.1 Direction/Degree

1. Planning a new degree of a ROADM involves creating an “OMS CLFI”. Planner specifies new ROADM locations, ROADM node IDs, and equipment vendors in locations (CLLIs), or specifies new degrees in existing ROADM nodes.
2. Planner selects fiber type, fiber # / line code to connect adjacent ROADM nodes
3. Unique OMS CLFIs are assigned to the facilities that connect ROADM nodes.
4. Equipment Engineer assigns HS LGX jacks for each new ROADM direction/degree to make connections to the OSP fiber.

The information described in Section [1.4.1](#) for a ROADM node and a direction/degree can be derived from steps (1) and (3) above.

Note:

Fiber spans, or Facility_Routing_Subpath, associated to each OMS CLFI are assumed to be recorded in the SRLG Database through an external application which identifies SRLGs for all Metro network facilities. The SRLG data is required for the PCE to perform constrained routing.

2.2 Add/Drop Group and SRG

To add an add/drop group or an SRG to a ROADM node, planner specifies an ID (#) to the planned add/drop group or SRG in a planned or existing ROADM node. Vendor of the add/drop group or SRG is the same as the vendor of the ROADM degrees.

The information described in Section [1.4.2](#) for an add/drop group can be derived as mentioned above.

2.3 Transponder

1. To add transponder to an add/drop group in a planned or an existing ROADM node, planner specifies an ID (#) to the planned transponder, identifies the ROADM node ID and the add/drop group (or SRG) # the transponder's line side is connected, and Customer Code.
2. To add pluggable unit to a planned or existing transponder, planner specifies the ID of the transponder and the vendor and type of the pluggable unit.
3. Equipment Engineer assigns port pair# in the add/drop group (or SRG) specified by planner to connect to the lineside of the planned transponder.

The information described in Section [1.5.1](#) for a transponder can be derived from the steps above.

2.4 External Pluggable

1. To add pluggable in a router and connect it to an add/drop group in a planned or an existing ROADM node, planner specifies an ID (#) for the planned pluggable, identifies the ROADM node ID, and the add/drop group # the pluggable is connected to.
2. Equipment Engineer assigns office LGX jacks for connection between the pluggable and the add/drop group specified by planner, including the port pair# in the add/drop group.

The information described in Section [1.5.2](#) for an external pluggable can be derived from step (1) and (2) above.

2.5 Tail

1. L0 and L2/L3 planners together determine where tail facilities should be created.
2. Per input from planners, equipment engineer creates a "tail CLFI" to represents the intra-office connection between client equipment and a ROADM's add/drop ports.

The information described in Section [1.5](#) for a tail facility can be derived from step (2) above.

Note:

Some Service Providers may decide to not pre-deploy transponders and pre-build tails. Thus, depending on how a service path is computed by the PCE in the Open ROADM Controller, required equipment will then be ordered, installed, and provisioned for the service.

3 Path Computation

The topology of the ROADM network can be constructed using the ROADM degrees/directions inventoried in the Open ROADM Topology Layer. The add/drop capabilities in each ROADM can be derived from the add/drop groups inventoried in the Open ROADM Topology Layer. An example of a 4-node ROADM network is shown in [Figure 3-1](#).

