Metro Open ROADM Network Model

Version 1.1

July 21, 2016

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

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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

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.

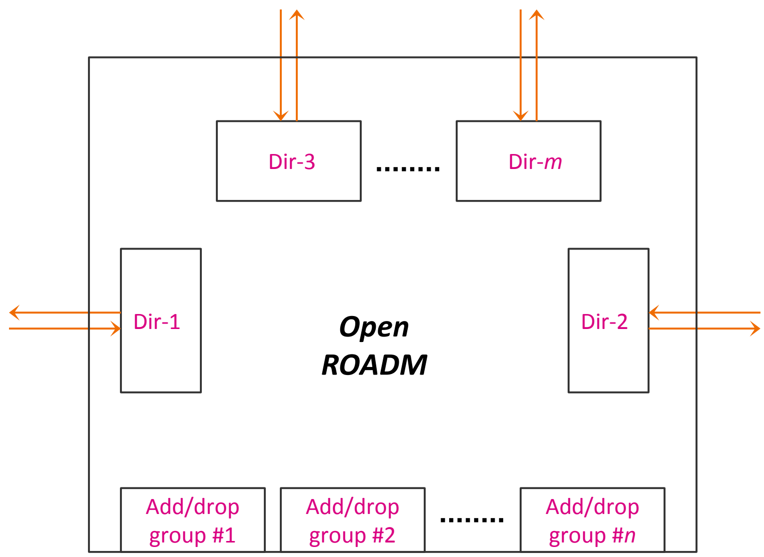


Figure 1-1. A generic representation of an *m*-degree ROADM with *n* add/drop groups.

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.

From network management point of view, the information associated to a ROADM includes the attributes described in Table 1-1:

Table 1-1. Attributes associated to a ROADM node.

Attribute	*Description*	*Note*
Office	Location CLLI where ROADM resides	Data from planning
Node Type	Specification of the type of the node, "RDM".	Data from planning
Node Number	Number assigned to a ROADM node in a given office, i.e., 1, 2, …, *N*	Data from planning
Node ID	Network-wide unique identifier for a ROADM node	*Constructed by concatenating office CLLI, FIC, and shelf #?*
Vendor	Identifier of the supplier for the ROADM equipment	Data from planning
Model Number	Identifier of the supplier's ROADM equipment	Data from planning
Domain-Subnetwork	Specific Domain-Subnetwork in which the ROADM node resides	Data from planning
IP address	IP address assigned to the ROADM node	Data from equipment engineering
*Relay Rack**	Frame Identification Code (FIC)	Data from equipment engineering
*Shelf**	Shelf in which the NE controller is equipped	Data from equipment engineering
# of degrees	# of directions/degrees supported by the node	Data accumulated thru growth
# of SRGs	# of SRGs supported by the node	Data accumulated thru growth

1.1 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.

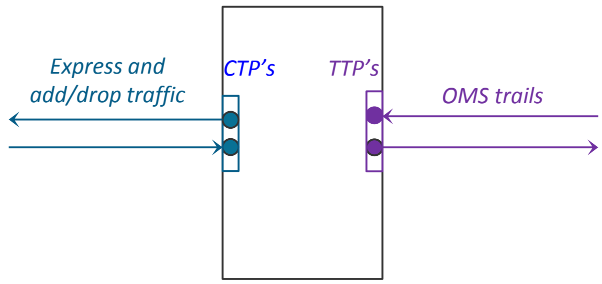


Figure 1-2. Network representation of a ROADM degree.

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 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.

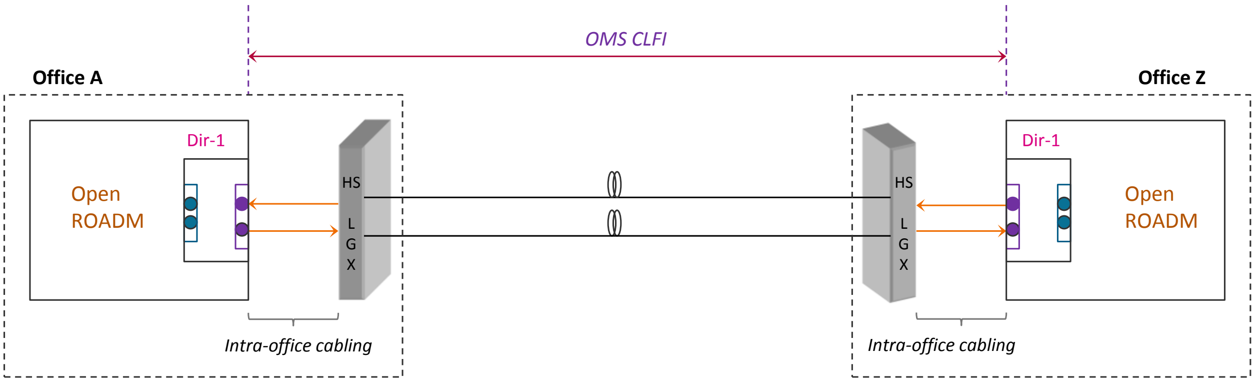


Figure 1-3. Connections between two ROADM nodes.

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.

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 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 1-2:

Table 1-2. Attributes associated to a ROADM degree.

Attribute		***Description***	***Note***
Degree #		Identifier for each direction/degree	Data from planning
External	*Far-end office*	Location CLLI of adjacent office where OMS trails are terminated	Data from planning
	Node Number	Number assigned to a ROADM node in the far-end office, i.e., 1, 2, …, *N*	Data from planning
	Node ID	Network-wide unique identifier for a ROADM node	*Constructed by concatenating office CLLI, FIC, and shelf #?*
	Degree #	Identifier for direction/degree in far-end ROADM	Data from planning
	OMS CLFI	Unique facility name given to the OMS tails	Data from planning
	Facility_routing_subpath	List of fiber spans (underlying fiber on which the OMS trail traverses) in sequence from the A-end of the OMS trail to the Z-end	Data from planning
	N	Numeric value specifies the maximum # of wavelengths supported by the OMS	Data obtained from vendor's device
	Available wavelengths	List of wavelengths that are supported by the degree	Data obtained from vendor's device
	Distance	Numeric value in km	Data from planning
	Span loss - Base	Numeric value in dB	Data from planning
	Span loss - Current	Numeric value in dB	Data measured by the equipment
	TTP-Tx	The TTPs are used to track services/circuits assigned to the external OMS CLFI above. A wavelength number *n* can be appended to the TTPs to represent a service/circuit supported by the OMS trails using wavelength *n*, where *n* is between 1 and *N*.	Auto generated and updated with wavelength #s when services are created
	TTP-Rx		
Internal	*CTP-Tx*	The CTPs are used to track add/drop traffic and express traffic inside a ROADM node. A wavelength number *n* can be appended to the CTPs to represent a service/circuit supported by the ROADM degree using wavelength *n*: where *n* is between 1 and *N*.	Auto generated and updated with wavelength #s when services are created
	CTP-Rx		

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 1-2 equals to 96), 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. 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, 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.

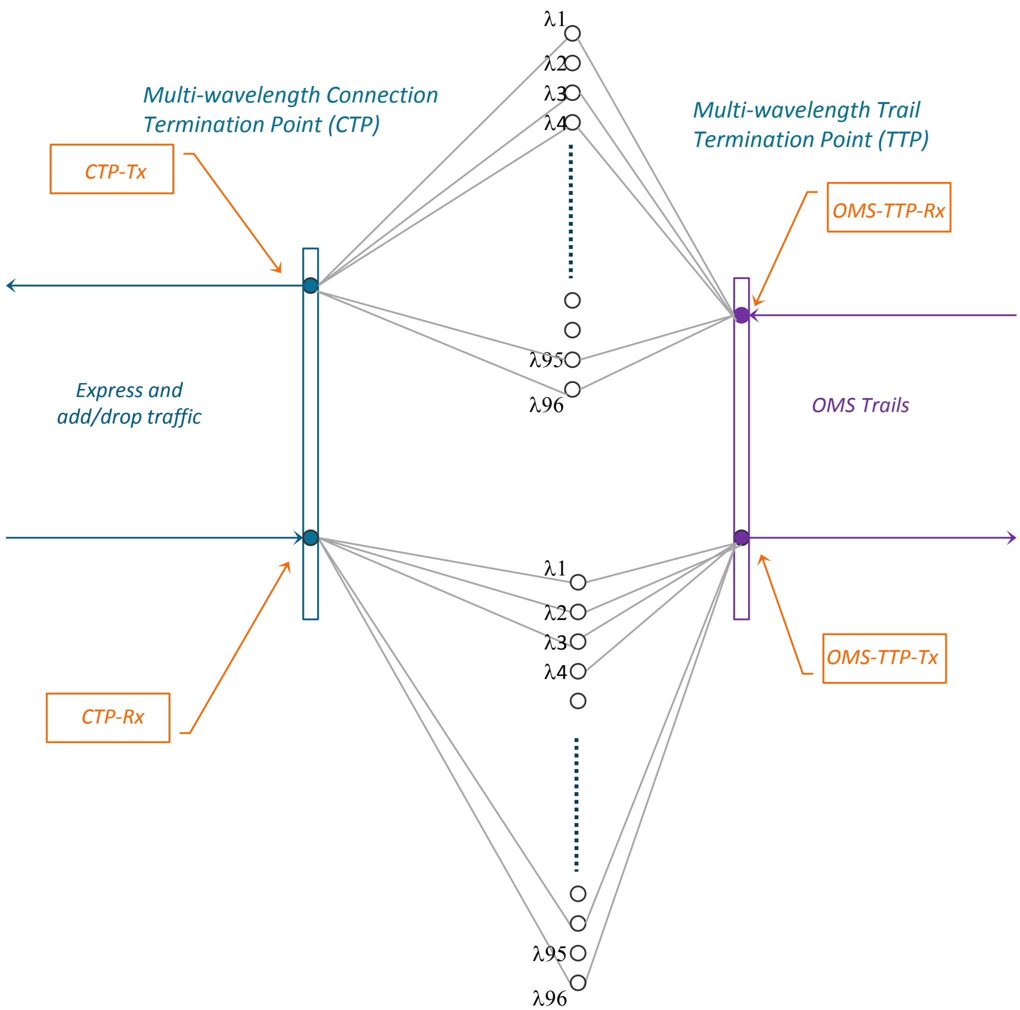


Figure 1-4. Multi-wavelength TTP and CTP in the Direction/Degree construct.

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, λ4 in CTP-Tx is matched to λ4 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.

