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Applicability of GMPLS for B100G Optical Transport Network
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Abstract

This document examines the applicability of using current existing GMPLS routing and signalling mechanisms to set up ODUk (e.g., ODUFlex) LSP over ODUCn links, as defined in the 2016 version of G.709.

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1. Introduction

The current GMPLS routing [RFC7138] and signalling [RFC7139] extensions support the control of OTN signals and capabilities that were defined in the 2012 version of G.709 [ITU-T_G709_2012].

In 2016 a new version of G.709 was published: [ITU-T_G709_2016]. This version introduces new higher rate OTU and ODU signals, termed OTUCn and ODUCn respectively, which have a nominal rate of $n \times 100$ Gbit/s. According to the definition in G.709 [ITU-T_G709_2016], OTUCn and ODUCn perform only section layer role and ODUCn supports only ODUk clients. This document focuses on the use of existing GMPLS mechanisms to set up ODUk (e.g., ODUFlex) LSP over ODUCn links, independently from how these links have been set up

This document presents an overview of the OTUCn and ODUCn signals introduced in [ITU-T_G709_2016] and analyses how the current GMPLS routing and signalling mechanisms can be utilized to setup ODUk (e.g., ODUFlex) LSPs over ODUCn links.

Note: after discussion, the authors did not see any impact of 2020 version of G.709 on this draft.

2. OTN terminology used in this document

- a. OPUCn: Optical Payload Unit - Cn. Where Cn = number of n-bit client data entities.
- b. ODUCn: Optical Data Unit - Cn.
- c. OTUCn: Fully standardized Optical Transport Unit - Cn.
- d. OTUCn-M: This signal is an extension of the OTUCn signal introduced above. This signal contains the same amount of overhead as the OTUCn signal, but contains a reduced amount of payload area. Specifically, the payload area consists of M 5G tributary slots (where M is strictly less than 20*n).
- e. PSI: OPU Payload Structure Indicator. This is a 256-byte signal that describes the composition of the OPU signal. This field is a concatenation of the Payload type (PT) and the Multiplex Structure Indicator (MSI) defined below.
- f. MSI: Multiplex Structure Indicator. This structure indicates the grouping of the tributary slots in an OPU payload area that realizes a client signal which is multiplexed into an OPU. The individual clients multiplexed into the OPU payload area are distinguished by the Tributary Port number (TPN).

Detailed description of these terms can be found in [ITU-T_G709_2016].

3. Overview of the OTUCn/ODUCn in G.709

This section provides an overview of OTUCn/ODUCn signals defined in [ITU-T_G709_2016].

3.1. OTUCn

In order to carry client signals with rates greater than 100 Gbit/s, [ITU-T_G709_2016] takes a general and scalable approach that decouples the rates of OTU signals from the client rate. The new OTU signal is called OTUCn, and this signal is defined to have a rate of

(approximately) $n \times 100\text{G}$. The following are the key characteristics of the OTUCn signal:

- a. The OTUCn signal contains one ODUc. The OTUCn and ODUc signals perform digital section roles only (see [ITU-T_G709_2016]:Section 6.1.1)
- b. The OTUCn signals can be viewed as being formed by interleaving n OTUC signals (which are labeled 1, 2, ..., n), each of which has the format of a standard OTUk signal without the FEC columns (per [ITU-T_G709_2016]Figure 7-1). The ODUc have a similar structure, i.e. they can be seen as being formed by interleaving n instances of ODU signals (respectively). The OTUC signal contains the ODU signals, just as in the case of fixed rate OTUs defined in G.709 [ITU-T_G709_2016].
- c. Each of the OTUC "slices" have the same overhead as the standard OTUk signal in G.709 [ITU-T_G709_2016]. The combined signal OTUCn has n instances of OTUC overhead, ODU overhead.
- d. The OTUC signal has a slightly higher rate compared to the OTU4 signal (without FEC); this is to ensure that the OPUC payload area can carry an ODU4 signal.

As explained above, within G.709 [ITU-T_G709_2016], the OTUCn, ODUc and OPUCn signal structures are presented in a (physical) interface independent manner, by means of n OTUC, ODUc and OPUC instances that are marked #1 to # n . Specifically, the definition of the OTUCn signal does not cover aspects such as FEC, modulation formats, etc. These details are defined as part of the adaptation of the OTUCn layer to the optical layer(s). The specific interleaving of OTUC/ODUC/OPUC signals onto the optical signals is interface specific and specified for OTN interfaces with standardized application codes in the interface specific recommendations (G.709.x).

OTUCn interfaces can be categorized as follows, based on the type of peer network element (see Figure 1):

- a. inter-domain interfaces: These types of interfaces are used for connecting OTN edge nodes to (a) client equipment (e.g. routers) or (b) hand-off points from other OTN networks. ITU-T has standardized the Flexible OTN (FlexO) interfaces to support these functions. For example, Recommendation [ITU-T_G709.1] specifies a flexible interoperable short-reach OTN interface over which an OTUCn ($n \geq 1$) is transferred, using bonded FlexO interfaces which belong to a FlexO group.

- b. intra-domain interfaces: In these cases, the OTUCn is transported using a proprietary (vendor specific) encapsulation, FEC etc. It may also be possible to transport OTUCn for intra-domain links using FlexO.

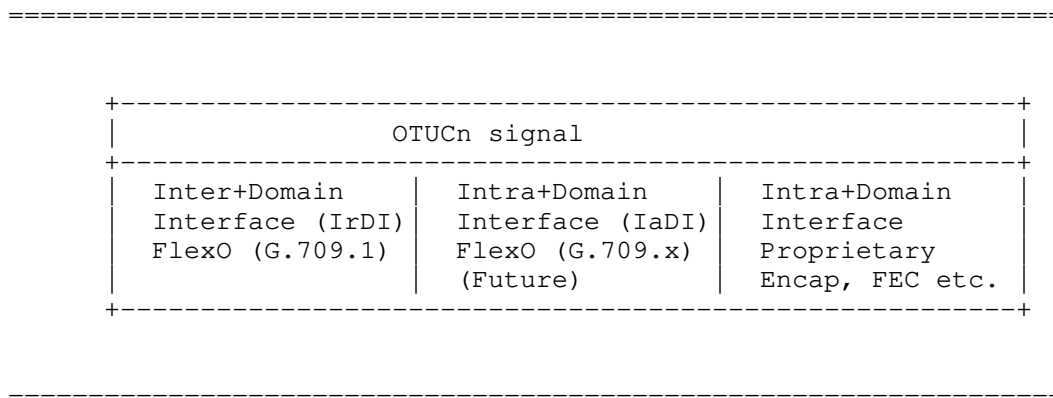


Figure 1: OTUCn transport possibilities

3.1.1. OTUCn-M

The standard OTUCn signal has the same rate as that of the ODUcn signal as shown in Table 1. This implies that the OTUCn signal can only be transported over wavelength groups which have a total capacity of multiples of (approximately) 100G. Modern DSPs support a variety of bit rates per wavelength, depending on the reach requirements for the optical path. In other words, it is possible to extend the reach of an optical path (i.e. increase the physical distance covered) by lowering the bitrate of the digital signal that is modulated onto the optical signals. If the total rate of the ODUk LSPs planned to be carried over an ODUcn link is smaller than $n \times 100G$, it is possible to "crunch" the OTUCn not to transmit some of unused timeslots. With this in mind, ITU-T supports the notion of a reduced rate OTUCn signal, termed the OTUCn-M. The OTUCn-M signal is derived from the OTUCn signal by retaining all the n instances of overhead (one per OTUC slice) but with only M (M is less than $20 \times n$) OPUCn tributary slots available to carry ODUk LSPs.

As the "crunching" algorithm is not standardized, knowing the value of M is not enough to decide the timeslot availability.

3.2. ODU_{Cn}

The ODU_{Cn} signal [ITU-T_G709_2016] can be viewed as being formed by the appropriate interleaving of content from n ODU_C signal instances. The ODU_C frames have the same structure as a standard ODU -- in the sense that it has the same Overhead area, and the payload area -- but has a higher rate since its payload area can embed an ODU₄ signal.

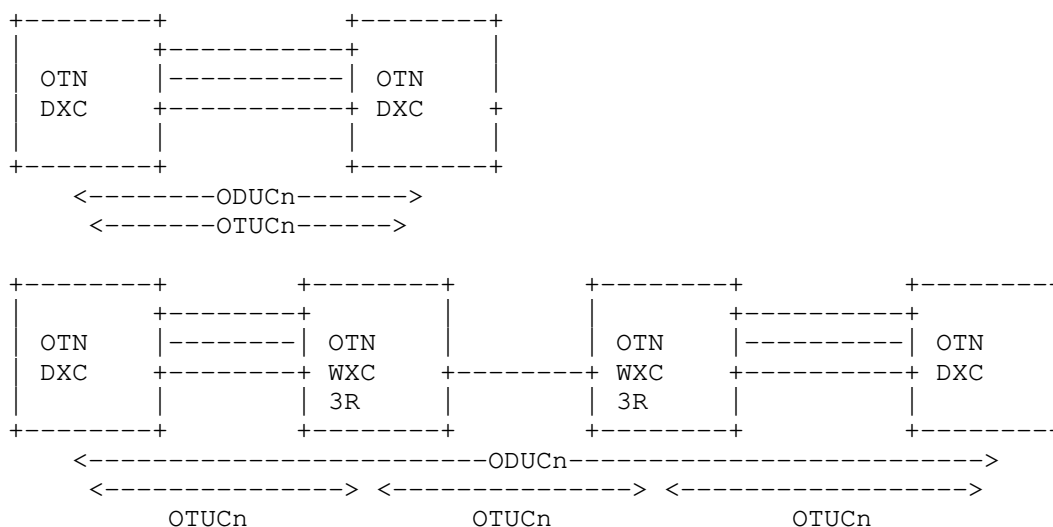
The ODU_{Cn} signals have a rate that is captured in Table 1.

ODU Type	ODU Bit Rate
ODU _{Cn}	$n \times 239/226 \times 99,532,800 \text{ Kbit/s} = n \times 105,258,138.053 \text{ Kbit/s}$

Table 1: ODU_{Cn} rates

The ODU_{Cn} is a multiplex section ODU signal, and is mapped into an OTU_{Cn} signal which provides the regenerator section layer. In some scenarios, the ODU_{Cn}, and OTU_{Cn} signals will be co-terminated, i.e. they will have identical source/sink locations. [ITU-T_G709_2016] allows for the ODU_{Cn} signal to pass through a digital regenerator node which will terminate the OTU_{Cn} layer, but will pass the regenerated (but otherwise untouched) ODU_{Cn} towards a different OTU_{Cn} interface where a fresh OTU_{Cn} layer will be initiated (see Figure 2). In this case, the ODU_{Cn} is carried by 3 OTU_{Cn} segments.

Specifically, the OPUC_n signal flows through these regenerators unchanged. That is, the set of client signals, their TPNs, trib-slot allocation remains unchanged. The ODU_{Cn} Overhead might be modified if TCM sub-layers are instantiated in order to monitor the performance of the regenerator hops. In this sense, the ODU_{Cn} should NOT be seen as a general ODU which can be switched via an ODU_k cross-connect.

Figure 2: ODU_{cN} signal

3.3. Time Slot Granularity

[ITU-T_G709_2012] has introduced the support for 1.25G granular tributary slots in OPU₂, OPU₃, and OPU₄ signals. With the introduction of higher rate signals, it is not practical for the optical networks (and the data plane hardware) to support a very large number of connections at such a fine granularity. [ITU-T_G709_2012] has defined the OPUC with a 5G tributary slot granularity. This means that the ODU_{cN} signal has $20 \times n$ tributary slots (of 5 Gbit/s capacity). It is worthwhile considering that the range of tributary port number (TPN) is $10 \times n$ instead of $20 \times n$, which restricts the maximum client signals that could be carried over one single ODU_{c1}.

3.4. Structure of OPUC_n MSI with Payload type 0x22

As mentioned above, the OPUC_n signal has $20 \times n$ 5G tributary slots. The OPUC_n MSI field has a fixed length of $40 \times n$ bytes and indicates the availability and occupation of each TS. Two bytes are used for each of the $20 \times n$ tributary slots, and each such information structure has the following format ([ITU-T_G709_2016] G.709:Section 20.4.1):

- a. The TS availability bit indicates if the tributary slot is available or unavailable
- b. The TS occupation bit indicates if the tributary slot is allocated or unallocated
- c. The tributary port number (14 bits) of the client signal that is being carried in this specific TS. A flexible assignment of tributary port to tributary slots is possible. Numbering of tributary ports is from 1 to $10 \times n$.

3.5. Client Signal Mappings

The approach taken by the ITU-T to map non-OTN client signals to the appropriate ODU containers is as follows:

- a. All client signals are mapped into an ODUk (e.g., ODUFlex) as specified in clause 17 of [ITU-T_G709_2016].
- b. ODU Virtual Concatenation has been deprecated. This simplifies the network, and the supporting hardware since multiple different mappings for the same client are no longer necessary. Note that legacy implementations that transported sub-100G clients using ODU VCAT shall continue to be supported.
- c. ODUFlex signals are low-order signals only. If the ODUFlex entities have rates of 100G or less, they can be transported over either an ODUk ($k=1..4$) or an ODUCn. For ODUFlex connections with rates greater than 100G, ODUCn is required.

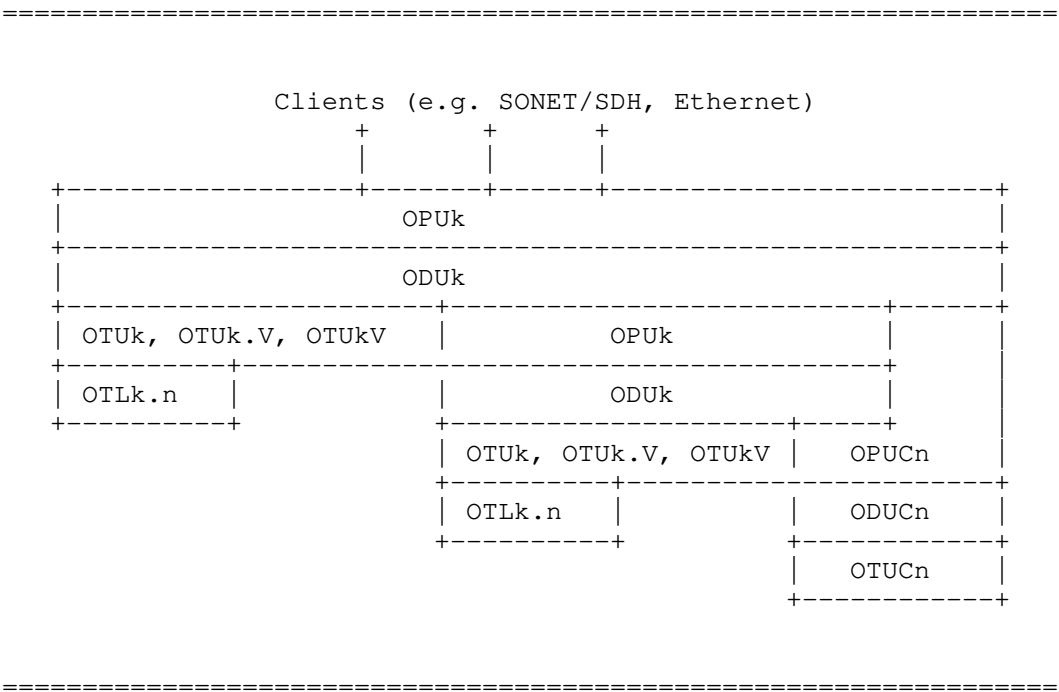


Figure 3: Digital Structure of OTN interfaces (from G.709:Figure 6-1)

4. GMPLS Implications and Applicability

4.1. TE-Link Representation

Section 3 of RFC7138 describes how to represent G.709 OTUk/ODUk with TE-Links in GMPLS. Similar to that, ODUCn links can also be represented as TE-Links, which can be seen in the figure below.