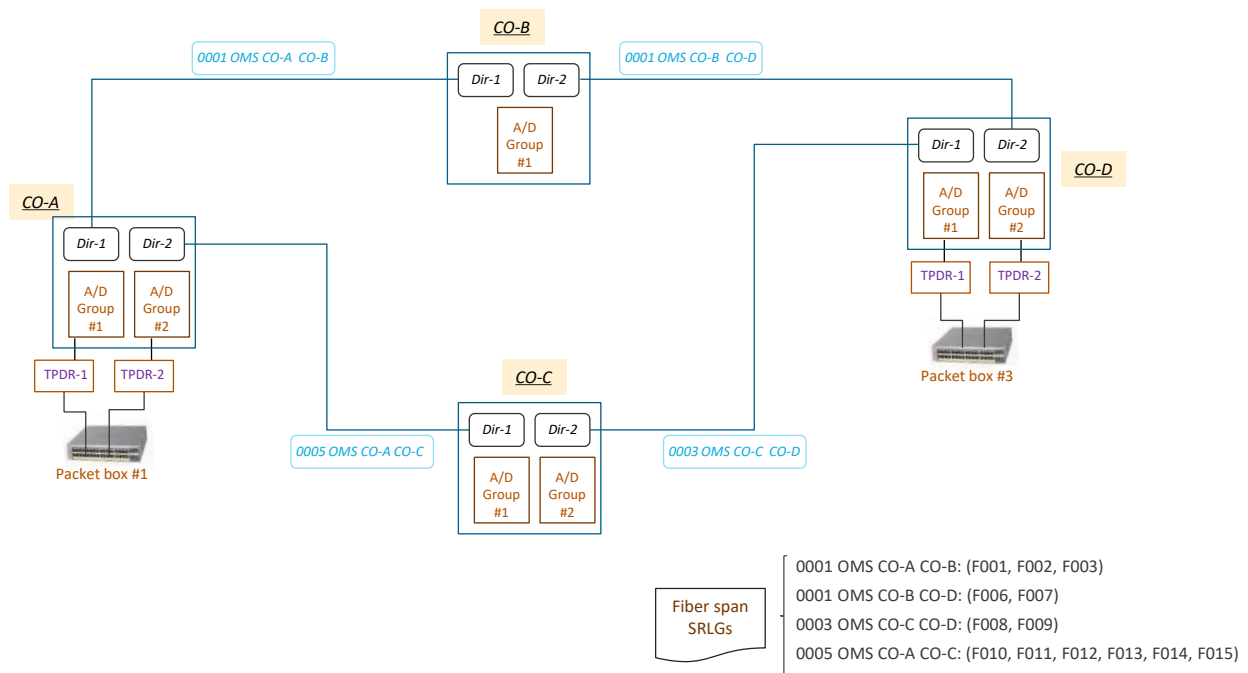


Figure 3-1. Topology of a 4-node ROADM network.

The fiber spans of each OMS section need to be made known to the Open ROADM Topology Layer. Those fiber spans corresponding to the OMS's (for example, those shown in in Figure 3-1) are stored in the SRLG (Shared Risk Link Group) Database along with fiber spans that are associated to embedded services that are either in the open ROADM network or outside of the open ROADM network. The SRLG Database is used by the PCE (Path Computation Element) in the Open ROADM Control Layer to compute paths for service demands that have routing constraints, e.g., diversity, exclude, include, etc.

When transponders are planned and deployed, they are also inventoried in the Open ROADM Topology Layer. Pre-deployed transponders can then be pre-cabled to switch/router equipment and represented by tail facilities. The tail facilities must be made known to the SDN Controller and the Open ROADM Topology Layer so that the SDN Controller can request links between existing tails and the PCE can calculate service paths between specified tails. [Figure 3-2](#) shows four tails (two in CO-A and two in CO-D) are pre-deployed in the 4-node ROADM network.