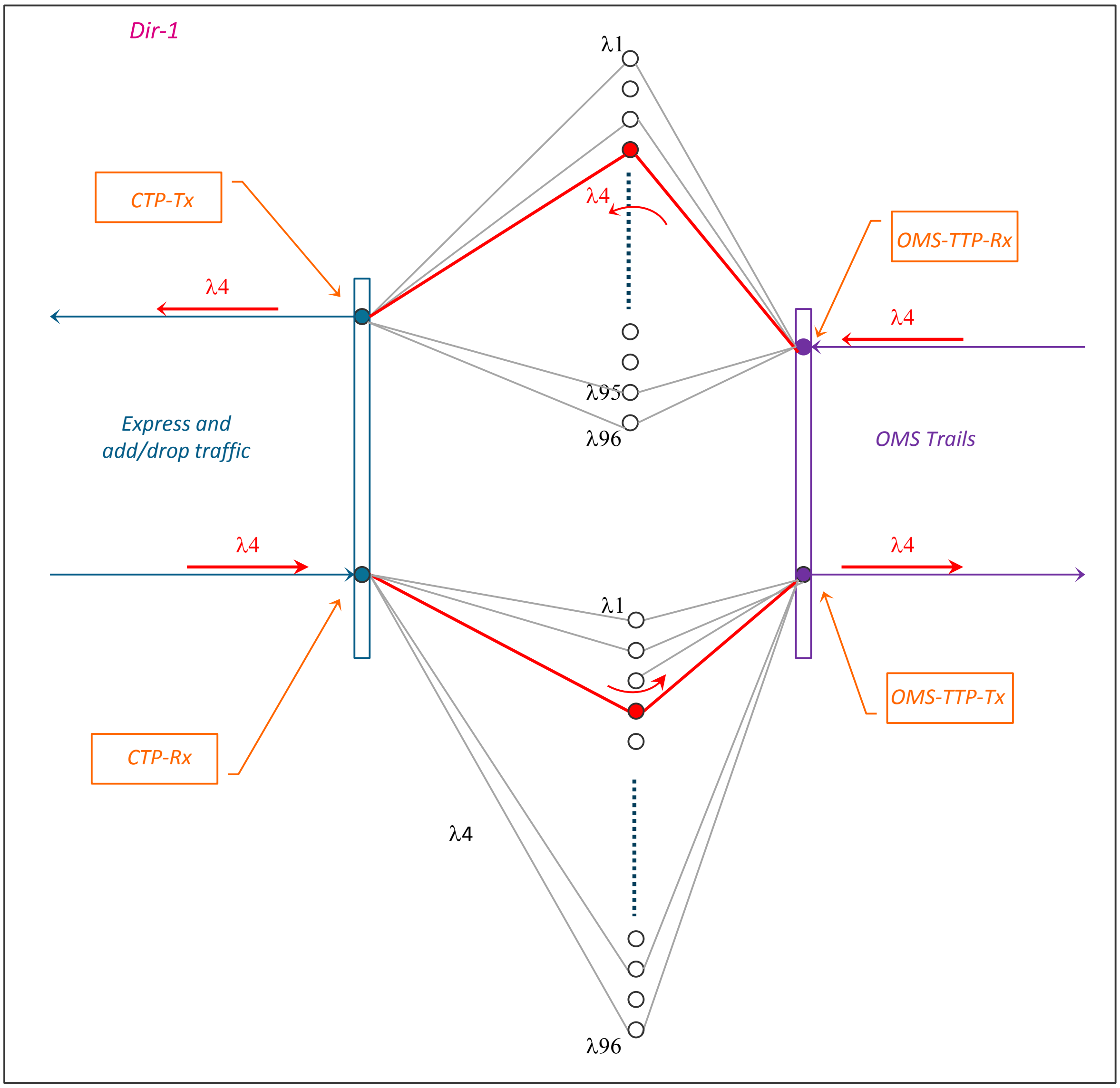


Figure 1-5. Wavelength #4 (λ4) is assigned to a service supported by Dir-1 of a ROADM.

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.

1.2 Add/drop Group and SRG

Each add/drop group 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 are considered to be three separate SRG's.

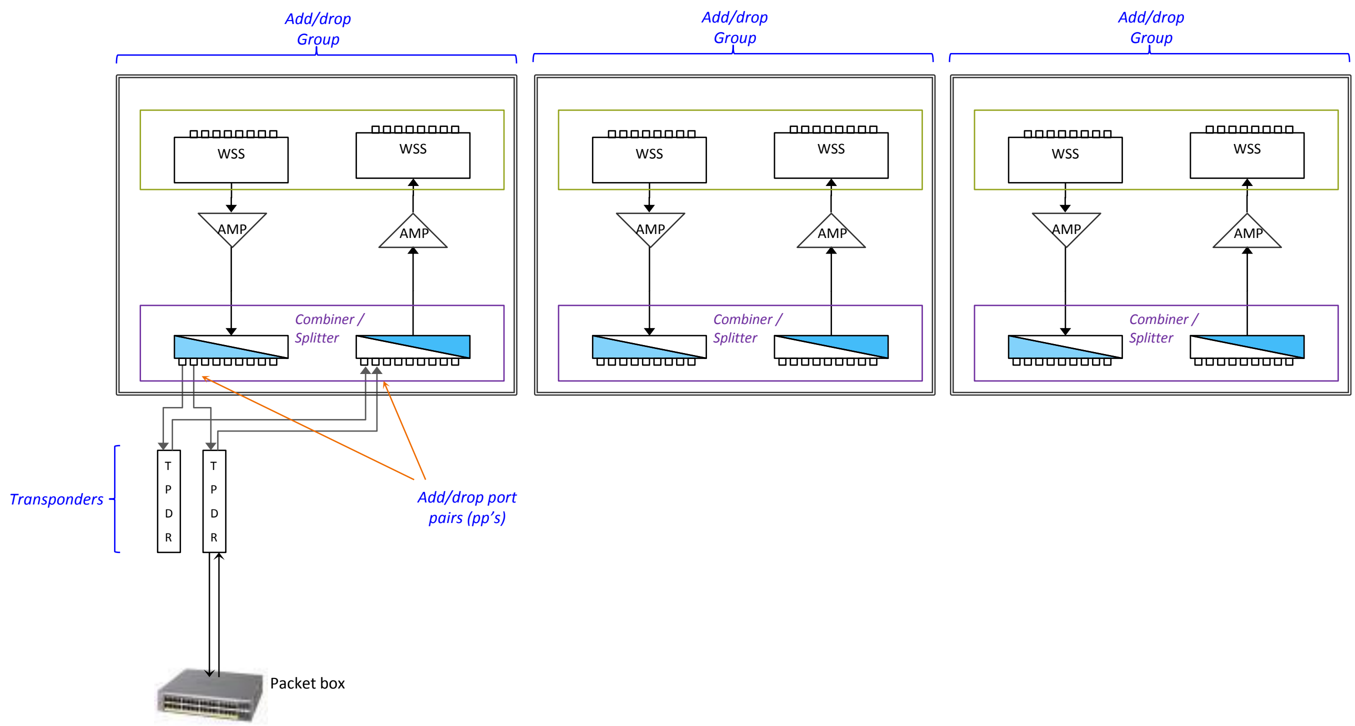


Figure 1-6. Three add/drop groups correspond to three SRGs.

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 #s 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 group. A pair of CP's (Connection Points) is included each SRG. Applying the model to the add/drop group 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 (OCLD) that are pre-cabled together with the OCLD being connected to an add/drop port pair (#4) in the 2nd SRG.

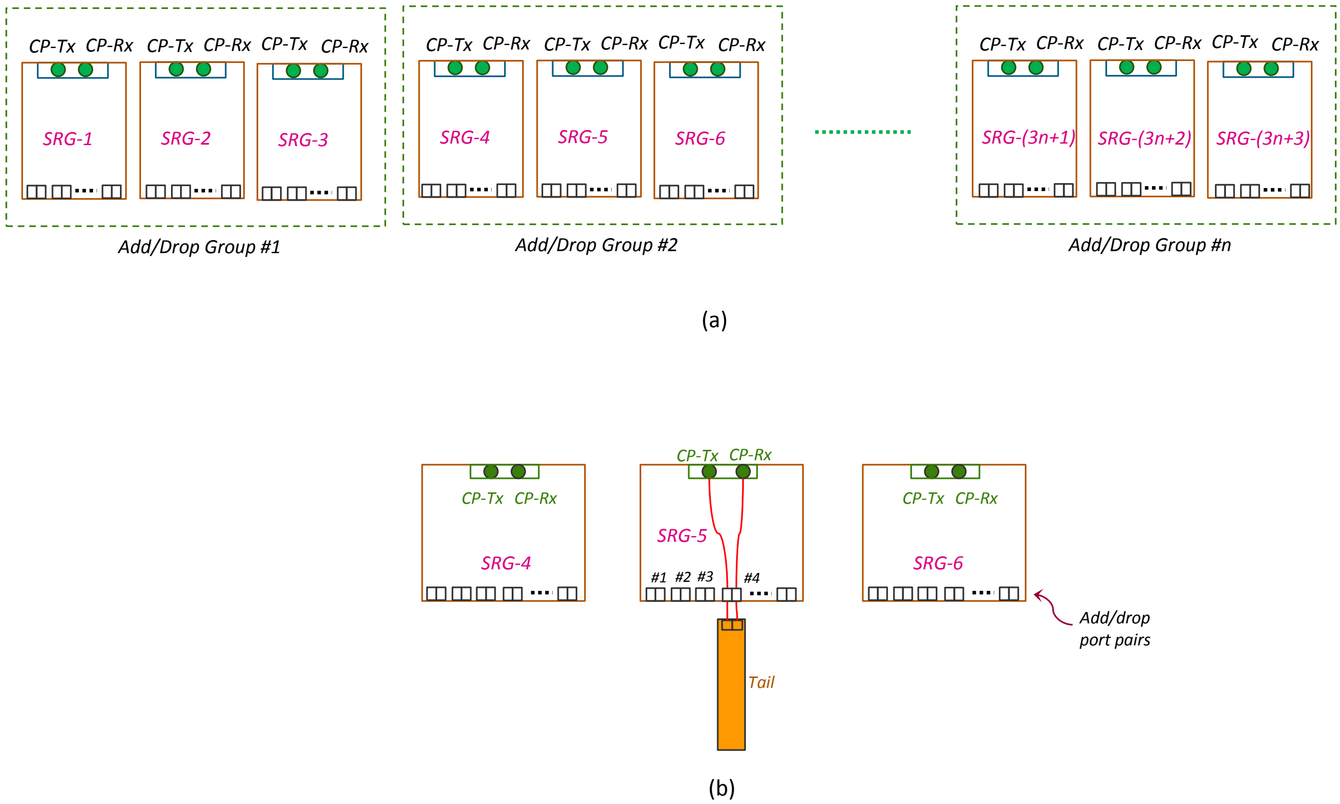


Figure 1-7. (a) A pair of Connection Points (CPs) is assigned to each SRG in an Add/drop group construct that contains three SRGs. (b) A "tail" facility is created via the 2nd SRG in a 3-SRG add/drop group.

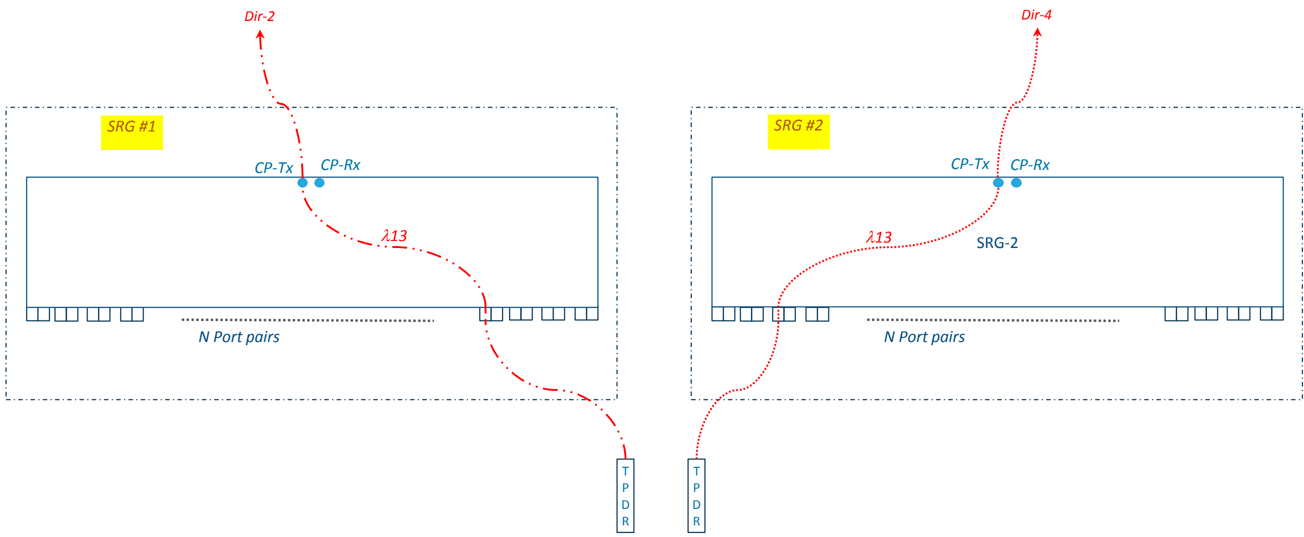
The number of port pairs in an add/drop group or in an SRG is vendor specific. All those ports are used for intra-office connections between the ROADM and client equipment. The connections, also known as "tails", may be direct interfaces with client equipment or may go through transponders or muxponders and intermediate LGXs (refer to Section 1.8 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:

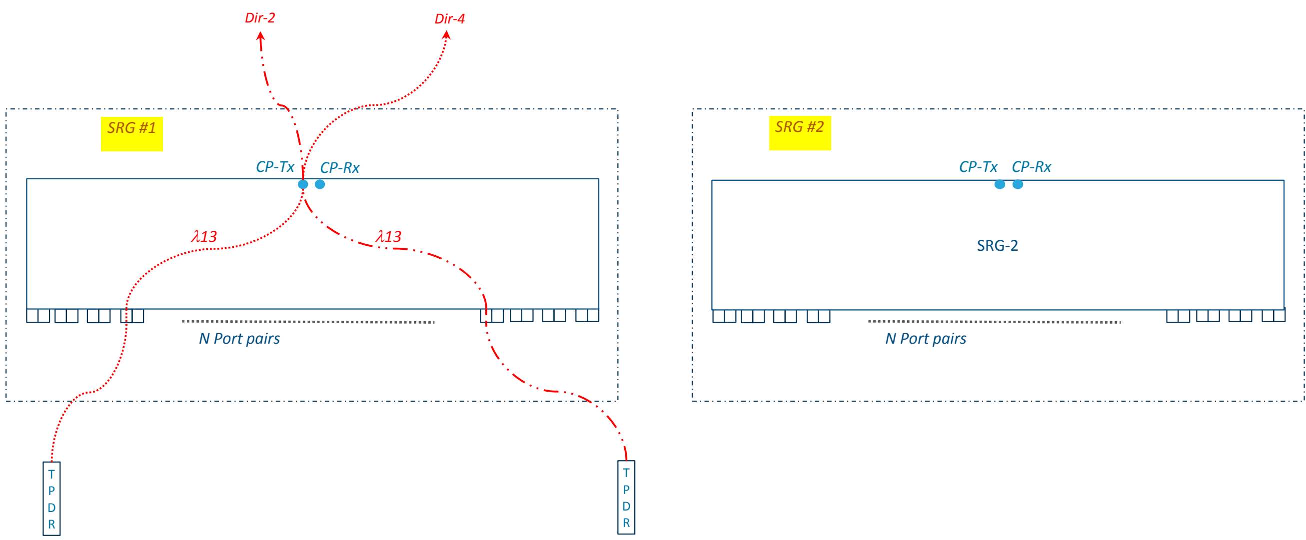
- A C/D add/drop group will fail to function if there is an equipment problem in the group; hence the whole add/drop group is considered as one SRG.
- A C/D/C add/drop group is comprised of multiple SRGs. Equipment failure in one of the SRGs will bring down only one SRG; the other SRGs in the same add/drop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



(a)



(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 1-3:

Table 1-3. Attributes associated to an SRG.

<table>
<tr><th colspan="2">Attribute</th><th>Description</th><th>Note</th></tr>
<tr><td colspan="2">SRG #</td><td>Identifier for each SRG</td><td>Data from planning</td></tr>
<tr><td colspan="2">N_{pp}</td><td>Maximum number of add/drop port pairs in an SRG</td><td>Data from vendor's Device Model</td></tr>
<tr><td colspan="2">Available Wavelength</td><td>List of wavelengths that are supported by the SRG</td><td>Data obtained from vendor's device</td></tr>
<tr><td colspan="2">Wavelength Duplication</td><td>Enumerated value:
• 1 – one per SRG
• 2 – one per Degree</td><td>Data from planning
• "One per SRG" is applied for C/D add/drop group
• "One per Degree" is applied for C/D/C add/drop group</td></tr>
<tr><td rowspan="2">CP-Tx</td><td></td><td>Through CP-Tx local traffic is transmitted to various degrees</td><td rowspan="4">CPs are used to manage the usage of add/drop port pairs in an SRG. A port pair number, p (where p is between 1 and N_{pp}) can be appended to the CPs to specify the port pair that is used to connect to a transponder, muxponder, or pluggable in packet box.
Auto generated and updated when tail facilities are created</td></tr>
<tr><td>Wavelengths</td><td>Wavelengths assigned to CP-Tx</td></tr>
<tr><td rowspan="2">CP-Rx</td><td></td><td>Through CP-Rx local traffic is received from various degrees</td></tr>
<tr><td>Wavelengths</td><td>Wavelengths assigned to CP-Rx</td></tr>
<tr><td rowspan="2">pp</td><td>pp number</td><td>Number assigned to a pp</td><td>Data from vendor's Device Model</td></tr>
<tr><td>Wavelength</td><td>The wavelength number assigned to the service that the pp supports</td><td>pp's (port pairs) are used to manage external connections with xponders or pluggables.</td></tr>
</table>

Note:

The # 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".

1.3 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:

- "ExpressLink*mn*"

  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). Figure 1-9 illustrates the three pairs of ExpressLinks between the three degrees of a ROADM node.

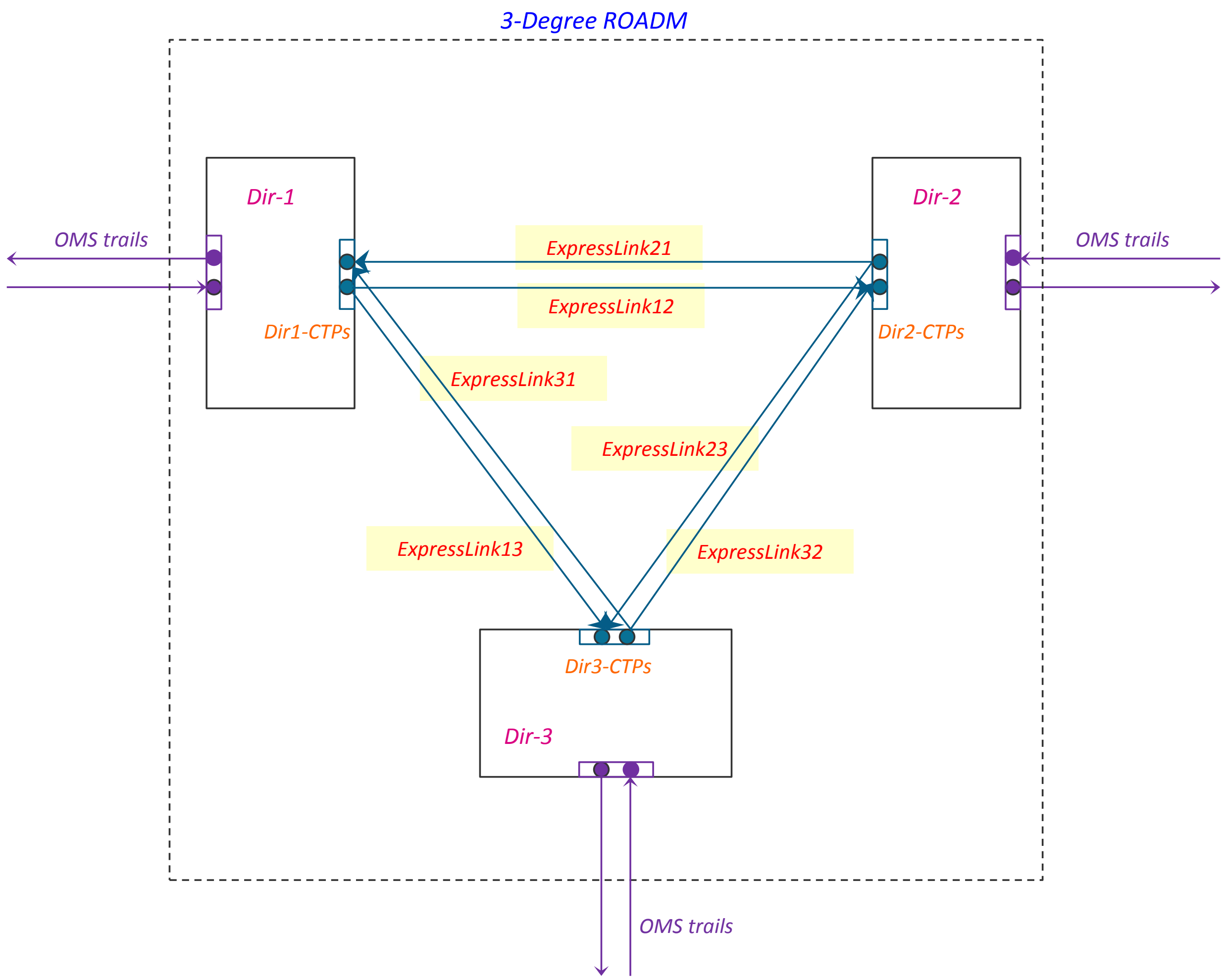


Figure 1-9. Logical ExpressLinks represent connectivity between ROADM degrees.

- "DropLink*xy*"

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

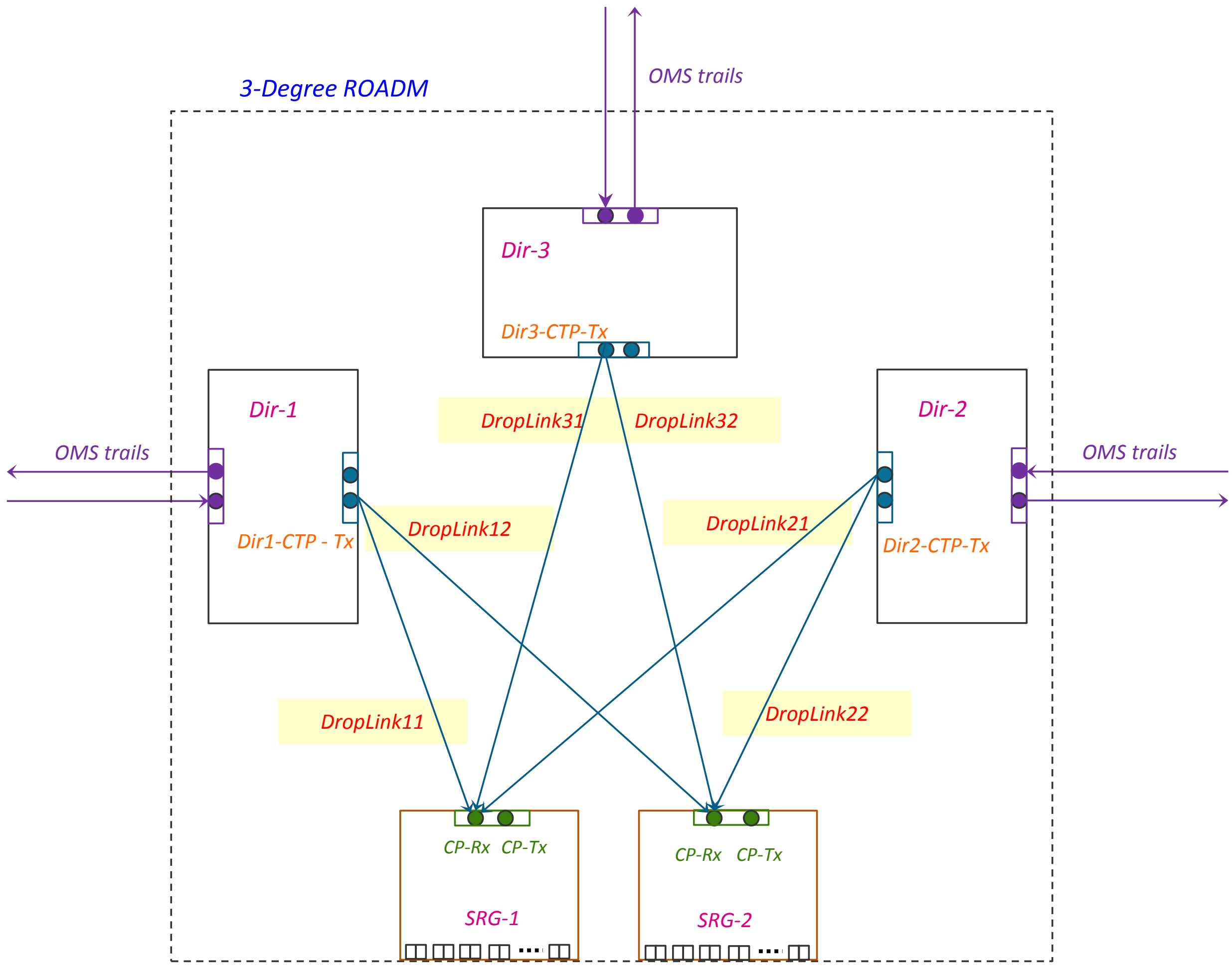


Figure 1-10. Logical drop links represent connectivity between ROADM degrees and SRG.