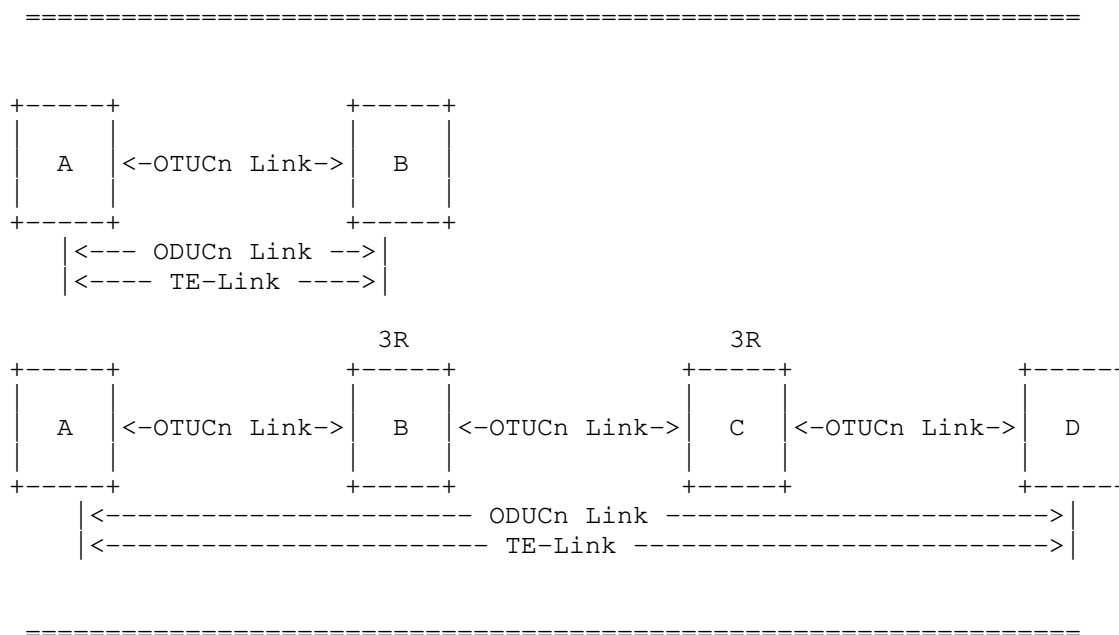


Figure 4: ODUcN TE-Links

Two endpoints of a TE-Link are configured with the supported resource information, which may include whether the TE-Link is supported by an ODUcN or an ODUk or an OTUk, as well as the link attribute information (e.g., slot granularity, list of available tributary slot).

4.2. Implications and Applicability for GMPLS Signalling

Once the ODUcN TE-Link is configured, the GMPLS mechanisms defined in RFC7139 can be reused to set up ODUk/ODUflex LSP with no/few changes. As the resource on the ODUcN link which can be seen by the client ODUk/ODUflex is a set of 5G slots, the label defined in RFC7139 is able to accommodate the requirement of the setup of ODUk/ODUflex over ODUcN link. In [RFC7139], the OTN-TDM GENERALIZED_LABEL object is used to indicate how the LO ODUj signal is multiplexed into the HO ODUk link. In a similar manner, the OTN-TDM GENERALIZED_LABEL object is used to indicate how the ODUk signal is multiplexed into the ODUcN link. The ODUk Signal Type is indicated by Traffic Parameters. The IF_ID RSVP_HOP object provides a pointer to the interface associated with TE-Link and therefore the two nodes terminating the TE-link know (by internal/local configuration) the attributes of the ODUcN TE Link.

One thing should be note is the TPN used in RFC7139 and defined in G.709-2016 for ODUCn link. Since the TPN currently defined in G.709 for ODUCn link has 14 bits, while this field in RFC7139 only has 12 bits, some extension work is needed, but this is not so urgent since for today networks scenarios 12 bits are enough, as it can support a single ODUCn link up to n=400, namely 40 Tbit/s.

An example is given below to illustrate the label format defined in RFC7139 for multiplexing ODU4 onto ODUC10. One ODUC10 has 200 5G slots, and twenty of them are allocated to the ODU4. Along with the increase of "n", the label may become lengthy, an optimized label format may be needed.

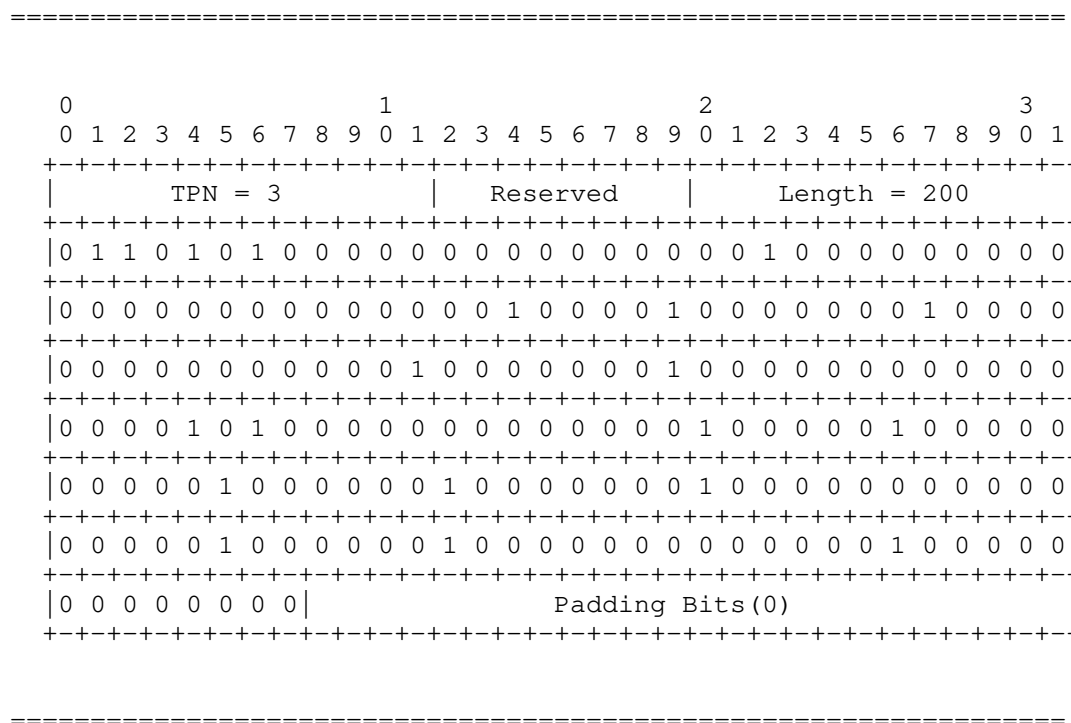


Figure 5: Label format

4.3. Implications and Applicability for GMPLS Routing

For routing, it is deemed that no extension to current mechanisms defined in RFC7138 are needed. Because, once an ODUCn link is up, the resources that need to be advertised are the resources that exposed by this ODUCn link and the multiplexing hierarchy on this link. Since the ODUCn link is the ultimate hierarchy of the ODU

multiplexing, there is no need to explicitly define a new value to represent the ODUCn signal type in the OSPF-TE routing protocol.

The OSPF-TE extension defined in section 4 of RFC7138 can be reused to advertise the resource information on the ODUCn link to help finish the setup of ODUk/ODUflex.

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8. IANA Considerations

This memo includes no request to IANA.

9. Security Considerations

None.

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10.1. Normative References

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- [RFC7139] Zhang, F., Ed., Zhang, G., Belotti, S., Ceccarelli, D., and K. Pithewan, "GMPLS Signaling Extensions for Control of Evolving G.709 Optical Transport Networks", RFC 7139, DOI 10.17487/RFC7139, March 2014, <<https://www.rfc-editor.org/info/rfc7139>>.

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A YANG Data Model for L1 Connectivity Service Model (L1CSM)
draft-ietf-ccamp-llcsm-yang-13

Abstract

This document provides a YANG data model for Layer 1 Connectivity Service Model (L1CSM). The intent of this document is to provide a Layer 1 service model exploiting YANG data model, which can be utilized by a customer network controller to initiate a service request connectivity as well as retrieving service states toward a Layer 1 network controller communicating with its customer network controller. This YANG model is NMDA-compliant.

Status of This Memo

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1. Introduction

This document provides a YANG data model for L1VPN Connectivity Service Model (L1CSM) which can be classified as Network Service YANG module per [RFC8199]. The intent of this document is to provide a transport service model exploiting YANG data model, which can be utilized by a client network controller to initiate a service request connectivity request as well as retrieving service states toward a transport network controller communicating with the client controller via a NETCONF [RFC8341] or a RESTCONF [RFC8040] interface.

[RFC4847] provides a framework and service level requirements for Layer 1 Virtual Private Networks (L1VPNs). It classifies service models as management-based service model, signaling-based service model (Basic Mode) and signaling and routing service model (Enhanced Mode).

In the management-based service model, customer management systems and provider management systems communicate with each other. Customer management systems access provider management systems to request layer 1 connection setup/deletion between a pair of CEs. Customer management systems may obtain additional information, such as resource availability information and monitoring information, from provider management systems. There is no control message exchange between a CE and PE.

In the signaling-based service model (Basic Model), the CE-PE interface's functional repertoire is limited to path setup signaling only. In the Signaling and routing service model (Enhanced Mode), the CE-PE interface provides the signaling capabilities as in the Basic Mode, plus permits limited exchange of information between the control planes of the provider and the customer to help such functions as discovery of customer network routing information (i.e., reachability or TE information in remote customer sites), or parameters of the part of the provider's network dedicated to the customer.

The primary focus of this document is to describe L1CS YANG model required for the instantiation of point-to-point L1VPN service. A L1VPN is a service offered by a core layer 1 network to provide layer 1 connectivity between two or more customer sites where the customer has some control over the establishment and type of the connectivity.

The data model presented in Section 3 is in consistent with [MEF63]. The data model includes configuration and state data according to the new Network Management Datastore Architecture [RFC8342].

1.1. Deployment Scenarios

Figure 1 depicts a deployment scenario of the L1VPN SDN control-based service model for an external customer instantiating L1 point-to-point connectivity to the provider.

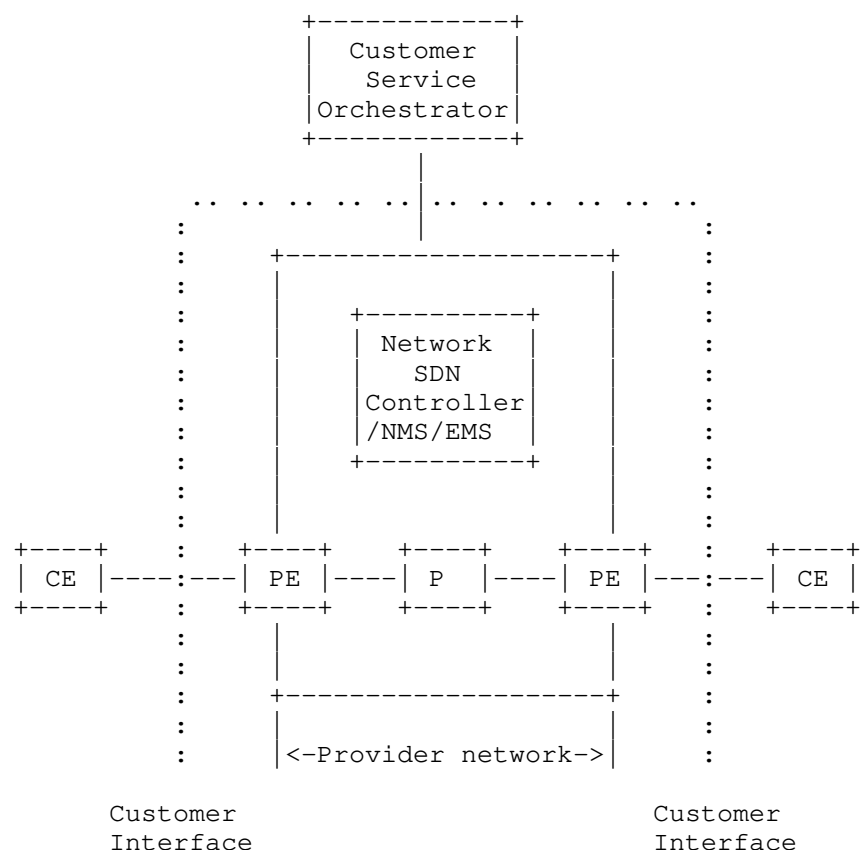


Figure 1: L1VPN SDN Controller/EMS/NMS-Based Service Model: External Customer

With this scenario, the customer service orchestrator interfaces with the network SDN controller of the provider using Customer Service Model as defined in [RFC8309].

Figure 2 depicts another deployment scenario for internal customer (e.g., higher-layer service management department(s)) interfacing the layer 1 transport network department. With this scenario, a multi-service backbone is characterized such that each service department of a provider (e.g., L2/3 services) that receives the same provider's L1VPN service provides a different kind of higher-layer service. The customer receiving the L1VPN service (i.e., each service department) can offer its own services, whose payloads can be any layer (e.g., ATM, IP, TDM). The layer 1 transport network and each service

network belong to the same organization, but may be managed separately. The Service SDN Controller is the control/management entity owned by higher-layer service department (e.g., L2/3 VPN) whereas the Network SDN Controller is the control/management entity responsible for Layer 1 connectivity service. The CEs in Figure 2 are L2/3 devices that interface with L1 PE devices.