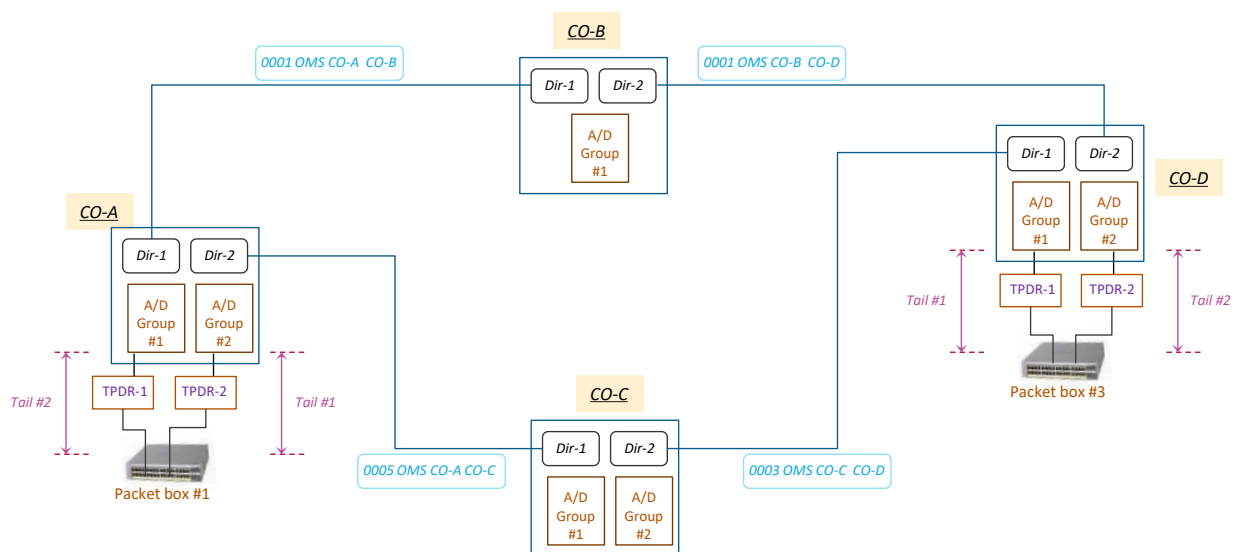


Figure 3-2. Tails are pre-deployed in the ROADM network.

PCE receives service request from the SDN Controller and performs service path computation. Routing constraints imposed on the requested service must be considered by the PCE to find an optimal route for the service demand. [Figure 3-3](#) shows two diverse services routed in the 4-node ROADM network.

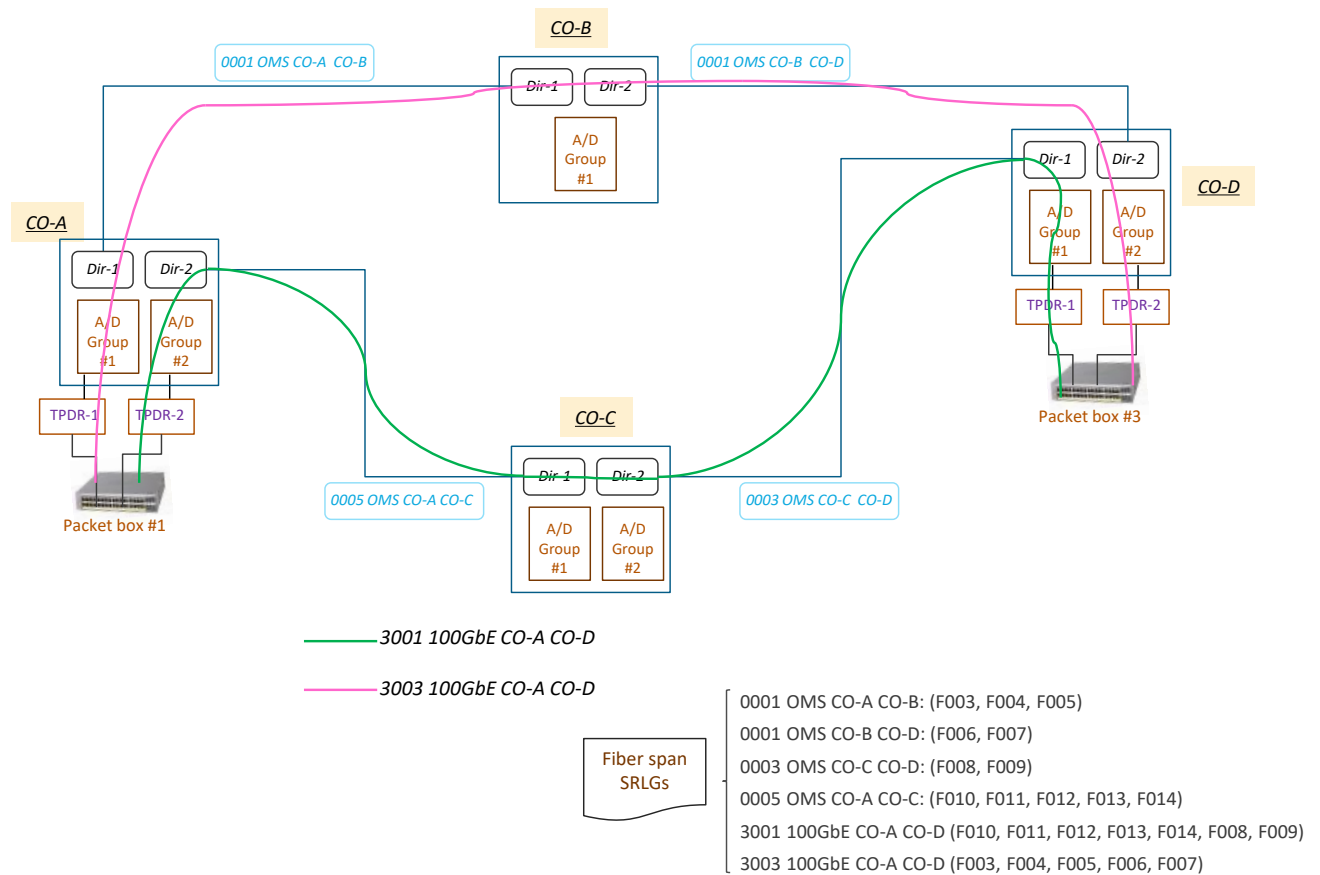


Figure 3-3. Two diverse services routed in the ROADM network.