- "AddLink*yx*"

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

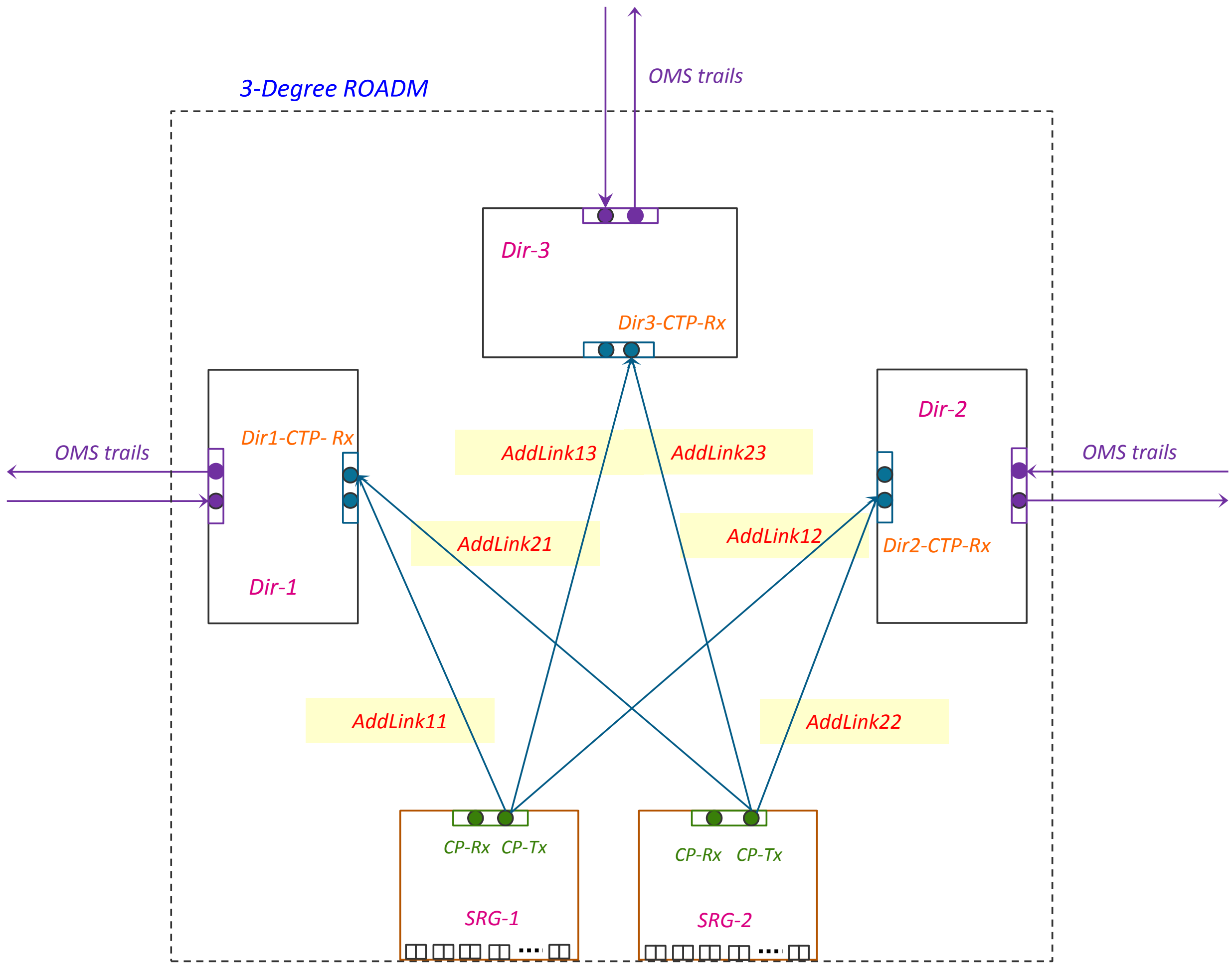


Figure 1-11. Logical add links represent connectivity between ROADM degrees and SRG.

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 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. Attributes of the Connectivity Map is described in Table 1-4.

Table 1-4. Attributes associated to Connectivity Map.

Attribute	*Source*	*Destination*	*Description*
ExpressLink*mn*	Dir*m*-CTP-Tx	Dir*n*-CTP-Rx	List of logical links to represent express traffic between ROADM degrees
DropLink*xy*	Dir*x*-CTP-Tx	SRG*y*-CP-Rx	List of logical links to represent drop traffic from ROADM degrees to SRGs
AddLink*yx*	SRG*y*-CP-Tx	Dir*x*-CTP-Rx	List of logical links to represent add traffic from SRGs to ROADM degrees

1.4 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.

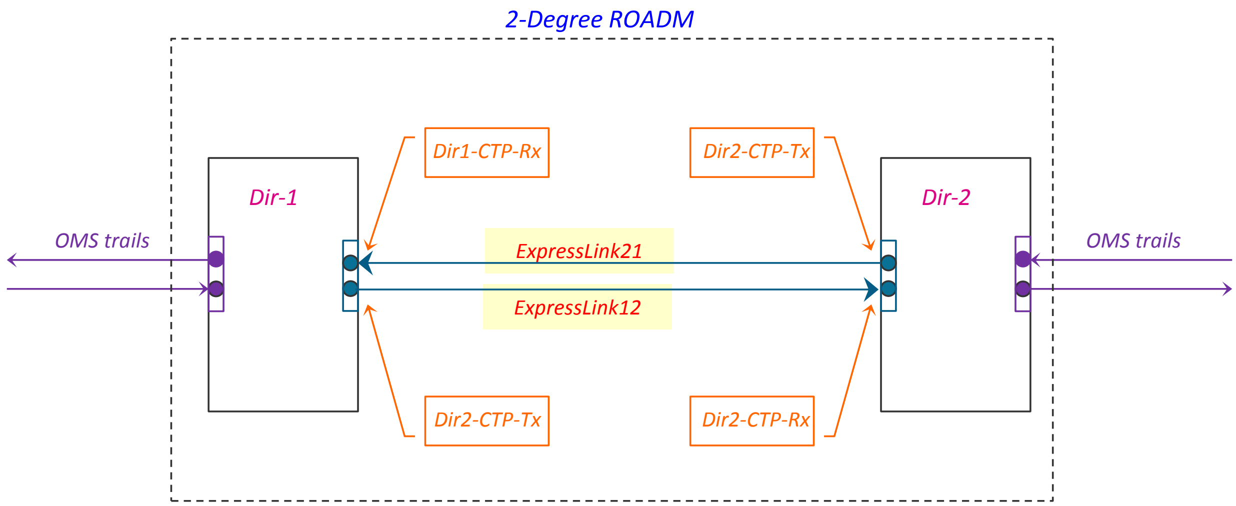


Figure 1-12. Logical links represent connections between two degrees of ROADM for express-through traffic.

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.

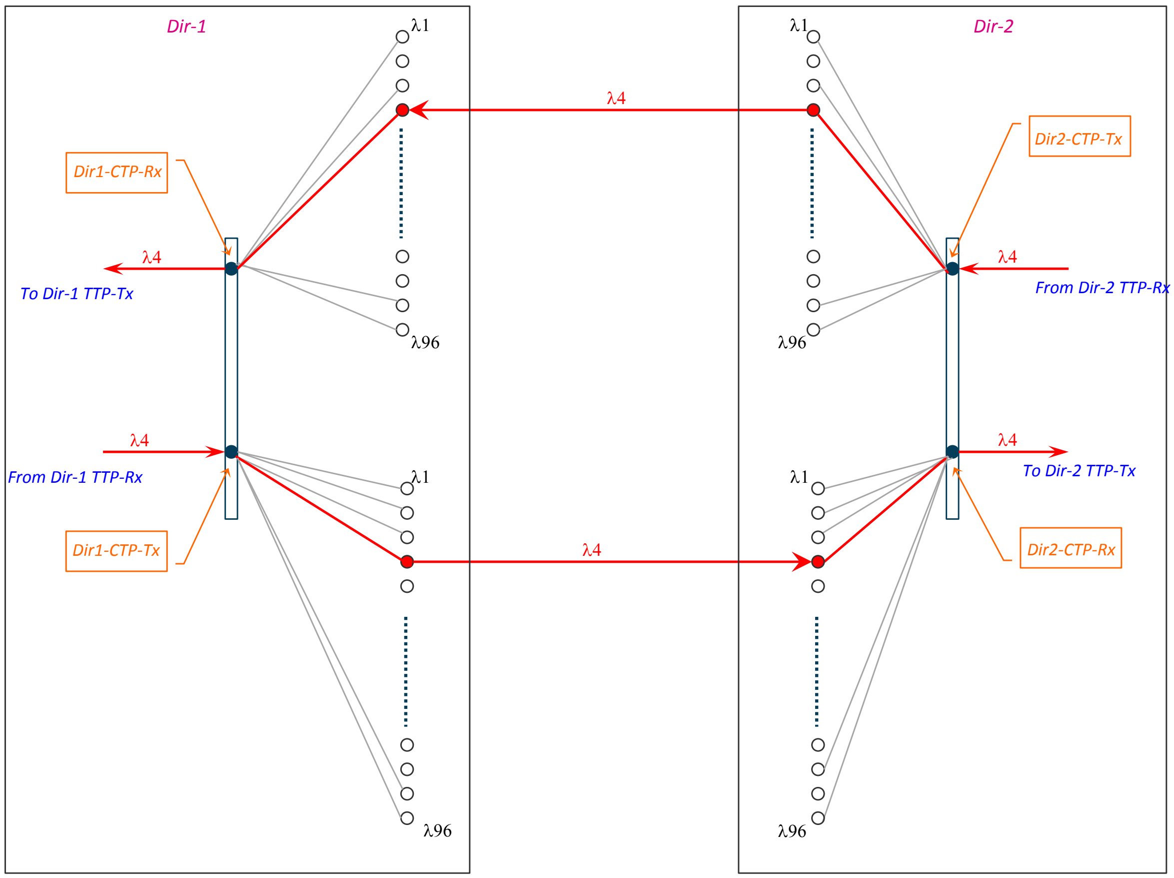


Figure 1-13. A service express through Dir-1 and Dir-2 using wavelength #4 (both degrees are shown).

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".

1.5 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.