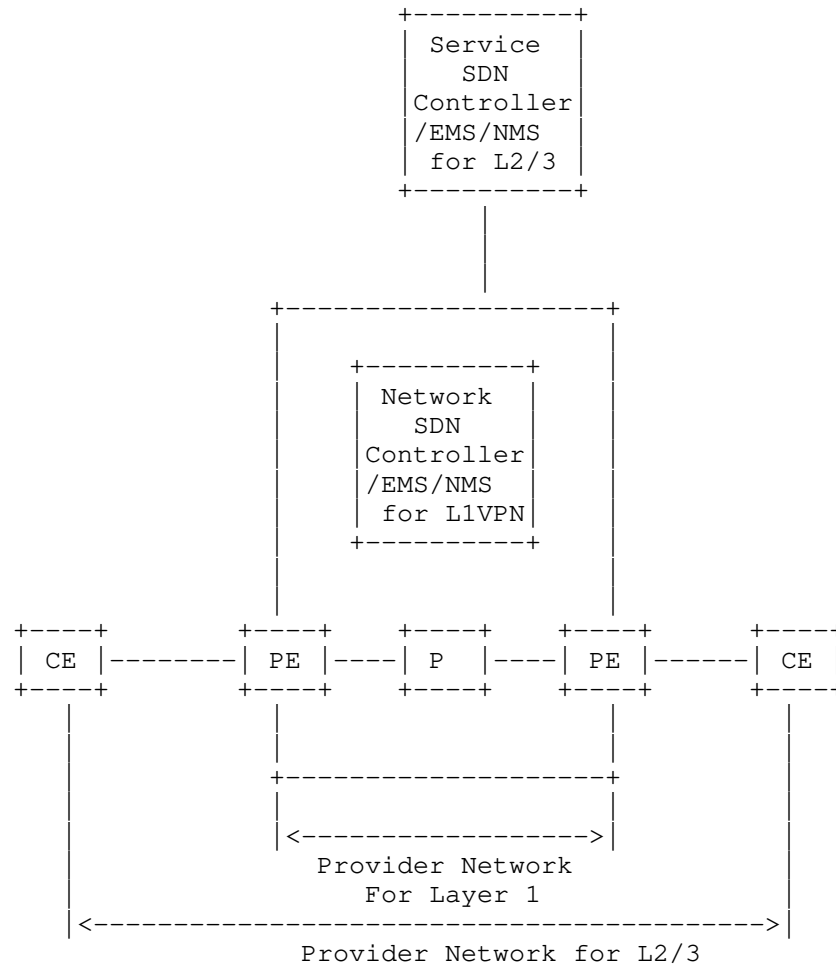


Figure 2: L1VPN SDN Controller/EMS/NMS-Based Service Model: Internal Customer

The benefit is that the same layer 1 transport network resources are shared by multiple services. A large capacity backbone network (data plane) can be built economically by having the resources shared by multiple services usually with flexibility to modify topologies, while separating the control functions for each service department. Thus, each customer can select a specific set of features that are needed to provide their own service [RFC4847].

1.2. Terminology

Refer to [RFC4847] and [RFC5253] for the key terms used in this document.

The following terms are defined in [RFC7950] and are not redefined here:

- o client
- o server
- o augment
- o data model
- o data node

The following terms are defined in [RFC6241] and are not redefined here:

- o configuration data
- o state data

The terminology for describing YANG data models is found in [RFC7950].

1.3. Tree Diagram

A simplified graphical representation of the data model is used in Section 3 of this document. The meaning of the symbols in these diagrams is defined in [RFC8340].

1.4. Prefixes in Data Node Names

In this document, names of data nodes and other data model objects are prefixed using the standard prefix associated with the corresponding YANG imported modules. The module ietf-layer1-types

specified in [I-D.ietf-ccamp-layer1-types] and ietf-yang-types specified in [RFC6991] are imported in this module.

Prefix	YANG module	Reference
l1csm	ietf-l1csm	[RFC XXXX]
l1-types	ietf-layer1-types	[I-D.ietf-ccamp-layer1-types]
yang	ietf-yang-types	[RFC6991]

Note: The RFC Editor will replace XXXX with the number assigned to the RFC once this document becomes an RFC.

2. Definitions

L1VC Layer 1 Virtual Connection

SLS Service Level Specification

UNI User Network Interface

PE Provider Edge

CE Customer Edge

EP End Point

P Protocol

C Coding

O Optical Interface

3. L1CSM YANG Model (Tree Structure)

```

module: ietf-llcsm
  +--rw ll-connectivity
    +--rw access
      +--rw unis
        +--rw uni* [id]
          +--rw id string
          +--rw (uni-access-type)?
            +--:(mef)
              +--rw protocol identityref
              +--rw coding identityref
              +--rw optical-interface identityref
            +--:(itu)
              +--rw client-signal identityref
      +--rw services
        +--rw service* [service-id]
          +--rw service-id string
          +--rw endpoint-1
            +--rw id string
            +--rw uni -> /ll-connectivity/access/unis/uni/id
          +--rw endpoint-2
            +--rw id string
            +--rw uni -> /ll-connectivity/access/unis/uni/id
          +--rw start-time? yang:date-and-time
          +--rw time-interval? int32
          +--rw performance-metric* identityref

```

4. L1CSM YANG Code

```

<CODE BEGINS>file "ietf-llcsm@2020-10-27.yang"
module ietf-llcsm {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-llcsm";
  prefix "llcsm";

  import ietf-yang-types {
    prefix "yang";
  }

  import ietf-layer1-types {
    prefix "l1-types";
  }

  organization
    "Internet Engineering Task Force (IETF) CCAMP WG";

```

contact

```
"Editor: Y. Lee (younglee.tx@gmail.com)
Editor: K. Lee (kwangkoog.lee@kt.com)
Editor: H. Zheng (zhenghaomian@huawei.com)
Editor: D. Dhody (dhruv.ietf@gmail.com)
Editor: O. G. de-Dios (oscar.gonzalezdedios@telefonica.com)
Editor: D. Ceccarelli (daniele.ceccarelli@ericsson.com)";
```

description

```
"This module describes L1 connectivity service based on MEF 63:
Subscriber Layer 1 Service Attribute Technical Specification.
Refer to MEF 63 for all terms and the original references
used in the module.
```

```
Copyright (c) 2020 IETF Trust and the persons identified as
authors of the code. All rights reserved.
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without modification, is permitted pursuant to, and subject
to the license terms contained in, the Simplified BSD
License set forth in Section 4.c of the IETF Trust's Legal
Provisions Relating to IETF Documents
(http://trustee.ietf.org/license-info).
```

```
This version of this YANG module is part of RFC XXXX; see
the RFC itself for full legal notices.";
```

```
revision "2020-10-27" {
  description "Initial revision.";
  reference "RFC XXXX: A Yang Data Model for L1 Connectivity
    Service Model (L1CSM)";
  // Note: The RFC Editor will replace XXXX with the number
  // assigned to the RFC once this draft becomes an RFC.
}
```

```
/*
 * Identities
 */
```

```
identity service-performance-metric {
  description
    "Base identity of service-specific performance metric";
  reference "MEF63: Subscriber Layer 1 Service Attributes";
}
```

```
identity one-way-delay {
  base "service-performance-metric";
  description "one way delay.";
```



```
    reference "MEF63: Subscriber Layer 1 Service Attributes";
}

identity one-way-errored-second {
    base "service-performance-metric";
    description "one way errored second";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
}

identity one-way-severely-errored-second {
    base "service-performance-metric";
    description "one way severely errored second";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
}

identity one-way-unavailable-second {
    base "service-performance-metric";
    description "one way unavailable second";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
}

identity one-way-availability {
    base "service-performance-metric";
    description "one way availability";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
}

/*
 * Groupings
 */

grouping protocol-coding-optical-interface {
    description
        "The 3-tuple <p,c,o> where p:protocol type;
        c:coding function; o:optical interface function.

        Valid combinations are defined in Tables 4, 5, 6 and 7
        of MEF 63.";
    reference "MEF 63";

    leaf protocol {
        type identityref {
            base "l1-types:protocol";
        }
        mandatory true;
        description "The protocol being used at the UNI.";
    }
    leaf coding {
```

```
    type identityref {
      base "l1-types:coding-func";
    }
    mandatory true;
    description "The coding function being used at the UNI.";
  }
  leaf optical-interface {
    type identityref {
      base "l1-types:optical-interface-func";
    }
    mandatory true;
    description
      "The optical interface function being used at the UNI.";
  }
}

grouping subscriber-llvc-sls-service-attribute {
  description
    "The value of the Subscriber L1VC SLS (Service Level
    Specification) Service Attribute";
  reference "MEF 63";

  leaf start-time {
    type yang:date-and-time;
    description "a time that represent the date and time
      for the start of the SLS";
  }
  leaf time-interval {
    type int32;
    units seconds;
    description
      "a time interval (e.g., 2,419,200 seconds which is 28 days)
      that is used in conjunction wuth time-start to specify a
      contiguous sequence of time intervals T for determining
      when performance objectives are met.";
  }
  leaf-list performance-metric {
    type identityref {
      base "service-performance-metric";
    }
    description "list of service performance metric.";
  }
}

grouping subscriber-llvc-endpoint-attributes {
  description
    "subscriber layer 1 connection endpoint attributes";
  reference "MEF 63";
```

```
    container endpoint-1 {
      description "One end of UNI id's - string and id";
      leaf id {
        type string;
        mandatory true;
        description "subscriber end point ID of one end";
      }
      leaf uni {
        type leafref {
          path "/l1-connectivity/access/unis/uni/id";
        }
        mandatory true;
        description "this is one end of subscriber L1VC end point
                     ID value = UNI-1";
      }
    }
    container endpoint-2 {
      description "One end of UNI id's - string and id";
      leaf id {
        type string;
        mandatory true;
        description "subscriber end point ID of the other end";
      }
      leaf uni {
        type leafref {
          path "/l1-connectivity/access/unis/uni/id";
        }
        mandatory true;
        description
          "this is one other end of subscriber L1VC end point
           ID value = UNI-2";
      }
    }
  }
}

/*
 * Data nodes
 */

container l1-connectivity {
  description
    "serves as a top-level container for a list of layer 1
     connection services (l1cs)";

  container access {
    description "UNI configurations for access networks";

    container unis {
```

```
description "the list of UNI's to be configured";

list uni {
  key "id";
  description "UNI identifier";
  leaf id {
    type string;
    description "the UNI id of UNI Service Attributes";
  }
  choice uni-access-type {
    description
      "The UNI access type can be specified either by the
      protocol, coding function and optical interface
      function, defined in MEF, or by the client-signal,
      defined in ITU-T.";
    case mef {
      uses protocol-coding-optical-interface;
    }
    case itu {
      leaf client-signal {
        type identityref {
          base "l1-types:client-signal";
        }
        mandatory true;
        description
          "The client signal being used at the UNI";
      }
    }
  }
}

}

}

}

container services {
  description "L1VC services";
  list service {
    key "service-id";
    description
      "an unique identifier of a subscriber L1VC service";

    leaf service-id {
      type string;
      mandatory true;
      description "a unique service identifier for
        subscriber L1VC.";
    }
    uses subscriber-l1vc-endpoint-attributes;
    uses subscriber-l1vc-sls-service-attribute;
  }
}
```

```
        } //end of service list
      } //end of service container
    } //service top container
  }
<CODE ENDS>
```

5. JSON Example

This section provides a JSON example of the YANG module described in Section 4. This example configures one L1VC service with two UNIs that describe the UNI endpoints. The service is configured with the starting time to be 06:06:09 on 2018-09-13 for the service life time of 2419200 seconds (which corresponds to 28 days). In addition, the service is configured to collect one performance metric, One-way-Delay.

```
{
  "l1-connectivity": {
    "access": {
      "unis": {
        "uni": [
          {
            "id": "MTL-HQ-Node3-Slot2-Port1",
            "protocol": "ETH-10GigE_LAN ",
            "coding": "ETH-10GR-PCS-49 ",
            "optical_interface": "LR-PMD-clause-52 "
          },
          {
            "id": "MTL-STL-Node5-Slot4-Port3",
            "protocol": "ETH-10GigE_LAN ",
            "coding": "ETH-10GR-PCS-49 ",
            "optical_interface": "ER-PMD-clause-52 "
          }
        ]
      },
    },
    "services": {
      "service": [
        {
          "service-id": "Sub-L1VC-1867-LT-MEGAMART",
          "endpoint-1": {
            "id": "MTL-HQ_1867-MEGAMART",
            "uni": "MTL-HQ-Node3-Slot2-Port1"
          },
          "endpoint-2": {
            "id": "MTL-STL_1867-MEGAMART",
            "uni": "MTL-STL-Node5-Slot4-Port3"
          },
          "start-time": "2018-09-13T06:06:09Z",
          "time-interval": 2419200,
          "performance-metric": "One-way-Delay "
        }
      ]
    },
  },
}
```

6. Security Considerations

The YANG module specified in this document defines a schema for data that is designed to be accessed via network management protocols such as NETCONF [RFC6241] or RESTCONF [RFC8040]. The lowest NETCONF layer is the secure transport layer, and the mandatory-to-implement secure transport is Secure Shell (SSH) [RFC6242]. The lowest RESTCONF layer is HTTPS, and the mandatory-to-implement secure transport is TLS [RFC8446].

The NETCONF access control model [RFC8341] provides the means to restrict access for particular NETCONF or RESTCONF users to a preconfigured subset of all available NETCONF or RESTCONF protocol operations and content.

A number of configuration data nodes defined in this document are writable/deletable (i.e., "config true") These data nodes may be considered sensitive or vulnerable in some network environments.

These are the subtrees and data nodes and their sensitivity/vulnerability:

unis:

- id

Service:

- service-id

- endpoint-1

- endpoint-2

- start-time

- time-interval

- performance-metric

The security considerations spelled out in the YANG 1.1 specification [RFC7950] apply for this document as well.

7. IANA Considerations

It is proposed that IANA should assign new URIs from the "IETF XML Registry" [RFC3688] as follows:

URI: urn:ietf:params:xml:ns:yang:ietf-llcsm
Registrant Contact: The IESG
XML: N/A; the requested URI is an XML namespace.

This document registers following YANG modules in the YANG Module Names registry [RFC7950].

name: iETF-llcsm
namespace: urn:ietf:params:xml:ns:yang:ietf-llcsm
prefix: llcsm
reference: RFC XXXX

8. Acknowledgements

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A YANG Data Model for Layer 1 Types
draft-ietf-ccamp-layer1-types-08

Abstract

This document defines a collection of common data types and groupings in the YANG data modeling language for use with layer 1 networks. These derived common types and groupings are intended to be imported by modules that specify OTN networks, such as topology, tunnel, client signal adaptation and service.

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1. Introduction

This document specifies common data types for use in YANG [RFC7950] data models of Layer 1 networks. The derived types and groupings are types applicable to modeling Traffic Engineering (TE) for Layer 1 networks.

The Optical Transport Networking, a typical Layer 1 network, is specified in [RFC7062]. The corresponding routing and signaling protocol are specified in [RFC7138] and [RFC7139]. The types and groupings defined in this document are consistent to those documents, and can be imported into other Layer 1 data models, including but not limited to, [I-D.ietf-ccamp-otn-topo-yang], [I-D.ietf-ccamp-otn-tunnel-model], [I-D.ietf-ccamp-client-signal-yang] and [I-D.ietf-ccamp-llcsm-yang].