After the two services are provisioned in the network, the SRLG Database is updated with the fiber spans corresponding to the two services, as shown in [Figure 3-3](#).

Note: The SRLG Database contains fiber spans associated to services routed outside of the open ROADM network. This is necessary because routing constraints may be referred to services routed either inside of outside of the open ROADM network.

Routing constraints cannot be neglected by the Open ROADM Topology Layer to make equipment assignment for new services. For example, the diverse constraint requires services to be assigned to tails that are connected to different add/drop groups. Conversely, the co-routing constrain requires services to be assigned to tails that are connected to the same add/drop group.

A service in the ROADM network can be specified with a start date and end date, which are to be used by the Open ROADM Topology Layer to turn up the service and remove the service, respectively.

4 Information Consolidation between Network Model and Device Model

The Open ROADM controller needs circuit pack level information to perform some management functions, e.g., fault isolation, power monitoring, etc. Since vendor specific equipment configuration is supposed to be specified in vendor's Device Model, the Device Model must be built in such a way that the representation of ROADM in the Network Model is an accurate and abstracted view of the ROADM that is detailed in the Device Model. The TTPs, CTPs, and CPs in the Network Model should have corresponding physical ports in circuit packs that are

described in the Device Model and perform precisely the functions the physical equipment does. This way, the information at circuit pack level can be easily obtained from the Device Model.

For example, if vendor's Device Model maps the optical amplifiers transmit and receive ports to TTP-Tx and TTP-Rx and some physical ports in the directional WSS (branching WSS or line WSS) to CTP-Rx and CTP-Tx and specifies the circuit packs and physical connections between the circuit packs, the actual equipment layout of a service that is represented at the network level between TTP and CTP can be derived from the vendor's Device Model. Similarly, by deriving the layout between the CTP and CP and layout between the CP from the Device Model, the abstracted layout of a service at the network level in [Table 1-18](#) and [Table 1-20](#) can be converted to a complete layout of actual equipment.

4.1 ROADM

1. Detailed equipment configurations shall be modeled in such a way that the required inventory data related to a **degree** can be generated automatically when it is instantiated.

- The circuit packs associated to the degree are generated from planning data. Validation of degree # is supported by the model, i.e., whether degree # exceeds the capability of vendor's ROADM product.
- The bay FIC and AIDs (bay/shelf/slots, U# in a rack, etc.) of the circuit packs are expected to be provided by a capacity planning tool based on engineering rules. The bay FIC and AIDs will be specified in the instantiation request so that the bay FIC and AIDs can be populated as attributes of the equipment instances that are generated automatically based on vendor's Device Model.

Note:

The bay FIC and AIDs should be provisioned in the NE and retrievable from the NE.

- Physical connections between the circuit packs are created based on planned device template. Physical connections must reflect precisely the cabling between physical ports in the circuit packs, e.g.,

<i>Physical Connection Name</i>	<i>Source Port</i>	<i>Destination Port</i>
Dir-TLink	Dir2-WSS-Tx	Dir2-TxAmp-IN
Dir-RLink	Dir2-WSS-Rx	Dir2-RxAmp-OUT

- Internal links between circuit pack's in and out ports are created automatically. [Figure 4-1](#) shows the internal links inside a 1x9 WSS where the 9 links between the Tx port and the 9 input ports are identified and the 9 links between the Rx port and the 9 output ports are identified.

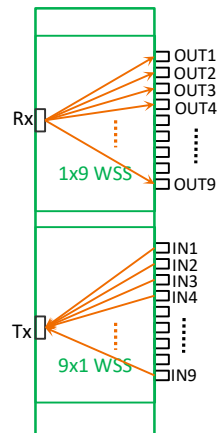


Figure 4-1. Internal links inside a WSS.