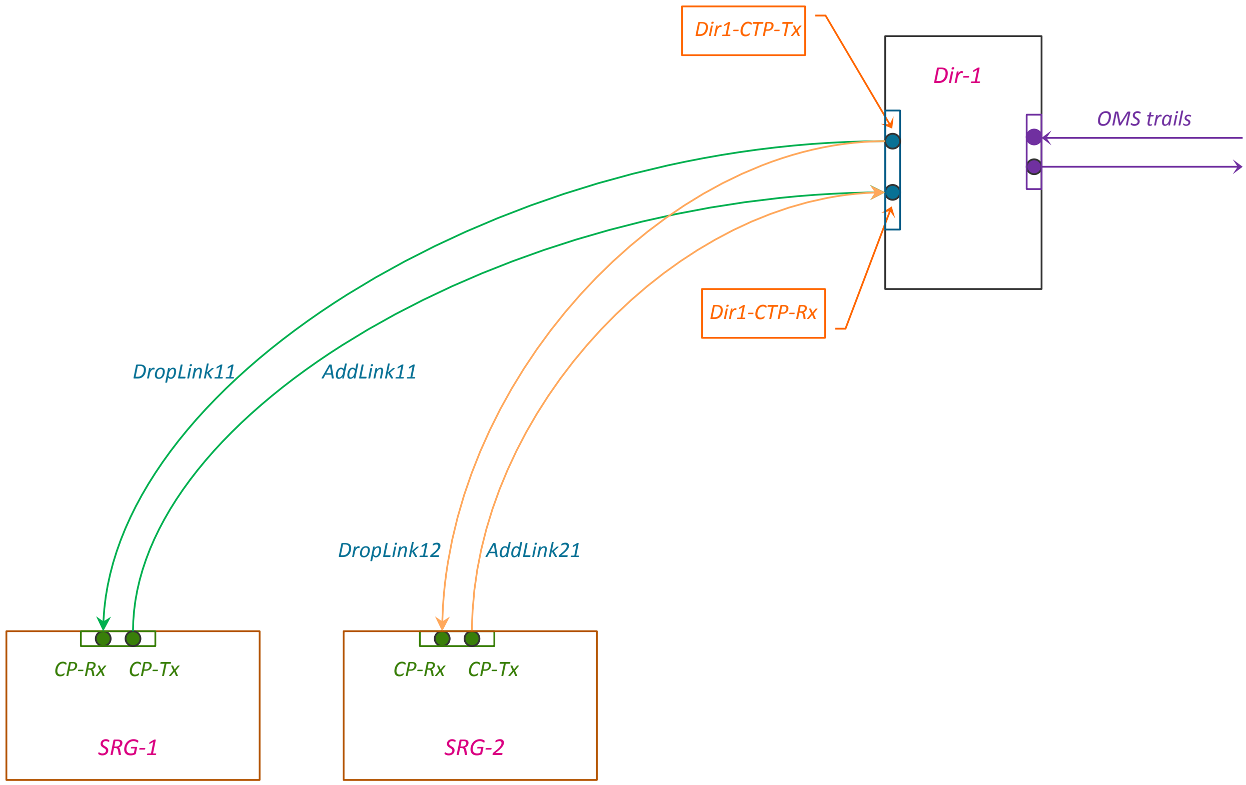


Figure 1-14. Logical links representing service traffic being transmitted between a Degree construct and two SRG constructs.

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.

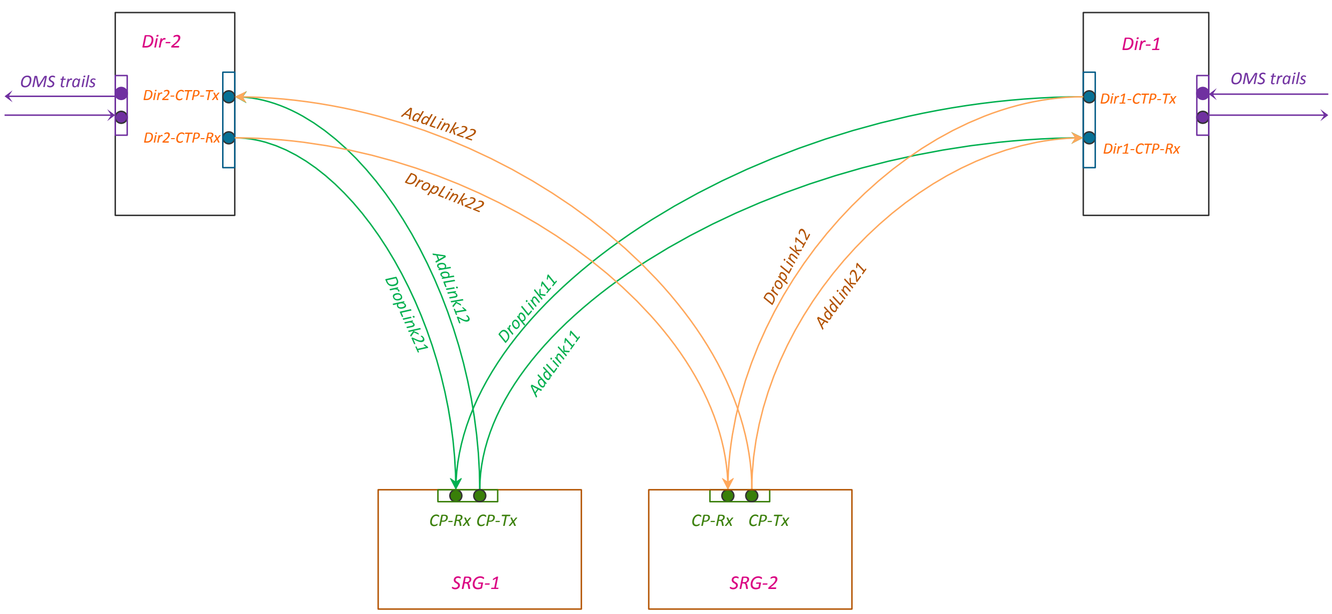


Figure 1-15. Logical links between two Degree constructs and two SRG constructs.

Wavelength numbers 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 connect 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.

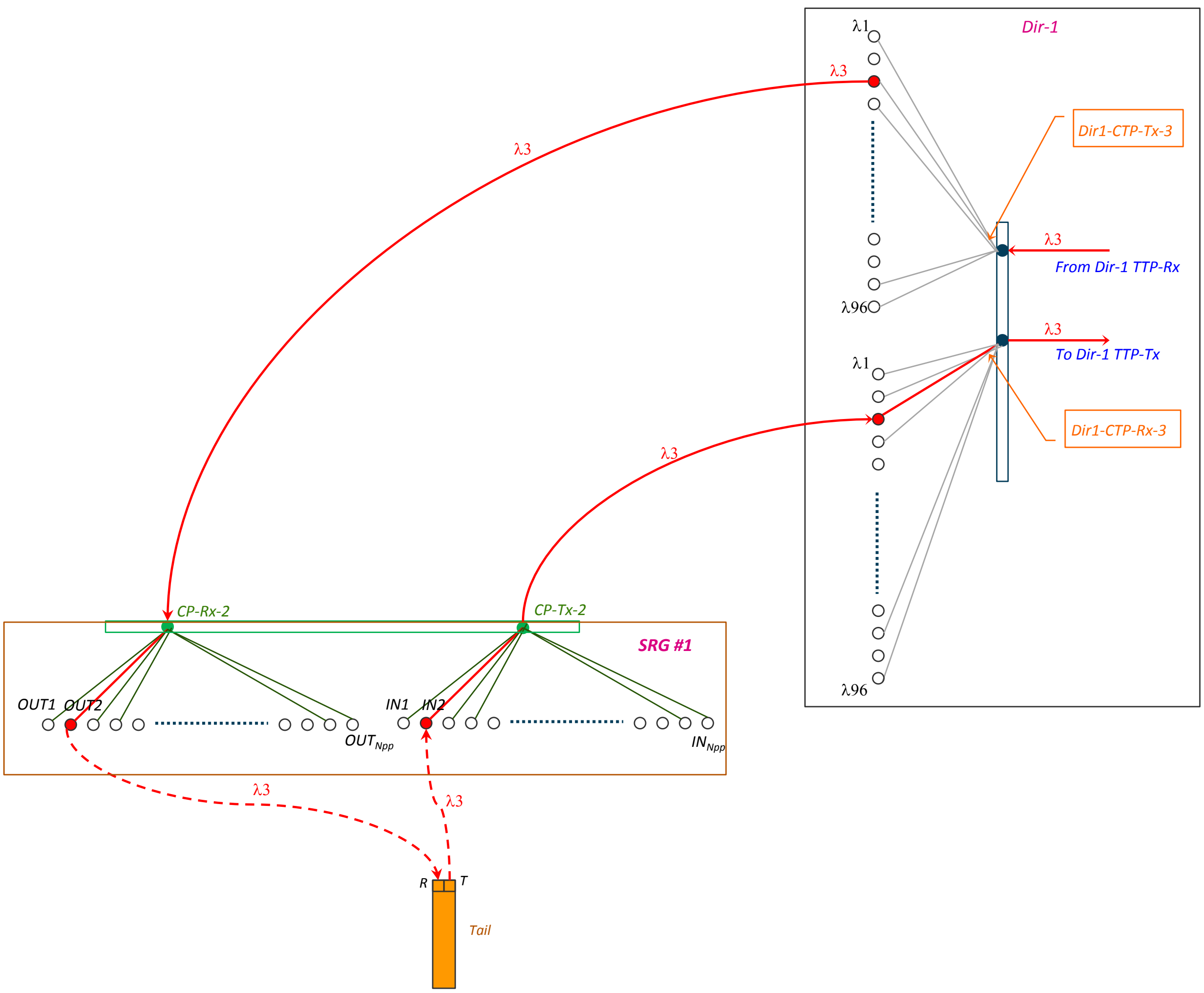


Figure 1-16. A service is added and dropped between Dir-1 and SRG #1.

When a service/circuit is added/dropped through an SRG, the wavelength information (λ3 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.

1.6 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.

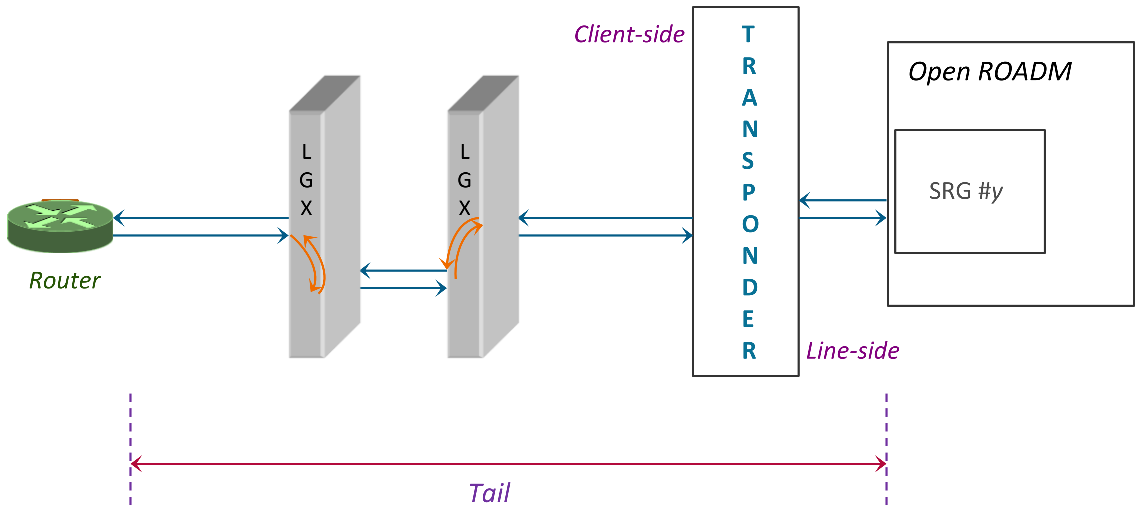


Figure 1-17. A transponder is used to support connection with router.

The information associated to an Xponder is described in Table 1-5.

Table 1-5. Attributes associated to an Xponder.