The data model in this draft only defines groupings, typedef and identities. There is no configuration or state data as specified in the Network Management Datastore Architecture [RFC8342]. The document is consistent with other specifications, including [MEF63] for Layer 1 service attributes, [ITU-Tg709] and [ITU-Tg743] for OTN data plane definitions.

2. Terminology and Notations

Refer to [RFC7062] for the key terms used in this document. The terminology for describing YANG data models can be found in [RFC7950].

3. Prefix in Data Node Names

In this document, names of data nodes and other data model objects are prefixed using the standard prefix associated with the corresponding YANG imported modules.

Prefix	YANG module	Reference
l1-types	ietf-layer1-types	This Document

4. Layer 1 Types Overview

4.1. Relationship with other Modules

This document defines one YANG module for common Layer 1 types. The aim is to specify common Layer 1 TE types (i.e. typedef, identity, grouping) that can be imported by layer 1 specific technology, for example OTN, in its technology-specific modules, such as topology and tunnels. It is worth noting that the generic traffic-engineering (TE) types module is specified in [RFC8776] as `ietf-te-types`, and both YANG modules, `ietf-te-types` and `ietf-layer1-types`, will need importing when the OTN is configured. Generic attributes such as `te-bandwidth` and `te-label`, are specified in `ietf-te-types` in [RFC8776], while the OTN-specific attributes, such as `odu-type`, are specified in `ietf-layer1-types` in this document.

4.2. Content in Layer 1 Type Module

The module `ietf-layer1-types` contains the following YANG reusable types and groupings:

`tributary-slot-granularity`:

This specifies the granularity of the server layer ODU Link (HO ODUk or ODUCn) supporting a client layer ODU LSP (LO ODUj or ODUk, respectively). Three granularities, 1.25G/2.5G/5G, have been specified.

odu-type:

This specifies the type of ODUk LSP, including the types specified in [RFC7139] and [RFC7963].

client-signal:

This specifies the client signal types of OTN networks. The initial input was the G-PID specified in [RFC7139]. Identities for some of the categories of client signal types, including ETH, STM-n, OC [Telcordia] and Fiber Channel, have been specified.

otn-label-range-type:

The label range type of OTN is represented in one of two ways, tributary slots (TS) and tributary port number (TPN), as specified in [RFC7139]. Two representations are enumerated in the otn-label-range-type.

otn-link-bandwidth:

This grouping defines the link bandwidth information and could be used in OTN topology model for link bandwidth representation. All the bandwidth related sections in generic module, [RFC8776], need to be augmented with this grouping for the usage of Layer 1.

otn-path-bandwidth:

This grouping defines the path bandwidth information and could be used in OTN topology model for path bandwidth representation. All the bandwidth related sections in generic module, [RFC8776], need to be augmented with this grouping for the usage of Layer 1. This grouping is also applicable when setting up the OTN tunnel.

otn-label-range-info and otn-label-step:

These groupings are used to augment an OTN label with type, granularity, priority and ODU types.

otn-label-start-end and otn-label-hop:

These groupings are used to augment a label for an OTN link and path respectively.

optical-interface-func:

The optical interface function is specified in [MEF63]. This grouping describes the functionality which encodes bits for transmission and decodes bits upon reception.

service-performance-metric:

The service performance metric is a quantitative characterization of the quality of the delivery of Layer 1 characteristic information as experienced by the Layer 1 subscriber.

4.3. OTN Label and Label Range

As described in [RFC7139], the OTN label usually represents the Tributary Port Number (TPN) and the related set of Tributary Slots (TS) assigned to a client layer ODU LSP (LO ODUj or ODUk) on a given server layer ODU (HO-ODU or ODUCn, respectively) Link (e.g., ODU2 LSP over ODU3 Link). Some special OTN label values are also defined for an ODUk LSP being set up over an OTUk Link.

The same OTN label must be assigned to the same ODUk LSP at the two ends of an OTN Link.

As described in [RFC7139], TPN can be a number from 1 to 4095 and TS are numbered from 1 to 4095, although the actual maximum values depend on the type of server layer ODU. For example, a server layer ODU4 provides 80 time slots (numbered from 1 to 80) and the TPN values can be any number from 1 to 80.

The OTN Label Range represents the values for the TPN and TS that are available for ODUk LSPs to be setup over a given OTN Link.

The OTN Label Range is defined by the label-restriction list, defined in [RFC8776], which, for OTN, should be augmented using the otn-label-range-info grouping.

Each entry in the label-restriction list represents either the range of the available TPN values or the range of the available TS values: the range-type attribute in the otn-label-range-info grouping defines the type of range for each entry of the list.

Each entry of the label-restriction list, as defined in [RFC8776], defines a label-start, a label-end, a label-step and a range-bitmap. The label-start and label-end definitions for OTN should be augmented using the otn-label-start-end grouping. The label-step definition for OTN should be augmented using the otn-label-step grouping. It is expected that the otn-label-step will always be equal to its default value (i.e., 1), which is defined in [RFC8776].

As described in [RFC7139], in some cases, the TPN assignment rules are flexible (e.g., ODU4 Link) while in other cases the TPN assignment rules are fixed (e.g., ODU1 Link). In the former case, both TPN and TS ranges are reported, while in the latter case, the TPN range is not reported which indicates that the TPN shall be set equal to the TS number assigned to the ODUk LSP.

As described in [RFC7139], in some cases, the TPN assignment rules depends on the TS Granularity (e.g., ODU2 or ODU3 Links). Different entries in the label-restriction list will report different TPN ranges for each TS granularity supported by the link, as indicated by the tsg attribute in the otn-label-range-info grouping.

As described in [RFC7139], in some cases the TPN ranges are different for different types of ODUk LSPs. For example, on an ODU2 Link with 1.25G TS granularity, the TPN range is 1-4 for ODU1 but 1-8 for ODU0 and ODUflex. Different entries in the label-restriction list will report different TPN ranges for different set of ODUk types, as indicated by the odu-type-list in the otn-label-range-info grouping.

Appendix A provides some examples of how the TPN and TS label ranges described in Table 3 and Table 4 of [RFC7139] can be represented in YANG using the groupings defined in this document.

4.4. ODUflex

ODUflex is a type of ODU which has a flexible bit rate which is configured when setting up an ODUflex LSP.

[ITU-Tg709], defines six types of ODUflex: ODUflex(CBR), ODUflex(GFP), ODUflex(GFP,n,k), ODUflex(IMP), ODUflex(IMP,s) and ODUflex(FlexE-aware).

The main difference between these types of ODUflex is the formula used to calculate the nominal bit rate of the ODUflex, as described in Table 7-2 of [ITU-Tg709]. A YANG choice has been defined to describe these cases:

```

+--rw (oduflex-type)?
  +--:(generic)
    | +--rw nominal-bit-rate          uint64
  +--:(cbr)
    | +--rw client-type              identityref
  +--:(gfp-n-k)
    | +--rw gfp-n                    uint8
    | +--rw gfp-k?                   11-types:gfp-k
  +--:(flexe-client)
    | +--rw flexe-client
    |   11-types:flexe-client-rate
  +--:(flexe-aware)
    | +--rw flexe-aware-n            uint16
  +--:(packet)
    +--rw opuflex-payload-rate       uint64

```

The 'generic' case has been added to allow the ODUflex nominal bit rate to be defined independently from the type of ODUflex. This could be useful for forward compatibility in the transit domain/nodes where the setup of ODUflex LSPs does not depend on the ODUflex type.

In order to simplify interoperability the 'generic' case should be used only when it is needed; the ODUflex type-specific case should be used whenever possible.

The 'cbr' case is used for Constant Bit Rate (CBR) client signals. The client-type indicates which CBR client signal is carried by the ODUflex and, implicitly, the client signal bit rate which is then used to calculate the ODUflex(CBR) nominal bit rate as described in Table 7-2 of [ITU-Tg709].

The 'gfp-n-k' case is used for GFP-F mapped client signals based on ODUk.ts and 'n' 1.25G tributary slots. 'gfp-k' defines the nominal bit-rate of the ODUk.ts which, together with the value of 'gfp-n', is used to calculate the ODUflex(GFP,n,k) nominal bit rate as described in Table 7-8 and Table L-7 of [ITU-Tg709]. With a few exceptions, shown in Table L-7 of [ITU-Tg709], the nominal bit-rate of the ODUk.ts could be inferred from the value of 'n', as shown in Table 7-8 of [ITU-Tg709] and therefore the 'gfp-k' is optional.

The 'flexe-client' case is used for Idle Mapping Procedure(IMP) mapped FlexE client signals. The 'flexe-client' represents the type of FlexE client carried by the ODUflex which implicitly defines the value of 's' used to calculate the ODUflex(s) nominal bit rate as described in Table 7-2 of [ITU-Tg709]. The '10G' and '40G' enumeration values are used for 10G and 40G FlexE clients to

implicitly define the values of $s=2$ and $s=8$. For the 'n x 25G' FlexE Clients the value of 'n' is used to defines the value of $s=5 \times n$.

The 'flexe-aware' case is used for FlexE-aware client signals. The flexe-aware-n represents the value n ($n = n1 + n2 + \dots + np$) which is used to calculate the ODUflex(FlexE-aware) nominal bit rate as described in Table 7-2 of [ITU-Tg709].

The 'packet' case is used for both the GFP-F mapped client signals and the IMP mapped client signals. The opuflex-payload-rate is either the GFP-F encapsulated-packet client nominal bit rate or the 64b/66b encoded-packet client nominal bit rate. The calculation of ODUflex(GFP) nominal bit rate is defined in section 12.2.5 of [ITU-Tg709], and the calculation of ODUflex(IMP) nominal bit rate is defined in section 12.2.6 of [ITU-Tg709]. The same formula is used in both cases.

Section 5.1 and 5.2 of [RFC7139] defines two rules to compute the number of tributary slots to be allocated to ODUflex(CBR) and ODUflex(GFP) LSPs when carried over a HO-ODUk link. According to section 19.6 of [ITU-Tg709], the rules in section 5.2 apply only to ODUflex(GFP,n,k) while the rules defined in section 5.1 apply to any other ODUflex type, including, but not limited, to ODUflex(CBR). Section 20.5 of [ITU-Tg709] defines the rules for computing the number of tributary slots to be allocated to ODUflex LSPs when carried over an ODUCn link.

Following the [ITU-Tg709] definitions, the rules defined for ODUflex(GFP,n,k) are used only when the 'gfp-n-k' case is used. In all the other cases, including the (generic) case, the rules defined any other ODUflex type are used.

The number of available ODUs, defined for each ODUk type, including ODUflex, together with the number of available time-slots, reported as part of the OTN label range, provide sufficient information to infer the OTN link bandwidth availability for ODUflex LSPs. This information is independent of the ODUflex type.

4.4.1. Resizable ODUflex

Resizable ODUflex is a special type of ODUflex that supports the procedures defined in [ITU-Tg7044] for hitless resizing of the ODUflex nominal bit rate.

Two odu-type identities have been defined for ODUflex:

- o The ODUflex identity, which is used with any type of non-resizable ODUflex, as defined in Table 7-2 of [ITU-Tg709].

- o The ODUflex-resizable identity, which is used only with resizable ODUflex(GFP,n,k).

These two identities are used to identify whether an ODUflex(GFP,n,k) LSP does or does support the [ITU-Tg7044] hitless resizing procedures. They also identify whether an OTN link only supports the setup of non-resizable ODUflex LSPs or also supports the setup of resizable ODUflex(GFP,n,k) LSP but with different capabilities (e.g., a lower number of LSPs).