- Interconnections with all existing directions/degrees are generated automatically.
 - Interconnections with all existing add/drop groups are generated automatically
 - The following physical ports should have attributes specifying which logical points in the Network Model the physical ports are mapped to:
 - The physical port in a given degree through which the outgoing signal to another ROADM is launched.
 - The physical port in a given degree through which the incoming signal from another ROADM is received.
 - The physical ports in a given degree through which express traffic going to other degrees of the same ROADM is transmitted.
 - The physical ports in a given degree through which express traffic coming from other degrees of the same ROADM is received.
 - The physical ports in a given degree through which add/drop traffic going to all add/drop groups is transmitted
 - The physical ports in a given degree through which add/drop traffic coming from all add/drop groups is received
 - OMS CLFI written in the node and associated to the equipment
 - Alarm messages should include the facility CLFIs
2. Detailed equipment configurations shall be modeled in such a way that the required inventory data related to an add/drop group or an SRG in an add/drop group can be generated automatically when it is instantiated.
- The circuit packs associated to the add/drop group or the SRG in an existing add/drop group are generated automatically. Validations of add/drop group # and SRG # in an add/drop group are supported by the model, i.e., whether the specified degree # or SRG# in an existing add/drop group exceeds the capability of vendor's ROADM product.
 - Each circuit pack in a given add/drop group can be identified with the specific add/drop group number and the SRG number, e.g., “ADG2-SRG3” (the 3rd SRG in the 2nd add/drop group).
 - The bay FIC and AIDs (bay/shelf/slots, U# in a rack, etc.) of the circuit packs are expected to be provided by a capacity planning tool based on operator's engineering rules. The bay FIC and AIDs will be specified in the instantiation request so that the bay FIC and AIDs can be

populated as attributes of the equipment instances that are generated automatically based on vendor's Device Model.

Note:

The bay FIC and AIDs should be provisioned in the NE and retrievable from the NE.

Bay/shelf information is in the planning system, not in the NE. Physical connections between the circuit packs are created based on planning input. Physical connections must reflect precisely the cabling between physical ports in the circuit packs.

- Internal links between circuit packs in and out ports are created automatically.
- Interconnections with existing directions/degrees are generated based on planning input. Those physical connections between ROADM degrees and between ROADM degrees and SRGs are one-to-one mapped to logical connectivity links described in Section [1.4.3](#).
- Query for the # of fan-out ports in each SRG, i.e., the # of Tx/Rx ports supported by each SRG. # of Tx/Rx ports can be increased incrementally. This can be self discovered.
- The following physical ports should have attributes specifying which logical points in the Network Model the physical ports are mapped to:
 - The physical ports in a given SRG in a given add/drop group through which add/drop traffic going to all ROADM degrees is transmitted
 - The physical ports in a given SRG in a given add/drop group through which add/drop traffic coming from all ROADM degrees is received

3. Descriptive metadata:

- Vendor
- # of wavelengths in OMS trails
- Maximum # of directions/degrees
- Maximum # of add/drop groups
- Type of add/drop group, CD vs. CDC
- Maximum # of SRGs in an add/drop group.
- Maximum # of Tx/Rx port pairs in an SRG

4.2 Transponder

1. A transponder shall be modeled in such a way that the required inventory data related to the transponder can be generated automatically when it is instantiated.
 - The transponder circuit pack is generated based in planning input.
 - The following values specified in the instantiation request are populated as attributes of the transponder instance.
 - Location CLLI
 - ID assigned to the transponder
 - AIDs (bay/shelf/slots) of the transponder
 - Line side connections, e.g., LGX jack #s, add/drop group port pair.

2. Internal links between circuit packs in and out ports are created automatically.
3. Descriptive metadata:
 - Vendor
 - Signal rate
 - SRG for multiple transponders on the same blade

4.3 Pluggable Module

1. A pluggable module shall be modeled in such a way that the required inventory data related to the pluggable module can be generated automatically when it is instantiated.
 - The pluggable module instance is generated based on planning input.
 - The following values specified in the instantiation request are populated as attributes of the transponder instance:
 - Location CLLI
 - ID assigned to the pluggable module
 - AIDs (bay/shelf/slots) of the pluggable module
 - Line side connections, e.g., LGX jack #s, add/drop group port pair.
2. Descriptive metadata:
 - Vendor
 - Signal rate