Attribute	***Description***	***Note***
Office	Location CLLI where the Xponder resides	Data from planning
Node Type	Specification of the type of the node, "XPD".	Data from planning
Xponder Number	Number assigned to an Xponder base unit in a given office, i.e., 1, 2, …, N_T	Data from planning
Xponder ID	Network-wide unique identifier for an Xponder	*Constructed by concatenating office CLLI, FIC, and shelf #?*
Vendor	Identifier of the Xponder base unit's supplier	Data from planning
Customer Code	Owner of the Xponder	Data from planning
Domain-Subnetwork	Specific Domain-Subnetwork in which the transponder resides	Data from planning
IP address	IP address assigned to the transponder	Data from equipment engineering
Relay Rack	Frame Identification Code (FIC)	Data from equipment engineering
Shelf	Shelf in which the NE controller is equipped	Data from equipment engineering

Output connection	*CLLI*		Data from planning
	ROADM node ID		Data from planning
	Accumulated bitrate		Data from planning
	Port name		List of output ports
	Vendor	Supplier of the output module	
	SRG #	Add/drop port pair the output module is connected to	
	Port Pair #		
	Local LGX		
	Bit Rate		
	Signal Format		
	Reach		
	Gray/color		
	State	Pluggable module in the port can be in one of the equipment state in Table 1-6.	
	Network Tail equipment	From SDN-C	
	Network Tail equipment ID	From SDN-C	
	Network Tail CLFI	From SDN-C	
Input connection	*Accumulated bitrate*		List of input ports
	Port name		
	Customer Code	Owner of the input module	
	Vendor	Supplier of the input module	
	Local LGX		
	Bit Rate		
	Signal Format		
	Reach		
	Gray/color		
	State	Pluggable module in the port can be in one of the equipment state in Table 1-6.	
	Client Tail equipment	From SDN-C	
	Client Tail equipment ID	From SDN-C	
	Client Tail CLFI	From SDN-C	

Table 1-6. Equipment states assigned by ROADM Controller.

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

1.7 External Pluggable

Transponder is not always required between packet box equipment and ROADM. Pluggable modules can be used in packet boxes to connect to add/drop groups directly, as shown in Figure 1-18.

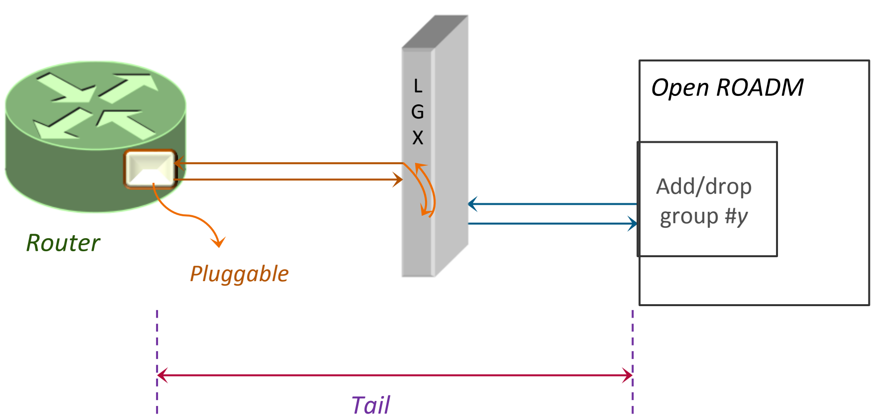


Figure 1-18. Connection between pluggable in router and add/drop group.

A pluggable installed in packet box equipment to interconnect with ROADM will be managed by the SDN-C through the packet box. However, the information associated to the pluggable and described in Table 1-7 is made known to the Open ROADM Controller:

Table 1-7. Attributes associated to a pluggable in packet box.

Attribute		***Description***	***Note***
Office	Location CLLI where the pluggable unit resides		Data from planning
Node Type	Specification of the type of the node, "PLG".		Data from planning
Pluggable Number	Identifier of the pluggable unit in a given office, i.e., 1, 2, …, N_P		Data from planning
Pluggable ID	Network-wide unique identifier for a pluggable		*Constructed by concatenating office CLLI, FIC, and shelf #?*
Vendor	Identifier of the pluggable unit's supplier		Data from planning
Customer Code	Owner of the pluggable unit		Data from planning
External connection	*ROADM node ID*		Data from planning
	SRG #		Data from planning
	Port Pair #		Data from planning
	Rate		
	Signal Format		
	Reach		
	Gray/color		
	State	Pluggable module in the port can be in one of the equipment state in Table 1-6.	
Tail	*Client equipment*		From SDN-C
	Client equipment ID		From SDN-C
	CLFI		From SDN-C

1.8 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. Figure 1-19 shows another intra-office tail in an example office.

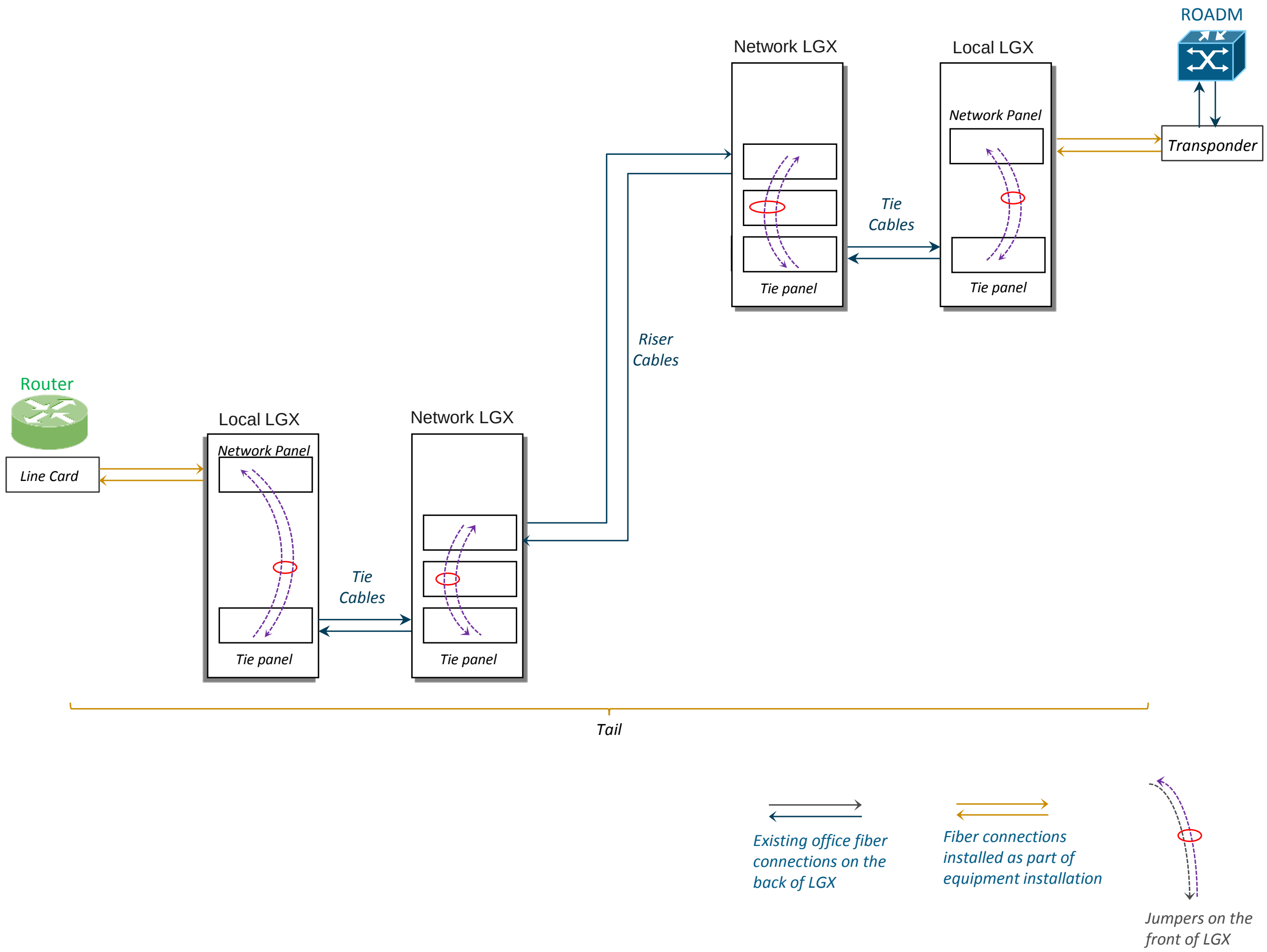


Figure 1-19. An intra-office tail.

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

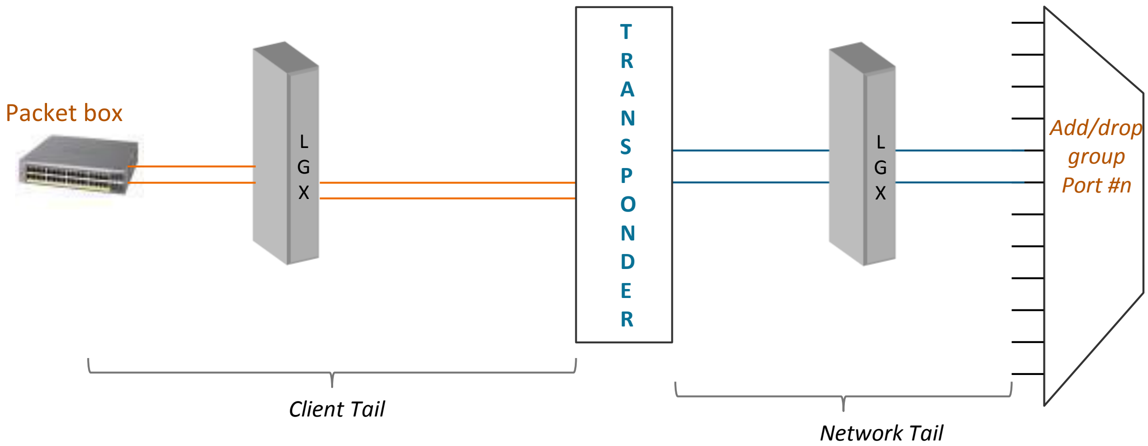
- Client Tail

  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.

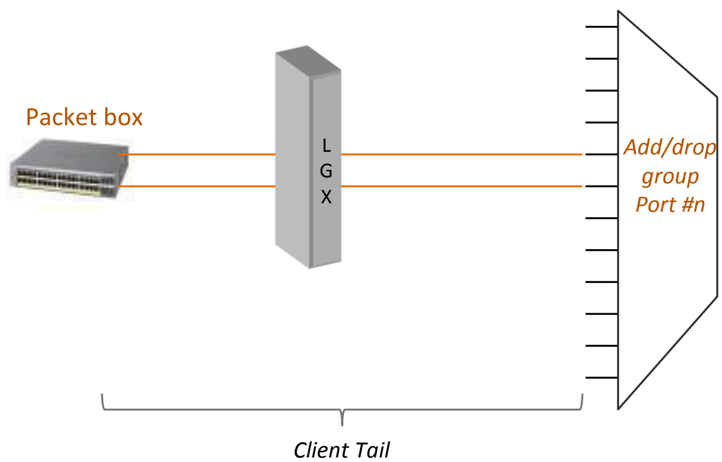
  When no transponder or muxponder is used, a Client tail becomes the entire intra-office tail, which includes the client equipment, the add/drop ports in ROADM SRG, and intermediate LGXs between them. Refer to Figure 1-20 (b) for an example.

- 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.

The information associated to a tail facility is shown in Table 1-8:

Table 1-8. Attributes associated to a tail facility.

Attribute		***Description***	***Note***
CLFI	Facility identifier of the tail		Data from planning
Time stamps	*Start date*		Data from planning
	End date		Data from planning
Layout	*Client equipment*		From SDN-C
	External pluggable	optional	
	List of intermediate LGXs (LGX ID + jack assignments)	optional	In Core, from legacy OSs In Metro, from Open ROADM Controller
	Transponder ID		From SDN-C
	List of intermediate LGXs (LGX ID + jack assignments)	optional	
	ROADM node ID		From SDN-C
	SRG #		From SDN-C
	Add/drop Port #		From SDN-C

1.9 Service/Circuit

When tail facilities exist 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 four facilities:

- 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 two 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.