5. YANG Code for Layer1 Types

```
<CODE BEGINS>file "ietf-layer1-types@2020-10-27.yang"
module iETF-layer1-types {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-layer1-types";
  prefix "l1-types";

  organization
    "IETF CCAMP Working Group";
  contact
    "WG Web: <http://tools.ietf.org/wg/ccamp/>
    WG List: <mailto:ccamp@ietf.org>

    Editor: Haomian Zheng
            <mailto:zhenghaomian@huawei.com>

    Editor: Italo Busi
            <mailto:Italo.Busi@huawei.com>";

  description
    "This module defines Layer 1 types. The model fully conforms
    to the Network Management Datastore Architecture (NMDA).

    Copyright (c) 2020 IETF Trust and the persons
    identified as authors of the code. All rights reserved.

    Redistribution and use in source and binary forms, with or
    without modification, is permitted pursuant to, and subject
    to the license terms contained in, the Simplified BSD License
    set forth in Section 4.c of the IETF Trust's Legal Provisions
    Relating to IETF Documents
    (https://trustee.ietf.org/license-info).
    This version of this YANG module is part of RFC XXXX; see
    the RFC itself for full legal notices.";

  revision "2020-10-27" {
```

```
    description
      "Initial Version";
    reference
      "RFC XXXX: A YANG Data Model for Layer 1 Types";
      // RFC Editor: replace XXXX with actual RFC number, update date
      // information and remove this note
  }

/*
 * Typedefs
 */

typedef otn-tpn {
  type uint16 {
    range "1..4095";
  }
  description
    "Tributary Port Number for OTN. ";
  reference
    "RFC7139: GMPLS Signaling Extensions for Control of Evolving
      G.709 Optical Transport Networks.";
}

typedef otn-ts {
  type uint16 {
    range "1..4095";
  }
  description
    "Tributary Slot for OTN. ";
  reference
    "RFC7139: GMPLS Signaling Extensions for Control of Evolving
      G.709 Optical Transport Networks.";
}

typedef otn-label-range-type {
  type enumeration {
    enum trib-slot {
      description
        "Defines a range of OTN tributary slots. ";
    }
    enum trib-port {
      description
        "Defines a range of OTN tributary ports. ";
    }
  }
  description
    "Defines the type of OTN label range: TS or TPN. ";
}
```

```
typedef gfp-k {
  type enumeration {
    enum 2 {
      description
        "The ODU2.ts rate (1,249,177.230 kbit/s) is used
        to compute the rate of an ODUflex(GFP,n,2). ";
    }
    enum 3 {
      description
        "The ODU3.ts rate (1,254,470.354 kbit/s) is used
        to compute the rate of an ODUflex(GFP,n,3). ";
    }
    enum 4 {
      description
        "The ODU4.ts rate (1,301,467.133 kbit/s) is used
        to compute the rate of an ODUflex(GFP,n,4). ";
    }
  }
  description
    "The ODUk.ts used to compute the rate of an ODUflex(GFP,n,k)";
  reference
    "Table 7-8 and L-7 of G.709";
}

typedef flexe-client-rate {
  type union {
    type uint16;
    type enumeration {
      enum "10G" {
        description
          "Represents a 10G FlexE Client signal (s=2)";
      }
      enum "40G" {
        description
          "Represents a 40G FlexE Client signal (s=8)";
      }
    }
  }
  description
    "The FlexE Client signal rate (s x 5,156,250.000 kbit/s)
    used to compute the rate of an ODUflex(IMP, s).
    Valid values for s are s=2 (10G), s=4 (40G) and
    s=5 x n (n x 25G).
    In the first two cases an enumeration value
    (either 10G or 40G) is used, while in the latter case
    the value of n is used";
  reference
    "Table 7-2 of G.709";
}
```

```
}

/*
 * Identities
 */

identity tributary-slot-granularity {
  description
    "Tributary slot granularity";
  reference
    "G.709/Y.1331, February 2016: Interfaces for the Optical
    Transport Network (OTN)";
}

identity tsq-1.25G {
  base tributary-slot-granularity;
  description
    "1.25G tributary slot granularity";
}

identity tsq-2.5G {
  base tributary-slot-granularity;
  description
    "2.5G tributary slot granularity";
}

identity tsq-5G {
  base tributary-slot-granularity;
  description
    "5G tributary slot granularity";
}

identity odu-type {
  description
    "Base identity from which specific ODU protocol is derived.";
}

identity ODU0 {
  base odu-type;
  description
    "ODU0 protocol (1.24Gb/s).";
  reference "RFC7139/ITU-T G.709";
}

identity ODU1 {
  base odu-type;
  description
    "ODU1 protocol (2.49Gb/s).";
```

```
    reference "RFC7139/ITU-T G.709";
  }

  identity ODU1e {
    base odu-type;
    description
      "ODU1e protocol (10.35Gb/s).";
    reference "RFC7963/ITU-T G.sup43";
  }

  identity ODU2 {
    base odu-type;
    description
      "ODU2 protocol (10.03Gb/s).";
    reference "RFC7139/ITU-T G.709";
  }

  identity ODU2e {
    base odu-type;
    description
      "ODU2e protocol (10.39Gb/s).";
    reference "RFC7139/ITU-T G.709";
  }

  identity ODU3 {
    base odu-type;
    description
      "ODU3 protocol (40.31Gb/s).";
    reference "RFC7139/ITU-T G.709";
  }

  identity ODU3e1 {
    base odu-type;
    description
      "ODU3e1 protocol (41.77Gb/s).";
    reference "RFC7963/ITU-T G.sup43";
  }

  identity ODU3e2 {
    base odu-type;
    description
      "ODU3e2 protocol (41.78Gb/s).";
    reference "RFC7963/ITU-T G.sup43";
  }

  identity ODU4 {
    base odu-type;
    description
```



```
    "ODU4 protocol (104.79Gb/s).";
    reference "RFC7139/ITU-T G.709";
}

identity ODUflex {
    base odu-type;
    description
        "ODUflex protocol (flexibile bit rate, not resizable).

        It could be used for any type of ODUflex, including
        ODUflex(CBR), ODUflex(GFP), ODUflex(GFP,n,k), ODUflex(IMP,s),
        ODUflex(IMP) and ODUflex(FlexE-aware).";
    reference "RFC7139/ITU-T G.709";
}

identity ODUflex-resizable {
    base odu-type;
    description
        "ODUflex protocol (flexibile bit rate, resizable).

        It could be used only for ODUflex(GFP,n,k).";
    reference "RFC7139/ITU-T G.709 and ITU-T G.7044";
}

identity protocol {
    description
        "Base identity from which specific protocol is derived.";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
}

identity Ethernet {
    base "protocol";
    description
        "Ethernet protocol.";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
}

identity Fibre-Channel {
    base "protocol";
    description
        "Fibre-Channel (FC) protocol.";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
}

identity SDH {
    base "protocol";
    description
        "SDH protocol.";
```

```
    reference "MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity SONET {
    base "protocol";
    description
      "SONET protocol.";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity client-signal {
    description
      "Base identity from which specific client signal is derived";
  }

  identity coding-func {
    description
      "Base identity from which specific coding function
       is derived.";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity ETH-1Gb {
    base client-signal;
    description
      "Client signal type of 1GbE";
    reference "RFC7139/ITU-T G.709";
  }

  identity ETH-10Gb-LAN {
    base client-signal;
    description
      "Client signal type of ETH-10Gb-LAN (10.3 Gb/s)";
    reference "RFC7139/ITU-T G.709/IEEE 802.3 Clause 49";
  }

  identity ETH-10Gb-WAN {
    base client-signal;
    description
      "Client signal type of ETH-10Gb-WAN (9.95 Gb/s)";
    reference "RFC7139/ITU-T G.709/IEEE 802.3 Clause 50";
  }

  identity ETH-40Gb {
    base client-signal;
    description
      "Client signal type of 40GbE";
    reference "RFC7139/ITU-T G.709";
  }
```

```
}

identity ETH-100Gb {
  base client-signal;
  description
    "Client signal type of 100GbE";
  reference "RFC7139/ITU-T G.709";
}

identity STM-1 {
  base client-signal;
  base "coding-func";
  description
    "Client signal type of STM-1;
    STM-1 G.707 (N=1) coding function.";
  reference
    "RFC7139/ITU-T G.709
    MEF63: Subscriber Layer 1 Service Attributes";
}

identity STM-4 {
  base client-signal;
  base "coding-func";
  description
    "Client signal type of STM-4;
    STM-4 G.707 (N=4) coding function.";
  reference
    "RFC7139/ITU-T G.709
    MEF63: Subscriber Layer 1 Service Attributes";
}

identity STM-16 {
  base client-signal;
  base "coding-func";
  description
    "Client signal type of STM-16;
    STM-16 G.707 (N=16) coding function.";
  reference
    "RFC7139/ITU-T G.709
    MEF63: Subscriber Layer 1 Service Attributes";
}

identity STM-64 {
  base client-signal;
  base "coding-func";
  description
    "Client signal type of STM-64;
    STM-64 G.707 (N=64) coding function.";
```

```
    reference
      "RFC7139/ITU-T G.709
      MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity STM-256 {
    base client-signal;
    base "coding-func";
    description
      "Client signal type of STM-256;
      STM-256 G.707 (N=256) coding function.";
    reference
      "RFC7139/ITU-T G.709
      MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity OC-3 {
    base client-signal;
    base "coding-func";
    description
      "Client signal type of OC3;
      OC-3 GR-253-CORE (N=3) coding function.";
    reference
      "ANSI T1.105-1995, Synchronous Optical Network (SONET)
      Basic Description including Multiplex Structure, Rates,
      and Formats
      MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity OC-12 {
    base client-signal;
    base "coding-func";
    description
      "Client signal type of OC12;
      OC-12 GR-253-CORE (N=12) coding function.";
    reference
      "ANSI T1.105-1995, Synchronous Optical Network (SONET)
      Basic Description including Multiplex Structure, Rates,
      and Formats
      MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity OC-48 {
    base client-signal;
    base "coding-func";
    description
      "Client signal type of OC48;
      OC-48 GR-253-CORE (N=48) coding function.";
```

```
reference
  "ANSI T1.105-1995, Synchronous Optical Network (SONET)
  Basic Description including Multiplex Structure, Rates,
  and Formats
  MEF63: Subscriber Layer 1 Service Attributes";
}

identity OC-192 {
  base client-signal;
  base "coding-func";
  description
    "Client signal type of OC192;
    OC-192 GR-253-CORE (N=192) coding function.";
  reference
    "ANSI T1.105-1995, Synchronous Optical Network (SONET)
    Basic Description including Multiplex Structure, Rates,
    and Formats
    MEF63: Subscriber Layer 1 Service Attributes";
}

identity OC-768 {
  base client-signal;
  base "coding-func";
  description
    "Client signal type of OC768;
    OC-768 GR-253-CORE (N=768) coding function.";
  reference
    "ANSI T1.105-1995, Synchronous Optical Network (SONET)
    Basic Description including Multiplex Structure, Rates,
    and Formats
    MEF63: Subscriber Layer 1 Service Attributes";
}

identity FC-100 {
  base client-signal;
  base "coding-func";
  description
    "Client signal type of Fibre Channel FC-100;
    FC-100 FC-FS-2 (1.0625 Gb/s) coding function.";
  reference
    "RFC7139/ITU-T G.709
    MEF63: Subscriber Layer 1 Service Attributes";
}

identity FC-200 {
  base client-signal;
  base "coding-func";
  description
```

```
        "Client signal type of Fibre Channel FC-200;
        FC-200 FC-FS-2 (2.125 Gb/s) coding function.";
    reference
        "RFC7139/ITU-T G.709
        MEF63: Subscriber Layer 1 Service Attributes";
}

identity FC-400 {
    base client-signal;
    base "coding-func";
    description
        "Client signal type of Fibre Channel FC-400;
        FC-400 FC-FS-2 (4.250 Gb/s) coding function.";
    reference
        "RFC7139/ITU-T G.709
        MEF63: Subscriber Layer 1 Service Attributes";
}

identity FC-800 {
    base client-signal;
    base "coding-func";
    description
        "Client signal type of Fibre Channel FC-800;
        FC-800 FC-FS-2 (8.500 Gb/s) coding function.";
    reference
        "RFC7139/ITU-T G.709
        MEF63: Subscriber Layer 1 Service Attributes";
}

identity FC-1200 {
    base client-signal;
    base "coding-func";
    description
        "Client signal type of Fibre Channel FC-1200;
        FC-1200 FC-10GFC (10.51875 Gb/s) coding function.";
    reference
        "RFC7139/ITU-T G.709
        MEF63: Subscriber Layer 1 Service Attributes";
}

identity FC-1600 {
    base client-signal;
    base "coding-func";
    description
        "Client signal type of Fibre Channel FC-1600;
        FC-1600 FC-FS-3 (14.025 Gb/s) coding function.";
    reference
        "RFC7139/ITU-T G.709
```

```
        MEF63: Subscriber Layer 1 Service Attributes";
    }

    identity FC-3200 {
        base client-signal;
        base "coding-func";
        description
            "Client signal type of Fibre Channel FC-3200;
            FC-3200 FC-FS-4 (28.05 Gb/s) coding function.";
        reference
            "RFC7139/ITU-T G.709
            MEF63: Subscriber Layer 1 Service Attributes";
    }

    identity FICON-4G {
        base client-signal;
        description
            "Client signal type of Fibre Connection 4G";
        reference "RFC4328/RFC7139";
    }

    identity FICON-8G {
        base client-signal;
        description
            "Client signal type of Fibre Connection 8G";
        reference "RFC4328/RFC7139";
    }

    identity ETH-1000X {
        base "coding-func";
        description
            "1000BASE-X PCS clause 36 coding function.";
        reference "MEF63: Subscriber Layer 1 Service Attributes";
    }

    identity ETH-10GW {
        base "coding-func";
        description
            "10GBASE-W (WAN PHY) PCS clause 49 and WIS clause 50
            coding function.";
        reference "MEF63: Subscriber Layer 1 Service Attributes";
    }

    identity ETH-10GR {
        base "coding-func";
        description
            "10GBASE-R (LAN PHY) PCS clause 49 coding function.";
        reference "MEF63: Subscriber Layer 1 Service Attributes";
    }
```

```
}

identity ETH-40GR {
  base "coding-func";
  description
    "40GBASE-R PCS clause 82 coding function.";
  reference "MEF63: Subscriber Layer 1 Service Attributes";
}

identity ETH-100GR {
  base "coding-func";
  description
    "100GBASE-R PCS clause 82 coding function.";
  reference "MEF63: Subscriber Layer 1 Service Attributes";
}

identity optical-interface-func {
  description
    "Base identity from which optical-interface-function
    is derived.";
  reference "MEF63: Subscriber Layer 1 Service Attributes";
}

identity SX-PMD-1000 {
  base "optical-interface-func";
  description
    "SX-PMD-clause-38 Optical Interface function for
    1000BASE-X PCS-36";
  reference "MEF63: Subscriber Layer 1 Service Attributes";
}

identity LX-PMD-1000 {
  base "optical-interface-func";
  description
    "LX-PMD-clause-38 Optical Interface function for
    1000BASE-X PCS-36";
  reference "MEF63: Subscriber Layer 1 Service Attributes";
}

identity LX10-PMD-1000 {
  base "optical-interface-func";
  description
    "LX10-PMD-clause-59 Optical Interface function for
    1000BASE-X PCS-36";
  reference "MEF63: Subscriber Layer 1 Service Attributes";
}

identity BX10-PMD-1000 {
```



```
    base "optical-interface-func";
    description
      "BX10-PMD-clause-59 Optical Interface function for
      1000BASE-X PCS-36";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity LW-PMD-10G {
    base "optical-interface-func";
    description
      "LW-PMD-clause-52 Optical Interface function for
      10GBASE-W PCS-49-WIS-50";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity EW-PMD-10G {
    base "optical-interface-func";
    description
      "EW-PMD-clause-52 Optical Interface function for
      10GBASE-W PCS-49-WIS-50";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity LR-PMD-10G {
    base "optical-interface-func";
    description
      "LR-PMD-clause-52 Optical Interface function for
      10GBASE-R PCS-49";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity ER-PMD-10G {
    base "optical-interface-func";
    description
      "ER-PMD-clause-52 Optical Interface function for
      10GBASE-R PCS-49";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity LR4-PMD-40G {
    base "optical-interface-func";
    description
      "LR4-PMD-clause-87 Optical Interface function for
      40GBASE-R PCS-82";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity ER4-PMD-40G {
```

```
    base "optical-interface-func";
    description
      "ER4-PMD-clause-87 Optical Interface function for
      40GBASE-R PCS-82";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity FR-PMD-40G {
    base "optical-interface-func";
    description
      "FR-PMD-clause-89 Optical Interface function for
      40GBASE-R PCS-82";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity LR4-PMD-100G {
    base "optical-interface-func";
    description
      "LR4-PMD-clause-88 Optical Interface function for
      100GBASE-R PCS-82";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity ER4-PMD-100G {
    base "optical-interface-func";
    description
      "ER4-PMD-clause-88 Optical Interface function for
      100GBASE-R PCS-82";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
  }

  /*
   * Groupings
   */

  grouping otn-link-bandwidth {
    description "link bandwidth attributes for OTN";
    list odl {
      key "odu-type";
      description
        "OTN bandwidth definition";
      leaf odu-type {
        type identityref {
          base odu-type;
        }
        description "ODU type";
      }
      leaf number {
```

```
        type uint16;
        description "Number of ODUs";
    }
}

grouping otn-path-bandwidth {
    description
        "path bandwidth attributes grouping for OTN";

    container otn {
        description
            "path bandwidth attributes for OTN";
        leaf odu-type {
            type identityref {
                base odu-type;
            }
            description "ODU type";
        }
        choice oduflex-type {
            when 'derived-from-or-self(./odu-type,"ODUflex") or
                derived-from-or-self(./odu-type,"ODUflex-resizable')' {
                description
                    "applicable when odu-type is ODUflex or
                     ODUflex-resizable";
            }
            description
                "Types of ODUflex used to compute the ODUflex
                 nominal bit rate.";
            reference
                "Table 7-2 of G.709";
            case generic {
                leaf nominal-bit-rate {
                    type uint64;
                    units "bps";
                    mandatory true;
                    description
                        "Nominal ODUflex bit rate.";
                }
            }
            case cbr {
                leaf client-type {
                    type identityref {
                        base client-signal;
                    }
                    mandatory true;
                    description
                        "The CBR client signal for an ODUflex(CBR).";
                }
            }
        }
    }
}
```

```
    }  
  }  
  case gfp-n-k {  
    leaf gfp-n {  
      type uint8 {  
        range "1..80";  
      }  
      mandatory true;  
      description  
        "The value of n for an ODUflex(GFP,n,k).";  
      reference  
        "Tables 7-8 and L-7 of G.709";  
    }  
    leaf gfp-k {  
      type gfp-k;  
      description  
        "The value of k for an ODUflex(GFP,n,k).  
        If omitted, it is calculated from the value of gfp-n  
        as described in Table 7-8 of G.709";  
      reference  
        "Tables 7-8 and L-7 of G.709";  
    }  
  }  
  case flexe-client {  
    leaf flexe-client {  
      type flexe-client-rate;  
      mandatory true;  
      description  
        "The rate of the FlexE-client for an ODUflex(IMP,s).";  
    }  
  }  
  case flexe-aware {  
    leaf flexe-aware-n {  
      type uint16;  
      mandatory true;  
      description  
        "The rate of FlexE-aware client signal  
        for ODUflex(FlexE-aware)";  
    }  
  }  
  case packet {  
    leaf opuflex-payload-rate {  
      type uint64;  
      units "Kbps";  
      mandatory true;  
      description  
        "Either the GFP-F encapsulated packet client nominal  
        bit rate for an ODUflex(GFP) or the 64b/66b encoded
```

```
        packet client nominal bit rate for an ODUflex(IMP).";
    }
}
}
}

grouping otn-label-range-info {
  description
    "label range information for OTN, is dependent on the
    range-type, must be used together with the following
    groupings: otn-label-start-end and otn-label-step. ";
  leaf range-type {
    type otn-label-range-type;
    description "The type of range (e.g., TPN or TS)
    to which the label range applies";
  }
  leaf tsg {
    type identityref {
      base tributary-slot-granularity;
    }
    description
      "Tributary slot granularity (TSG) to which the label range
      applies.
      This leaf shall be present when the range-type is TS;
      This leaf can be omitted when mapping an ODUk over an OTUk
      Link. In this case the range-type is tpn, with only one
      entry (ODUk), and the tpn range has only one value (1).";
    reference
      "G.709/Y.1331, February 2016: Interfaces for the
      Optical Transport Network (OTN)";
  }
  leaf-list odu-type-list {
    type identityref {
      base odu-type;
    }
    description
      "List of ODU types to which the label range applies.
      An Empty odu-type-list means that the label range
      applies to all the supported ODU types.";
  }
  leaf priority {
    type uint8;
    description
      "Priority in Interface Switching Capability
      Descriptor (ISCD).";
    reference "RFC4203.";
  }
}
```

```
}

grouping otn-label-start-end {
  description
    "The OTN label-start or label-end used to specify an OTN label
    range. this grouping is dependent on the range-type,
    must be used together with the following groupings:
    otn-label-range-info and otn-label-step.";
  choice range-type {
    description
      "OTN label range type, either TPN range or TS range";
    case trib-port {
      leaf otn-tpn {
        when "../../range-type = 'trib-port'" {
          description
            "valid only when range-type represented by trib-port";
        }
        type otn-tpn;
        description
          "Tributary Port Number.";
        reference
          "RFC7139: GMPLS Signaling Extensions for Control of
          Evolving G.709 Optical Transport Networks.";
      }
    }
    case trib-slot {
      leaf otn-ts {
        when "../../range-type = 'trib-slot'" {
          description
            "valid only when range-type represented by trib-slot";
        }
        type otn-ts;
        description
          "Tributary Slot Number.";
        reference
          "RFC7139: GMPLS Signaling Extensions for Control of
          Evolving G.709 Optical Transport Networks.";
      }
    }
  }
}

grouping otn-label-hop {
  description "OTN Label. ";
  reference "RFC7139, section 6. ";
  leaf otn-tpn {
    type otn-tpn;
    description
```

```
        "Tributary Port Number.";
    reference
        "RFC7139: GMPLS Signaling Extensions for Control of Evolving
        G.709 Optical Transport Networks.";
}
leaf tsg {
    type identityref {
        base tributary-slot-granularity;
    }
    description "Tributary slot granularity.";
    reference
        "G.709/Y.1331, February 2016: Interfaces for the
        Optical Transport Network (OTN)";
}
leaf ts-list {
    type string {
        pattern "([1-9][0-9]{0,3}(-[1-9][0-9]{0,3})?"+
            "([1-9][0-9]{0,3}(-[1-9][0-9]{0,3})?)*)";
    }
    description
        "A list of available tributary slots ranging
        between 1 and 4095. If multiple values or
        ranges are given, they all must be disjoint
        and must be in ascending order.
        For example 1-20,25,50-1000.";
    reference
        "RFC 7139: GMPLS Signaling Extensions for Control
        of Evolving G.709 Optical Transport Networks";
}
}

grouping otn-label-step {
    description
        "Label step for OTN, is dependent on the range-type,
        must be used together with the following groupings:
        otn-label-range-info and otn-label-start-end. ";
    choice range-type {
        description
            "OTN label range type, either TPN range or TS range";
        case trib-port {
            leaf otn-tpn {
                when "../range-type = 'trib-port'" {
                    description
                        "valid only when range-type represented by trib-port";
                }
                type otn-tpn;
                description
                    "Label step which represents possible increments for
```

```

        Tributary Port Number.";
reference
    "RFC7139: GMPLS Signaling Extensions for Control of
      Evolving G.709 Optical Transport Networks.";
}
}
case trib-slot {
leaf otn-ts {
when "../range-type = 'trib-slot'" {
description
    "valid only when range-type represented by trib-slot";
}
type otn-ts;
description
    "Label step which represents possible increments for
      Tributary Slot Number.";
reference
    "RFC7139: GMPLS Signaling Extensions for Control of
      Evolving G.709 Optical Transport Networks.";
}
}
}
}
<CODE ENDS>
```