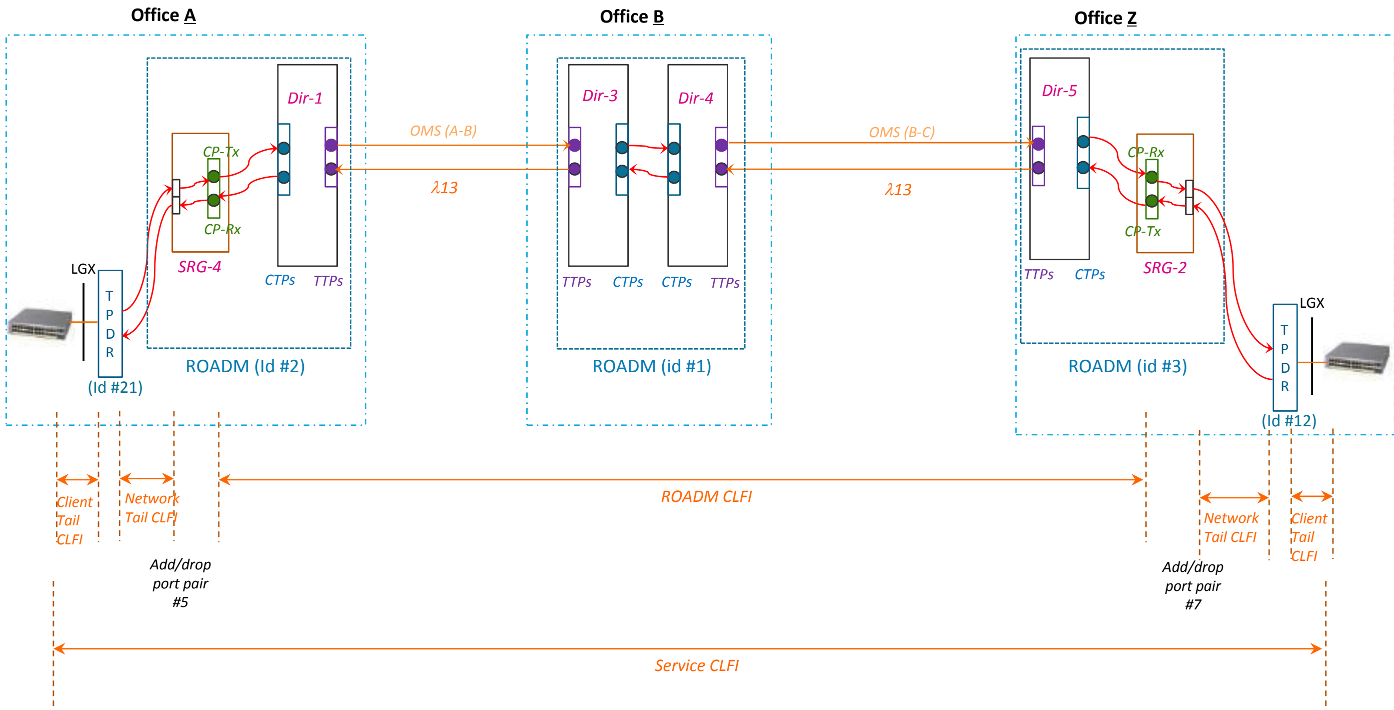


Figure 1-21. A service supported by three open ROADM nodes.

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 1-9 (not an exhaustive list):

Table 1-9. 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 or tail facility	
Z-end CLLI	Service's Z-end office or tail facility	
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 1-9 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 selects 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 1-10 shows the layout in the ROADM Facility's A-to-Z direction.

Table 1-10. A-to-Z Layout of a ROADM Facility maintained in the Network level.

Office A CLLI	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]		
Office X CLLI	Node ID + [Dir ID$_1$] + [TTP-Rx]-[wavelength #]	
	Node ID + [Dir ID$_1$] + [CTP-Tx]-[wavelength #]	

	Node ID + ExpressLink[Dir ID_1][Dir ID_2]	Zero or multiple express-thru ROADM
	Node ID + [Dir ID_2] + [CTP-Rx]-[wavelength #]	
	Node ID + [Dir ID_2] + [TTP-Tx]-[wavelength #]	
[OMS Trail CLFI]		
Office Z CLLI	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 1-11 shows the service's ROADM Facility layout in the A-to-Z direction.

Table 1-11. Example of an A-to-Z layout of a ROADM Facility in the Network level.

Office A CLLI	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)		
Office B CLLI	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)		
Office Z CLLI	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 1-12.

Table 1-12. Z-to-A Layout of a service maintained in the Network level.

Office A CLLI	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]		
Office X CLLI	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]		
Office Z CLLI	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 1-13 shows the service's ROADM Facility layout in the A-to-Z direction.

Table 1-13. Example of an A-to-Z layout of a ROADM Facility in the Network level.

Office A CLLI	Node #2 + SRG #4 + CP-Rx–5	
	Node #2 + DropLink14	
	Node #2 + Dir-1 + CTP-Tx–13	
	Node #2 + Dir-1 + TTP-Rx–13	
OMS (B-A)		
Office B CLLI	Node #1 + Dir-3 + TTP-Tx–13	Express-thru ROADM
	Node #1 + Dir-3 + CTP-Rx–13	
	Node #1 + ExpressLink43	
	Node #1 + Dir-4 + CTP-Tx–13	
	Node #1 + Dir-4 + TTP-Rx–13	
OMS (C-B)		
Office Z CLLI	Node #3 + Dir-5 + TTP-Tx–13	
	Node #3 + Dir-5 + CTP-Rx–13	
	Node #3 + AddLink25	
	Node #3 + SRG #2 + CP-Rx–7	

Using the service in Figure 1-21, Table 1-14 shows the tail facility in Office A.

Table 1-14. Example of a tail facility.

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

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 1.1 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.

Note:

Depending the technology of the add/drop group (C/D vs. C/D/C), the ID of a planned add/drop group may not be the same as the ID of a planned SRG.

The information described in Section 1.2 for an add/drop group can be derived from step (1) 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. In Core, Equipment Engineer also assigns office LGX jacks for transponder's client-side connection. In Metro, Equipment Engineer needs to obtain office LGX jacks for transponder's client-side connection from the Open ROADM Controller.

The information described in Section 1.6 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 1.7 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 1.8 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 Control Layer. The add/drop capabilities in each ROADM can be derived from the add/drop groups inventoried in the Open ROADM Control Layer. An example of a 4-node ROADM network is shown in Figure 3-1.

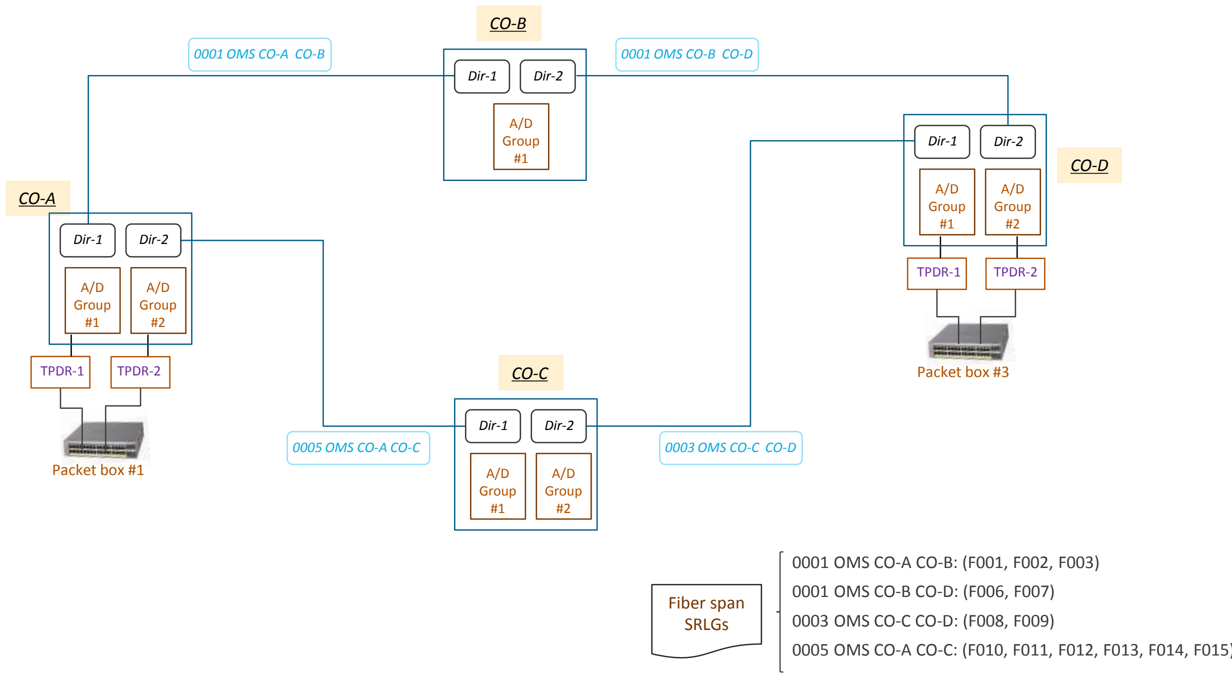


Figure 3-1. Topology of a 4-node ROADM network.

The fiber spans of each OMS section need to be made known to the Open ROADM Control 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 Control 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 Control 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.

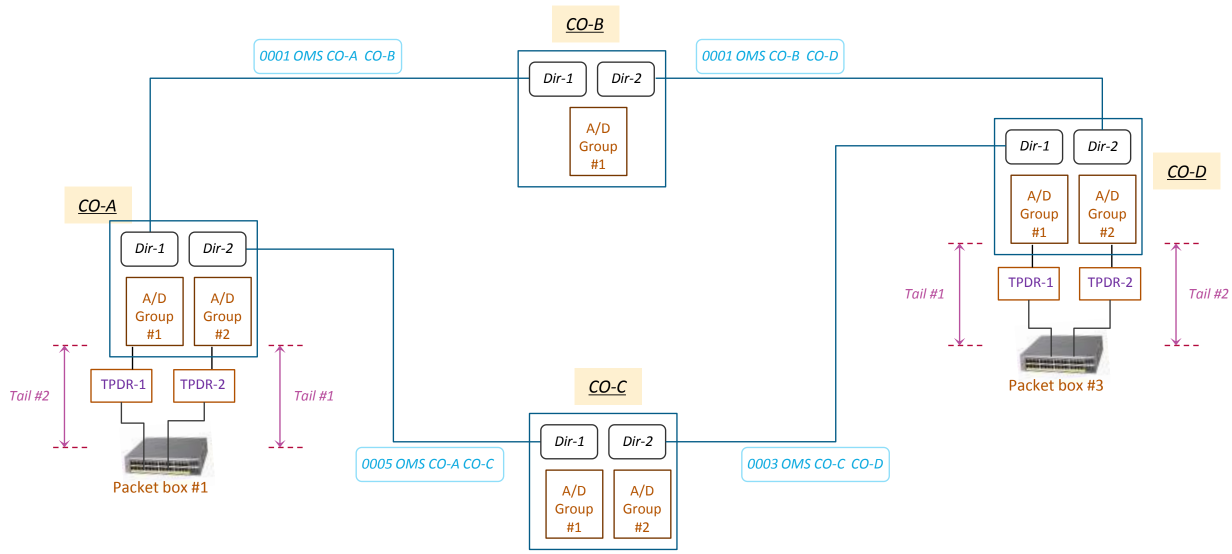


Figure 3-2. Tails are pre-deployed in the ROADM network.