The YANG module specified in this document defines a schema for data that is designed to be accessed via network management protocols such as NETCONF [RFC6241] or RESTCONF [RFC8040]. The lowest NETCONF layer is the secure transport layer, and the mandatory-to-implement secure transport is Secure Shell (SSH) [RFC6242]. The lowest RESTCONF layer is HTTPS, and the mandatory-to-implement secure transport is TLS [RFC8446].

The NETCONF access control model [RFC8341] provides the means to restrict access for particular NETCONF or RESTCONF users to a preconfigured subset of all available NETCONF or RESTCONF protocol operations and content.

The YANG module in this document defines layer 1 type definitions (i.e., typedef, identity and grouping statements) in YANG data modeling language to be imported and used by other layer 1 technology-specific modules. When imported and used, the resultant schema will have data nodes that can be writable, or readable. The access to such data nodes may be considered sensitive or vulnerable

in some network environments. Write operations (e.g., edit-config) to these data nodes without proper protection can have a negative effect on network operations.

The security considerations spelled out in the YANG 1.1 specification [RFC7950] apply for this document as well.

7. IANA Considerations

It is proposed that IANA should assign new URIs from the "IETF XML Registry" [RFC3688] as follows:

```
URI: urn:ietf:params:xml:ns:yang:ietf-layer1-types
Registrant Contact: The IESG
XML: N/A; the requested URI is an XML namespace.
```

This document registers following YANG modules in the YANG Module Names registry [RFC7950].

```
name:      ietf-layer1-types
namespace: urn:ietf:params:xml:ns:yang:ietf-layer1-types
prefix:    l1-types
reference:  RFC XXXX
```

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Appendix A. Examples of OTN Label Ranges

This appendix provides some examples of how the TPN and TS label ranges described in Table 3 and Table 4 of [RFC7139] can be represented in YANG using the groupings defined in this document.

It also considers the OTUk links in addition to HO-ODUk links.

The JSON code examples provided in this appendix provides some embedded comments following the conventions in section 3.2 of [I-D.ietf-ccamp-transport-nbi-app-statement] and have been folded using the tool in [RFC8792].

===== NOTE: '\\' line wrapping per BCP XXX (RFC XXXX) =====

```
{
  "examples of label-restrictions for different OTN Links": [
    {
      "// ": "HO-ODU1 or OTU1 Link",
      "label-restrictions": {
        "label-restriction": [
          {
            "index ": 1,
            "// ____DEFAULT__ restriction": "inclusive",
```

```

        "range-type": "label-range-trib-port",
        "/* ___NOT-PRESENT___ tsg": "",
        "odu-type-list": "[ ODU1 ]",
        "/* ___DEFAULT___ priority": 7,
        "/* tpn-range": 1,
        "/* ___ COMMENT ___": "Since no TS range and no TSG are \
\reported for ODU1, the link is an OTU1 Link. TS allocation is not n\
\eeded and TPN shall be set to '1' for mapping ODU1 over OTU1. This \
\entry is not present if the OTN Link is an HO-ODU1 Link."
    },
    {
        "index ": 2,
        "/* ___DEFAULT___ restriction": "inclusive",
        "range-type": "label-range-trib-slot",
        "tsg": "tsg-1.25G",
        "odu-type-list": "[ ODU0 ]",
        "/* ts-range": "1-2",
        "/* ___ COMMENT ___": "Since no TPN range is reportd for\
\ ODU0 with 1.25G TSG, the TPN allocation rule is fixed (TPN = TS#) \
\for mapping LO-ODU0 over HO-ODU1 with 1.25G TSG. See Table 4 of [RF\
\C7139]."
    }
  ]
}
},
{
  "/* ": "HO-ODU2 or OTU2 Link",
  "label-restrictions": {
    "label-restriction": [
      {
        "index ": 1,
        "/* ___DEFAULT___ restriction": "inclusive",
        "range-type": "label-range-trib-port",
        "/* ___NOT-PRESENT___ tsg": "",
        "odu-type-list": "[ ODU2 ]",
        "/* ___ DEFAULT ___ priority": 7,
        "/* tpn-range": 1,
        "/* ___ COMMENT ___": "Since no TS range and no TSG are \
\reported for ODU2, the link is an OTU2 Link. TS allocation is not n\
\eeded and TPN shall be set to '1' for mapping ODU2 over OTU2. This \
\entry is not present if the OTN Link is an HO-ODU2 Link."
      },
      {
        "index ": 2,
        "/* ___DEFAULT___ restriction": "inclusive",
        "range-type": "label-range-trib-slot",
        "tsg": "tsg-1.25G",
        "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, ODU1\

```

```

\ ]",
    "/// __ DEFAULT __ priority": 7,
    "/// ts-range": "1-8"
  },
  {
    "index ": 3,
    "/// __DEFAULT__ restriction": "inclusive",
    "range-type": "label-range-trib-port",
    "tsg": "tsg-1.25G ",
    "odu-type-list": "[ ODUflex-cbr, ODUflex-gfp, ODU0 ]",
    "/// __ DEFAULT __ priority": 7,
    "/// tpn-range": "1-8",
    "/// __ COMMENT __": "Since this TPN range is reported \
\for ODUflex and ODU0 with 1.25G TSG, the TPN assignment rule is fle\
\xible within a common range for mapping LO-ODUflex and LO-ODU0 over\
\ HO-ODU2 with 1.25G TSG. See Table 4 of [RFC7139].",
  },
  {
    "index ": 4,
    "/// __DEFAULT__ restriction": "inclusive",
    "range-type": "label-range-trib-port",
    "tsg": "tsg-1.25G",
    "odu-type-list": "[ ODU1 ]",
    "/// __ DEFAULT __ priority": 7,
    "/// tpn-range": "1-4",
    "/// __ COMMENT __": "Since this TPN range is reported \
\for ODU1 with 1.25G TSG, the TPN assignment rule is flexible within\
\ a common range for mapping LO-ODU1 over HO-ODU2 with 1.25G TSG. Se\
\ e Table 4 of [RFC7139].",
  },
  {
    "index ": 5,
    "/// __DEFAULT__ restriction": "inclusive",
    "range-type": "label-range-trib-slot",
    "tsg": "tsg-2.5G",
    "odu-type-list": "[ ODU1 ]",
    "/// __ DEFAULT __ priority": 7,
    "/// ts-range": "1-4",
    "/// __ COMMENT __": "Since no TPN range is reported fo\
\r ODU1 with 2.5G TSG, the TPN allocation rule is fixed (TPN = TS#) \
\for mapping LO-ODU1 over HO-ODU2 with 2.5G TSG. See Table 3 of [RFC\
\7139].",
  }
]
}
},
{
  "/// ": "HO-ODU3 or OTU3 Link",

```

```

"label-restrictions": {
  "label-restriction": [
    {
      "index ": 1,
      "/* __DEFAULT__ restriction": "inclusive",
      "range-type": "label-range-trib-port",
      "/* __NOT-PRESENT__ tsg": "",
      "odu-type-list": "[ ODU3 ]",
      "/* __ DEFAULT __ priority": 7,
      "/* tpn-range": 1,
      "/* __ COMMENT __": "Since no TS range and no TSG are \
\reported for ODU3, the link is an OTU3 Link. TS allocation is not n\
\eeded and TPN shall be set to '1' for mapping ODU3 over OTU3. This \
\entry is not present if the OTN Link is an HO-ODU3 Link."
    },
    {
      "index ": 2,
      "/* __DEFAULT__ restriction": "inclusive",
      "range-type": "label-range-trib-slot",
      "tsg": "tsg-1.25G",
      "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, ODU1\
\, ODU2, ODU2e ]",
      "/* __ DEFAULT __ priority": 7,
      "/* ts-range": "1-32"
    },
    {
      "index ": 3,
      "/* __DEFAULT__ restriction": "inclusive",
      "range-type": "label-range-trib-port",
      "tsg": "tsg-1.25G",
      "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, ODU2\
\e ]",
      "/* __ DEFAULT __ priority": 7,
      "/* tpn-range": "1-32",
      "/* __ COMMENT __": "Since this TPN range is reported \
\for ODUflex, ODU0 and ODU2e with 1.25G TSG, the TPN assignment rule\
\ is flexible within a common range for mapping LO-ODUflex, LO-ODU0 \
\and LO-ODU2e over HO-ODU3 with 1.25G TSG. See Table 4 of [RFC7139]."
    },
    {
      "index ": 4,
      "/* __DEFAULT__ restriction": "inclusive",
      "range-type": "label-range-trib-port",
      "tsg": "tsg-1.25G",
      "odu-type-list": "[ ODU1 ]",
      "/* __ DEFAULT __ priority": 7,
      "/* tpn-range": "1-16",
      "/* __ COMMENT __": "Since this TPN range is reported \

```



```

\for ODU1 with 1.25G TSG, the TPN assignment rule is flexible within\
\ a common range for mapping LO-ODU1 over HO-ODU3 with 1.25G TSG. Se\
\ e Table 4 of [RFC7139]."
    },
    {
        "index ": 5,
        "/* __DEFAULT__ restriction": "inclusive",
        "range-type": "label-range-trib-port",
        "tsg": "tsg-1.25G",
        "odu-type-list": "[ ODU2 ]",
        "/* __ DEFAULT __ priority": 7,
        "/* tpn-range": "1-4",
        "/* __ COMMENT __": "Since this TPN range is reported \
\for ODU2 with 1.25G TSG, the TPN assignment rule is flexible within\
\ a common range for mapping LO-ODU2 over HO-ODU3 with 1.25G TSG. Se\
\ e Table 4 of [RFC7139]."
    },
    {
        "index ": 6,
        "/* __DEFAULT__ restriction": "inclusive",
        "range-type": "label-range-trib-slot",
        "tsg": "tsg-2.5G",
        "odu-type-list": "[ ODU1, ODU2 ]",
        "/* __ DEFAULT __ priority": 7,
        "/* ts-range": "1-16"
    },
    {
        "index ": 7,
        "/* __DEFAULT__ restriction": "inclusive",
        "range-type": "label-range-trib-port",
        "tsg": "tsg-2.5G ",
        "odu-type-list": "[ ODU2 ]",
        "/* __ DEFAULT __ priority": 7,
        "/* tpn-range": "1-4",
        "/* __ COMMENT __": "Since this TPN range is reported \
\for ODU2 with 2.5G TSG, the TPN assignment rule is flexible within \
\ a common range for mapping LO-ODU2 over HO-ODU3. Since no TPN range\
\ is reported for ODU1 with 2.5G TSG, the TPN allocation rule is fix\
\ ed (TPN = TS#) for mapping LO-ODU1 over HO-ODU3 with 2.5G TSG. See \
\ Table 3 of [RFC7139]."
    }
]
}
},
{
    "/* ": "HO-ODU4 or OTU4 Link",
    "label-restrictions": {
        "label-restriction": [

```

```

    {
      "index ": 1,
      "/* ____DEFAULT____ restriction": "inclusive",
      "range-type": "label-range-trib-port",
      "/* ____NOT-PRESENT____ tsg": "",
      "odu-type-list": "[ ODU4 ]",
      "/* ____ DEFAULT ____ priority": 7,
      "/* tpn-range": 1,
      "/* ____ COMMENT ____": "Since no TS range and no TSG are \
\reported for ODU4, the link is an OTU4 Link. TS allocation is not n\
\eeded and TPN shall be set to '1' for mapping ODU4 over OTU4. This \
\entry is not present if the OTN Link is an HO-ODU4 Link."
    },
    {
      "index ": 2,
      "/* ____DEFAULT____ restriction": "inclusive",
      "range-type": "label-range-trib-slot",
      "tsg": "tsg-1.25G",
      "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, ODU1\
\, ODU2, ODU2e, ODU3 ]",
      "/* ____ DEFAULT ____ priority": 7,
      "/* ts-range": "1-80"
    },
    {
      "index ": 3,
      "/* ____DEFAULT____ restriction": "inclusive",
      "range-type": "label-range-trib-port",
      "tsg": "tsg-1.25G",
      "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, ODU1\
\, ODU2, ODU2e, ODU3 ]",
      "/* ____ DEFAULT ____ priority": 7,
      "/* tpn-range": "1-80",
      "/* ____ COMMENT ____": "Since this TPN range is reported \
\for any LO-ODUj with 1.25G TSG, the TPN assignment rule is flexible\
\ within a common range for mapping any LO-ODUj over HO-ODU4 with 1.\
\25G TSG. See Table 4 of [RFC7139]."
    }
  ]
}
},
{
  "/* ": "ODUC1 Link",
  "label-restrictions": {
    "label-restriction": [
      {
        "index ": 1,
        "/* ____DEFAULT____ restriction": "inclusive",
        "range-type": "label-range-trib-slot",

```

```

        "tsg": "tsg-5G",
        "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, ODU1\
\, ODU2, ODU2e, ODU3, ODU4 ]",
        "/// __ DEFAULT __ priority": 7,
        "/// ts-range": "1-20",
        "/// __ COMMENT __": "Since the TS range is specified f\
\or any ODUk, the OTN Link is an ODUCn Link."
    },
    {
        "index ": 2,
        "/// __ DEFAULT __ restriction": "inclusive",
        "range-type": "label-range-trib-port",
        "tsg": "tsg-5G",
        "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, ODU1\
\, ODU2, ODU2e, ODU3, ODU4 ]",
        "/// __ DEFAULT __ priority": 7,
        "/// tpn-range": "1-10",
        "/// __ COMMENT __": "Since this TPN range is reported \
\for any ODUk with 5G TSG, the TPN assignment rule is flexible withi\
\n a common range for mapping any ODUk over ODUCn with 5G TSG."
    }
  ]
}
}
]
}

```

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A Yang Data Model for Optical Impairment-aware Topology
draft-ietf-ccamp-optical-impairment-topology-yang-05

Abstract

In order to provision an optical connection through optical networks, a combination of path continuity, resource availability, and impairment constraints must be met to determine viable and optimal paths through the network. The determination of appropriate paths is known as Impairment-Aware Routing and Wavelength Assignment (IA-RWA) for WSON, while it is known as Impairment-Aware Routing and Spectrum Assignment (IA-RSA) for SSON.

This document provides a YANG data model for the impairment-aware TE topology in optical networks.

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1. Introduction

In order to provision an optical connection (an optical path) through a wavelength switched optical networks (WSONs) or spectrum switched optical networks (SSONs), a combination of path continuity, resource availability, and impairment constraints must be met to determine viable and optimal paths through the network. The determination of appropriate paths is known as Impairment-Aware Routing and Wavelength Assignment (IA-RWA) [RFC6566] for WSON, while it is known as IA-Routing and Spectrum Assignment (IA-RSA) for SSON.

This document provides a YANG data model for the impairment-aware Traffic Engineering (TE) topology in WSONs and SSONs. The YANG model described in this document is a WSON/SSON technology-specific Yang model based on the information model developed in [RFC7446] and the two encoding documents [RFC7581] and [RFC7579] that developed protocol independent encodings based on [RFC7446].

The intent of this document is to provide a Yang data model, which can be utilized by a Multi-Domain Service Coordinator (MDSC) to collect states of WSON impairment data from the Transport PNCs to enable impairment-aware optical path computation according to the ACTN Architecture [RFC8453]. The communication between controllers is done via a NETCONF [RFC8341] or a RESTCONF [RFC8040]. Similarly, this model can also be exported by the MDSC to a Customer Network Controller (CNC), which can run an offline planning process to map latter the services in the network.

This document augments the generic TE topology draft [I-D.ietf-teas-yang-te-topo] where possible.

This document defines one YANG module: ietf-optical-impairment-topology (Section 3) according to the new Network Management Datastore Architecture [RFC8342].

1.1. Terminology

Refer to [RFC6566], [RFC7698], and [G.807] for the key terms used in this document.

The following terms are defined in [RFC7950] and are not redefined here:

- o client
- o server
- o augment
- o data model
- o data node

The following terms are defined in [RFC6241] and are not redefined here:

- o configuration data
- o state data

The terminology for describing YANG data models is found in [RFC7950].

1.2. Tree Diagram

A simplified graphical representation of the data model is used in Section 2 of this this document. The meaning of the symbols in these diagrams is defined in [RFC8340].

1.3. Prefixes in Data Node Names

In this document, names of data nodes and other data model objects are prefixed using the standard prefix associated with the corresponding YANG imported modules, as shown in Table 1.

Prefix	YANG module	Reference
optical-imp- topo	ietf-optical-impairment- topology	[RFCXXXX]
layer0-types	ietf-layer0-types	[I-D.ietf-ccamp-layer0- types]
nw	ietf-network	[RFC8345]
nt	ietf-network-topology	[RFC8345]
tet	ietf-te-topology	[I-D.ietf-teas-yang-te- topo]

Table 1: Prefixes and corresponding YANG modules

[Editor's note: The RFC Editor will replace XXXX with the number assigned to the RFC once this draft becomes an RFC.]

2. Reference Architecture

2.1. Control Plane Architecture

Figure 1 shows the control plane architecture.

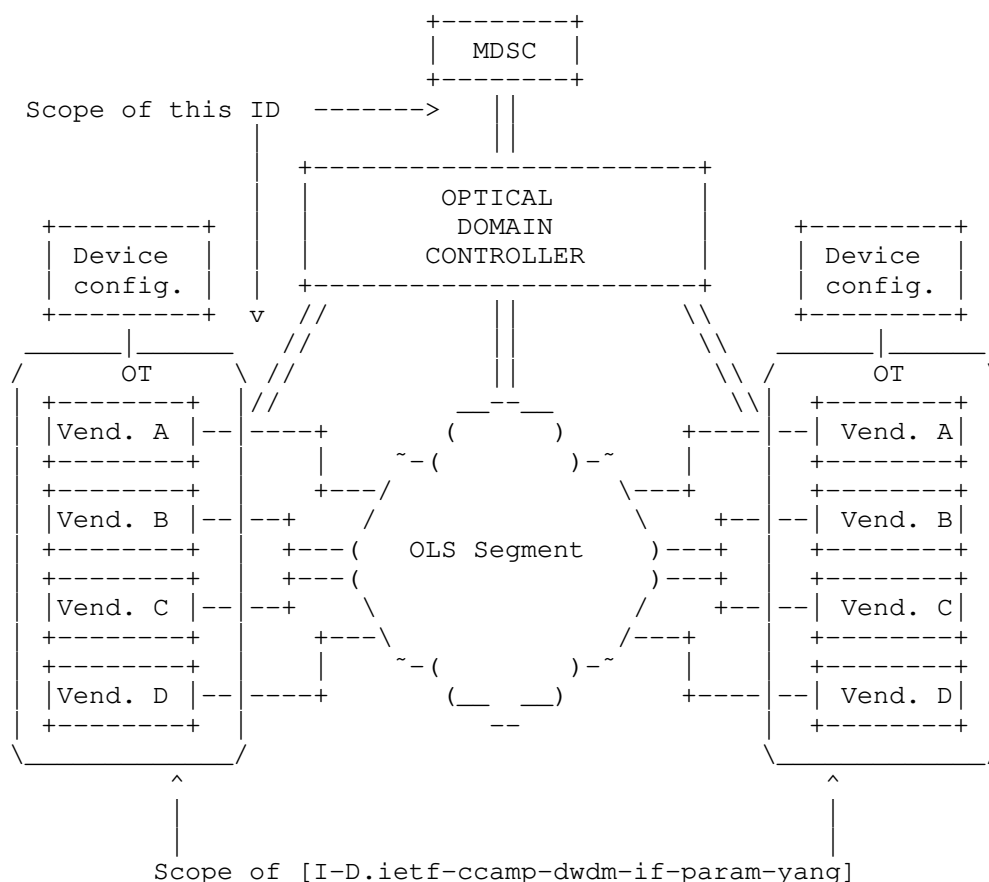


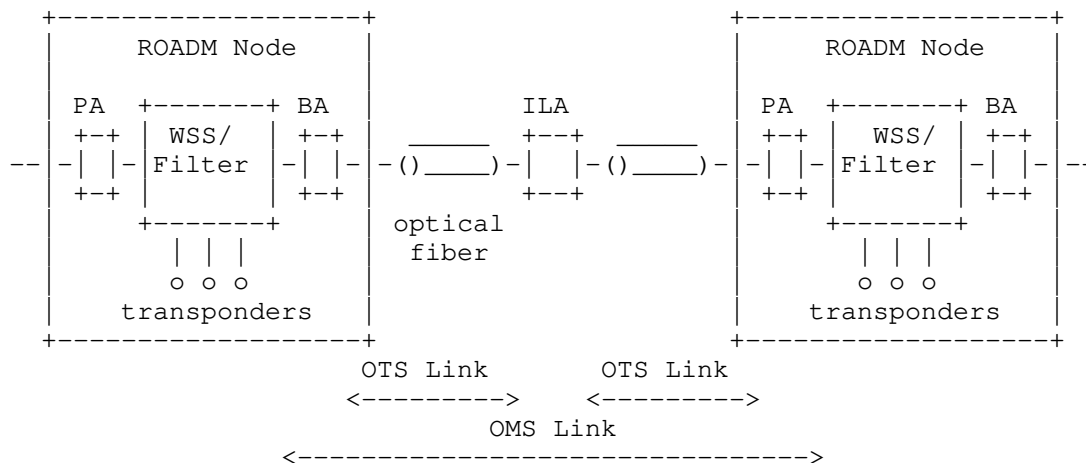
Figure 1: Scope of draft-ietf-ccamp-dwdm-if-param-yang

The models developed in this document is an abstracted Yang model that may be used in the interfaces between the MDSC and the Optical Domain Controller (aka MPI) and between the Optical Domain Controller and the Optical Device (aka SBI) in Figure 1. It is not intended to support a detailed low-level DWDM interface model. DWDM interface model is supported by the models presented in [I-D.ietf-ccamp-dwdm-if-param-yang].

2.2. Transport Data Plane

This section provides the description of the reference optical network architecture and its relevant components to support optical impairment-aware path computation.

Figure 2 shows the reference architecture.



PA: Pre-Amplifier
 BA: Booster Amplifier
 ILA: In-Line Amplifier

Figure 2: Reference Architecture for Optical Transport Network

BA (on the left side ROADM) is the ingress Amplifier and PA (on the right side ROADM) is the egress amplifier for the OMS link shown in Figure 2.

2.3. OMS Media Links

According to [G.872], OMS Media Link represents a media link between two ROADMs. Specifically, it originates at the ROADM's Filter in the source ROADM and terminates at the ROADM's Filter in the destination ROADM.

OTS Media Link represents a media link:

- (i) between ROADM's BA and ILA;
- (ii) between a pair of ILAs;
- (iii) between ILA and ROADM's PA.

OMS Media link can be decomposed in a sequence of OTS links type (i), (ii), and (iii) as discussed above. OMS Media link would give an abstracted view of impairment data (e.g., power, OSNR, etc.) to the network controller.

For the sake of optical impairment evaluation OMS Media link can be also decomposed in a sequence of elements such as BA, fiber section, ILA, concentrated loss and PA.

[Editor's note: text below related to [G.807] needs to be revised! [G.807] is now in publication process.]

2.3.1. Optical Tributary Signal (OTSi)

The OTSi is defined in ITU-T Recommendation G.959.1, section 3.2.4 [G.959.1]. The YANG model defined below assumes that a single OTSi consists of a single modulated optical carrier. This single modulated optical carrier conveys digital information. Characteristics of the OTSi signal are modulation scheme (e.g. QPSK, 8-QAM, 16-QAM, etc.), baud rate (measure of the symbol rate), pulse shaping (e.g. raised cosine - complying with the Nyquist inter symbol interference criterion), etc.