PCE receives service request from the SDN Controller and perform 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.

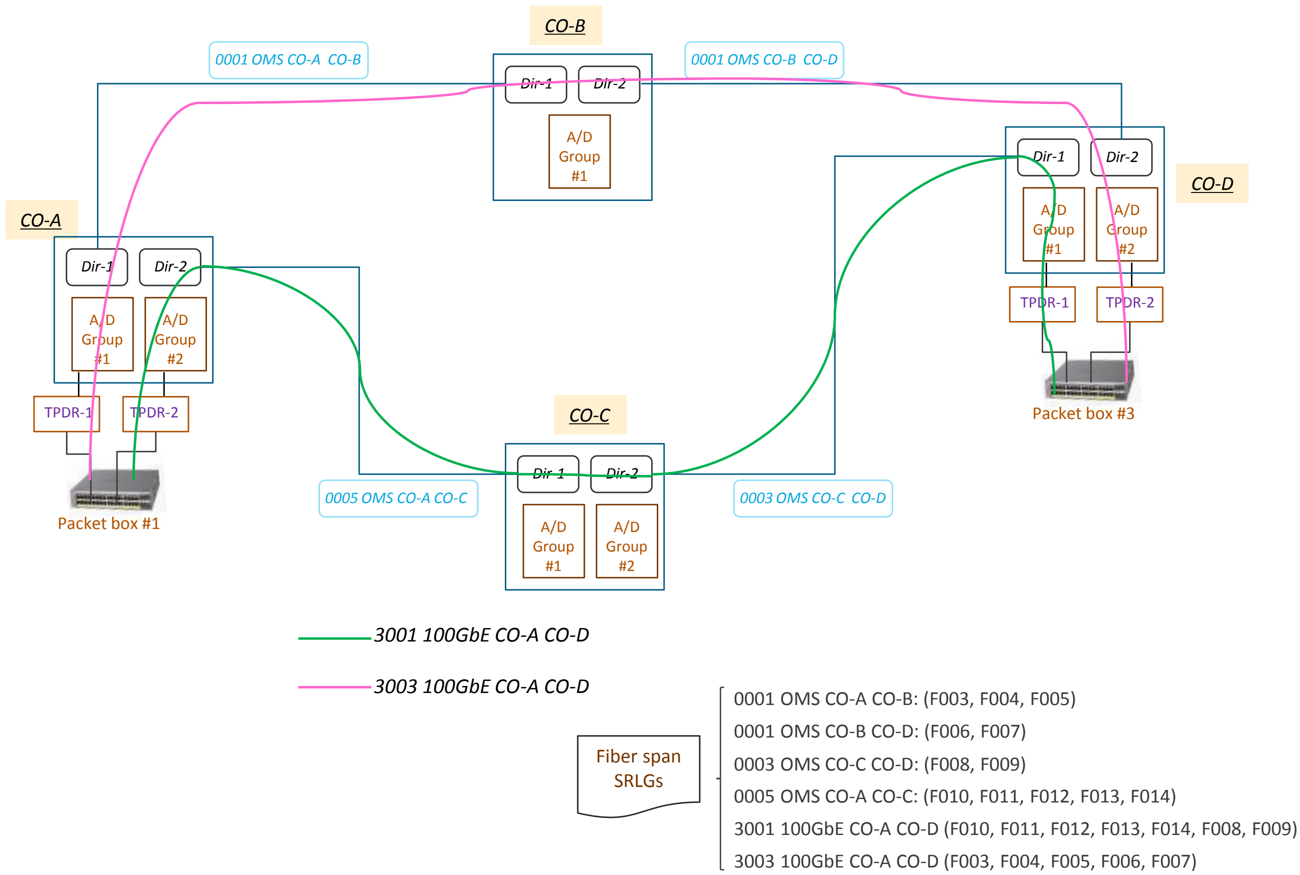


Figure 3-3. Two diverse services routed in the ROADM network.

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 Control 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 Control 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 1-10 and Table 1-12 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 automatically. Validation of degree # is supported by the model, i.e., whether degree # exceeds the capability of vendor's ROADM product.

    - Each circuit pack can be identified with the specific degree #, e.g., "***Degree 2***", "***Degree-5***", etc.

    - 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 AT&T 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.

      Validation of bay/shelf? Bay/shelf information is in the OSs, not in the NE (shelf # is known to the NE?)

    - External connections between the circuit packs are created automatically. External connections must reflect precisely the cabling between physical ports in the circuit packs, e.g.,

External Connection Name	*Source Port*	*Destination Port*
Dir-TLink	Dir2-WSS-Tx	Dir2-TxAmp-IN
Dir-RLink	Dir2-WSS-Rx	Dir2-RxAmp-OUT

      Type – workstep marking for external connections vs. non-workstep marking for internal connections

    - 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.

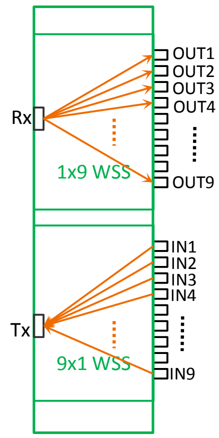


Figure 4-1. Internal links inside a WSS.

- 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 AT&T 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.

  Validation of bay/shelf? Bay/shelf information is in the OSs, not in the NE (shelf # is known to the NE?)

- External connections between the circuit packs are created automatically. External connections must reflect precisely the cabling between physical ports in the circuit packs.

- Internal links between circuit pack's in and out ports are created automatically.

- Interconnections with existing directions/degrees are generated automatically 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 1.3.

- *Query for the # of SRGs in an add/drop group*. (Can this be self discovered?)

- *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*. (Can this 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 automatically.
    - 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 pack's 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 automatically.
    - 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

5 Alarm and surveillance

5.1 Framework for Open ROADM alarm and surveillance

Open ROADM device and controller will cooperate to perform network alarm and surveillance functions. At high level, the device will perform the atomic fault detection and performance monitoring functions while the controller and northbound application will perform the high level data operations such as alarm correlation, service impact assessment, and ticketing with priority assignment and proper corrective actions recommended.

In principle, if a specific function can be performed in either the device or the northbound systems, it should be done in the northbound systems (which is implemented in a virtualized environment) to maximize the benefits of software defined network. By this principle, the fault and performance notification message generated from the device should exclude associated static attributes that can be derived from the device data model by the controller. This practice will not only make more efficient use of the management network bandwidth, it will also mitigate unnecessary data processing requirements against the device.

The device model should include these essential fault management modules/models to support business alarm and surveillance functions:

- A fault inventory list;
- A fault history collection that contains all the fault events detected by the device during some time window. The window size should be at least two times of the node MTTR, but no less than 48 hours.
- A configurable option to enable/disable fault event forwarding for any specific resource ids or a group of resource ids (under the resource node);
- A configurable option to enable/disable fault event forwarding for any specific fault type (under the fault node);
- RPCs used to support configuration of fault event forwarding and event sync (after failed communication to northbound is restored).

Similarly, the device model should include the following modules/models needed for network/service performance monitoring functions:

- A performance monitoring (PM) inventory list;
- A PM history collection that contains all the binned PM values collected by the device during some time window in 15-min intervals and 1-day intervals. The 15-min window size should be at least two times of the node MTTR, but no less than 8 hours. The 1-day window size should be at least 2 days.
- A configurable option to enable/disable PM event forwarding for any specific resource ids or a group of resource ids (under the resource node);
- A configurable option to enable/disable PM event forwarding for any specific or combination of fault type (s) and time intervals (under pm node);
- RPCs used to support configuration of PM event forwarding and PM event sync (after failed communication to northbound is restored or on-demand).

A detailed vendor agnostic alarm correlation model or logic is beyond the scope of device model itself, but in developing this device fault/PM management model I made these assumptions about how the vendor agnostic alarm correlation logic operates:

- The device data model hierarchy (containment relationship among data nodes) will be used to perform downward vertical correlation, i.e. a fault posted against the containing data node will correlate/group/flag the contained data node faults.

- The topology graph of associated (directional) links (inter- and intra-nodal) is used to perform horizontal alarm correlation. The ideal output of this horizontal correlation should be a replaceable link consist of a transmit port, a medium and a receive port at the most upstream section.
- If we define an end-to-end bi-directional transmission service with two uni-directional trails, a-z and z-a. A BDI fault detected in the a-z component reflects a fault in the z-a trail. So there is a need for a binding entity in the topological graph that associates the two trails of the same service. In addition, the BDI type of faults needs to clearly identified in the alarm inventory for proper horizontal correlation.
- Network attributes (i.e. CLFIs) and actual end-to-end customer service (CLSIs) impact assessment can be performed at the controller/northbound applications based on stored configuration data.

Furthermore, to support the above vendor agnostic alarm correlation logic, I made the following assumptions about the device data model implementations:

- The topological components (ports, fibers etc.) are all modelled as unidirectional. This is obvious in the analog domain, but digital entities such as OTUk/ODUk has traditionally been modelled as bi-directional entity and used a "dir(ection)" attribute to differentiate the transmit and receive directions. To support the above vendor agnostic alarm correlation model, we need the device model to post the digital layer faults (i.e. LOF-OTU4) against the physical port supporting the digital entity and direction instead of a logical internal bi-directional digital entity (OTU4) with a direction attribute.
- The traditional device model (shelf-slot-sub_slot-port) needs to be extended with a logical_port underneath the port data node to support multiplexer implementations. Fault detected at the tributary level (OCH LOS) through tap or internal monitoring points should be posted against the individual logical port instead of the aggregated port. Posting faults detected at channel level against the aggregated port resource could complicate the vertical correlation to the least, if workable at all. So the device data model hierarchy should support shelf – slot – sub_slot – port – **logical_port.**
- A fault detected will be properly posted against the data node in the extended device model that reflects the nature and extent of the fault. The data node will be identified as a resource_id which shows the full data path to the node in the device data model, i.e. shelf – slot – sub_slot – port – **logical_port.** Furthermore, the controller has the facility to map this resource_id to all associated network and service attributes.
- The device data model will support fault/PM notification control attributes so that we can control the event reporting to best use the network resources. Fault/PM notification control attributes should be available for every reportable data node instance. This is useful to mitigate unnecessary notifications and processing due to pending provisioning activities or customer actions. Furthermore, a system-level fault/pm notification control might be required to shut down all notifications in the event of emergency recovery where notifications are competing for scarce network/processing resources needed for service restore actions.

Traditionally PM threshold alert along with the threshold settings are implemented in the device. Since the threshold settings and derived alerts can easily be implemented by the software in the controller applications, I removed all PM threshold functions from the device model. The tradeoff made is that a threshold crossing alert (TCA) event implemented in the controller application might come in 15 minutes later than what the device would have reported if it were implemented in the device due to the PM reporting interval of 15-minutes. This should be acceptable since the current practice applies some form of "r out of w" patterning rules against the device reported TCAs before ticketing anyway, so generating a TCA at the end of 15-minute collection period by the controller application, in contrast to generating it during the 15-min in real-time, should have negligible impact to timeliness of ticketing from TCAs. In addition to the timing difference, there might be a subtle difference for the gauge-based parameters (aka metered, analog PM) on the values used to derive the TCA. In device TCA implementation, the threshold might be compared against the instantaneous measurement (i.e. 1 sample/second), while in controller TCA implementation, the threshold should be compared against the minimum or maximize tidemark values reported/recorded for the (15-min) collection period. Again, this change should not impact the effectiveness of the TCA since the min/max value reported for the collection period by the device should have all the instantaneous measurement incorporated already.

Other device event notifications, if any, i.e. database change event, is not in the alarm/surveillance scope.

5.2 References

IETF draft alarm-yang module https://tools.ietf.org/html/draft-vallin-alarm-yang-module-00#page-14

ITU G.7710 Common equipment management function requirements

http://www.itu.int/ITU-T/recommendations/rec.aspx?rec=11508

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