2.3.2. Optical Tributary Signal Group (OTSiG)

The definition of the OTSiG is currently being moved from ITU-T Recommendation G.709 [G.709] to the new draft Recommendation G.807 (still work in progress) [G.807]. The OTSiG is an electrical signal that is carried by one or more OTSi's. The relationship between the OTSiG and the OTSi's is described in ITU-T draft Recommendation G.807, section 10.2 [G.807]. The YANG model below supports both cases: the single OTSi case where the OTSiG contains a single OTSi (see ITU-T draft Recommendation G.807, Figure 10-2) and the multiple OTSi case where the OTSiG consists of more than one OTSi (see ITU-T draft Recommendation G.807, Figure 10-3). From a layer 0 topology YANG model perspective, the OTSiG is a logical construct that associates the OTSi's, which belong to the same OTSiG. The typical application of an OTSiG consisting of more than one OTSi is inverse multiplexing. Constraints exist for the OTSi's belonging to the same OTSiG such as: (i) all OTSi's must be co-routed over the same optical fibers and nodes and (ii) the differential delay between the different OTSi's may not exceed a certain limit. Example: a 400Gbps client signal may be carried by 4 OTSi's where each OTSi carries 100Gbps of client traffic.

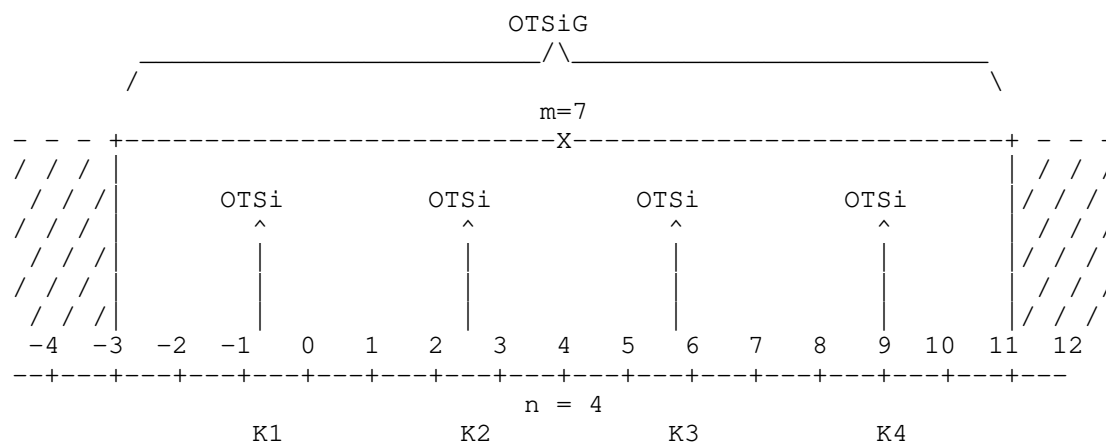


Figure 3: MC Example containing all 4 OTSi signals of an OTSiG

2.3.3. Media Channel (MC)

The definition of the MC is currently being moved from ITU-T Recommendation G.872 [G.872] to the new draft Recommendation G.807 (still work in progress) [G.807]. Section 3.2.2 defines the term MC and section 7.1.2 provides a more detailed description with some examples. The definition of the MC is very generic (see ITU-T draft Recommendation G.807, Figure 7-1). In the YANG model below, the MC is used with the following semantics:

The MC is an end-to-end topological network construct and can be considered as an "optical pipe" with a well-defined frequency slot between one or more optical transmitters each generating an OTSi and the corresponding optical receivers terminating the OTSi's. If the MC carries more than one OTSi, it is assumed that these OTSi's belong to the same OTSiG.

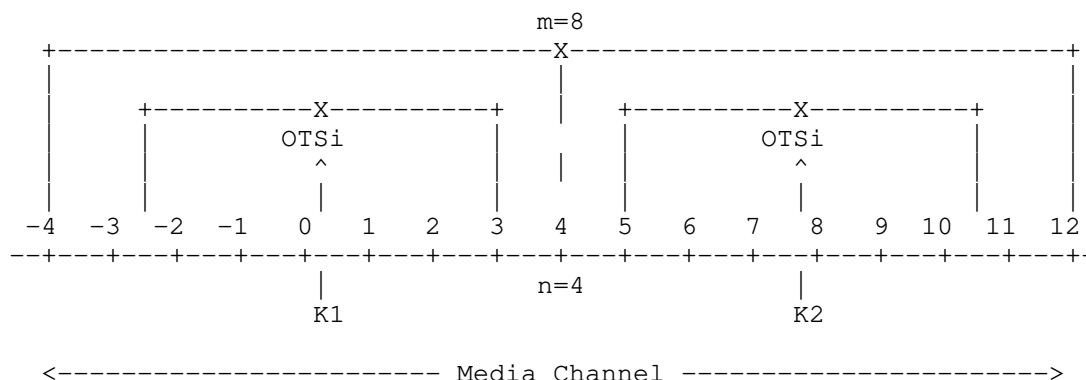


Figure 4: Figure Caption TBA

The frequency slot of the MC is defined by the n value defining the central frequency of the MC and the m value that defines the width of the MC following the flexible grid definition in ITU-T Recommendation G.694.1 [G.694.1]. In this model, the effective frequency slot as defined in ITU-T draft Recommendation G.807 is equal to the frequency slot of this end-to-end MC. It is also assumed that ROADMs can switch MCs. For various reasons (e.g. differential delay), it is preferred to use a single MC for all OTSi's of the same OTSiG. It may however not always be possible to find a single MC for carrying all OTSi's of an OTSiG due to spectrum occupation along the OTSiG path.

2.3.4. Media Channel Group (MCG)

The definition of the MCG is currently work in progress in ITU-T and is defined in section 7.1.3 of the new ITU-T draft Recommendation G.807 (still work in progress) [G.807]. The YANG model below assumes that the MCG is a logical grouping of one or more MCs that are used to carry all OTSi's belonging to the same OTSiG.

The MCG can be considered as an association of MCs without defining a hierarchy where each MC is defined by its (n,m) value pair. An MCG consists of more than one MC when no single MC can be found from source to destination that is wide enough to accommodate all OTSi's (modulated carriers) that belong to the same OTSiG. In such a case the set of OTSi's belonging to a single OTSiG have to be split across 2 or more MCs.

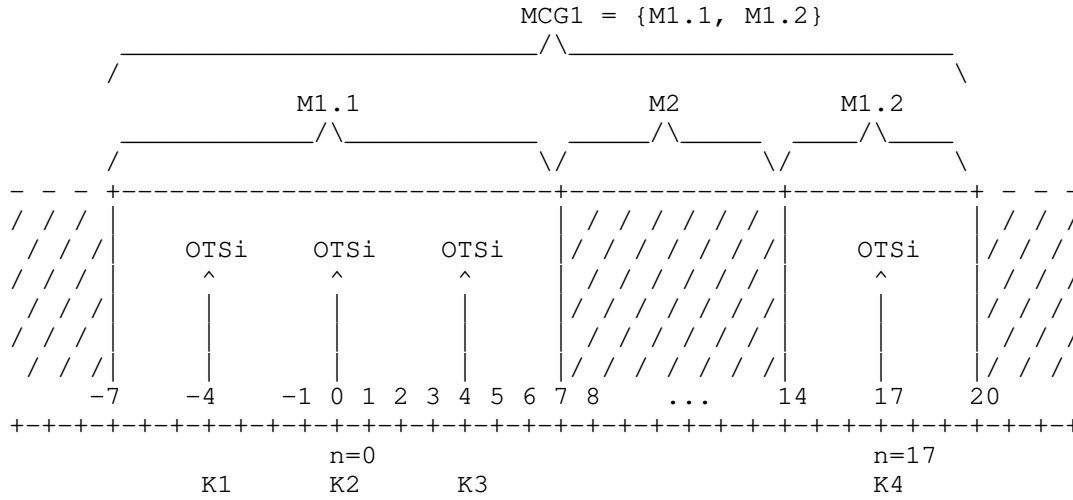


Figure 5: Figure Caption TBA

The MCG is relevant for path computation because all end-to-end MCs belonging to the same MCG have to be co-routed, i.e., have to follow the same path. Additional constraints may exist (e.g. differential delay).

2.4. Amplifiers

Optical amplifiers are in charge of amplifying the optical signal in the optical itself without any electrical conversion. There are three main technologies to build amplifiers: Erbium Doped Fiber Amplifier (EDFA), Raman Fiber Amplifier (RFA), and Semiconductor Optical Amplifier (SOA). Nowadays, most of optical networks uses EDFAs. However, RFA has an attractive feature that it works in any wavelength band with a similar or lower noise figures compared to EDFA. On the other hand, RFAs consumes more power and are more expensive than EDFAs.

Amplifiers can be classified according to their location in the communication link. There are three basic types of amplifiers: ILA, Pre-Amplifier and Booster. ILA is In-Line Amplifier which is a separate node type while Pre-Amplifier and Booster Amplifier are integral elements of ROADM node. From a data modeling perspective, Pre-Amplifier and Booster Amplifier are internal functions of a ROADM node and as such these elements are hidden within ROADM node. In this document, we would avoid internal node details, but attempt to abstract as much as possible.

One modeling consideration of the ROADM internal is to model power parameter through the ROADM, factoring the output power from the Pre-Amplifier minus the ROADM power loss would give the input power to the Booster Amplifier. In other words, $\text{Power_in (@ ROADM Booster)} = \text{Power_out (@ ROADM Pre-Amplifier)} - \text{Power_loss (@ ROADM WSS/Filter)}$.

2.5. Transponders

[Editor's note: The relationship between the transponder and the OTSi in the YANG model described in Section 3 needs further clarification and refinement.]

A Transponder is the element that sends and receives the optical signal from a DWDM network. A transponder can comprise one or more transceivers. A transceiver can be seen as a pair of transmitter and receiver, as defined in ITU-T Recommendation G.698.2 [G.698.2].

A transponder is typically characterized by its data/symbol rate and the maximum distance the signal can travel. Other transponder properties are: carrier frequency for the optical channels, output power per channel, measured input power, modulation scheme, FEC, etc.

From a path computation perspective, the selection of the compatible configuration of the source and the destination transceivers is an important factor for optical signals to traverse through the DWDM network.

The YANG model defines three different approaches to describe the transceiver capabilities (called "modes") that are needed to determine optical signal compatibility:

- o Application Codes as defined in ITU-T Recommendation G.698.2 [G.698.2]
- o Organizational Modes
- o Explicit Modes

2.5.1. Application Codes

An application code represents a standard ITU-T G.698.2 optical interface specification towards the realization of transversely compatible DWDM systems. Two transceivers supporting the same application code and a line system matching the constraints, defined in ITU-T G.698.2, for that application code will interoperate.

2.5.2. Organizational Modes

Organizations like operator groups, industry fora, or equipment vendors can define organizational modes, which will allow these organizations to make use of advanced transceiver capabilities going beyond existing standardized application codes. Such an organizational mode is identified by the organization-identifier attribute defining the scope and an operational-mode that is meaningful within the scope of the organization. Hence, the two attributes must always be considered together. Two transceivers are inter-operable, if they have at least one (organization-identifier, operational-mode) pair in common and if the supported carrier frequency and power attributes have a matching range. This is a necessary condition for path computation in the context of organizational modes. An operational mode is a transceiver preset (a configuration with well-defined parameter values) subsuming several transceiver properties including:

- o FEC type
- o Modulation scheme
- o Encoding (mapping of bit patterns to symbols in the constellation diagram)
- o Baud rate (symbol rate)
- o Carrier bandwidth (typically measured in GHz)

The major reason for these transceiver presets is the fact that the attribute values typically cannot be configured independently and are therefore advertised as supported operational mode capabilities. It is the responsibility of the organization to assign operational modes and to ensure that operational modes are unique and not ambiguous within the scope of the organization.

In addition to the transceiver properties subsumed by the operational mode, optical power and carrier frequency related properties are modeled separately, i.e., outside of the operational mode. This modeling approach allows transponders using different transceiver variants (e.g. optical modules) with slightly different power and/or frequency range properties to interoperate without defining separate operational modes. Different optical modules (pluggables) from different suppliers typically have slightly different input and output power ranges or may have slightly different carrier frequency tuning ranges.

The received channel power and the received total power are two parameters that can be measured by the receiver and can be provided by the transceiver in order to allow a controller to determine the expected performance of the end-to-end service taking into account the optical impairments along the path.

2.5.3. Explicit Modes

The explicit mode allows to encode, explicitly, any subset of parameters e.g., FEC type, Modulation type, etc, to enable a controller entity to check for interoperability by means outside of this draft. It shall be noted that using the explicit encoding does not guarantee interoperability between two transceivers even in case of identical parameter definitions. The explicit mode shall therefore be used with care, but it could be useful when no common Application Codes or Organizational Modes exist or the constraints of common Application Codes or Organizational Modes cannot be met by the line system.

2.5.4. Transponder Capabilities and Current Configuration

The YANG model described in Section 3 defines the optical transceiver properties. They are divided between:

- a. Optical transceiver capabilities, describing how it can be configured
- b. Current transceiver setting, indicating how it is currently configured

The transceiver capabilities are described by the set of modes the transceiver is supporting. Each mode MUST follow only one of the three mode options defined above (choice in the YANG model). The YANG model allows to describe the transceiver capabilities by mixing different modes. A transceiver may support some ITU-T application codes and in addition some organizational or explicit modes.

A transceiver mode description comprises the following properties:

- o Supported transmitter tuning range with min/max nominal carrier frequency [f_tx_min, f_tx_max]
- o Supported transmitter tunability grid, the distance between two adjacent carrier frequencies (in GHz)
- o Supported transmitter power range [p_tx-min, p_tx_max]
- o Supported receiver channel power range [p_rx-min, p_rx_max]
- o Supported maximum total power, rx power for all channels fed into the receiver

These optical transceiver properties are explicitly defined in the model for explicit and organizational modes, while they are implicitly defined for the application codes (see ITU-T G698.2 [G.698.2]).

The set of optical impairment limits, e.g., min OSNR, max PMD, max CD, max PDL, Q-factor limit, are explicitly defined for the explicit

modes while they are defined implicitly for the application codes and organizational modes.

It is possible that the set of parameter values defined for an explicit mode may also be represented in form of an organizational mode or one or more application codes. The "supported-mode" container may provide two different lists with pointers to application codes and organizational modes, respectively.

The current transponder configuration describes the properties of the OTSi transmitted or received by the transceiver attached to a specific transponder port.

Each OTSi has the following three pointer attributes modeled as leafrefs:

- o Pointer to the transponder instance containing the transceiver terminating the OTSi
- o Pointer to the transceiver instance terminating the OTSi
- o Pointer to the currently configured transceiver mode

Additionally, the OTSi is described by the following frequency and optical power related attributes:

- o current carrier-frequency
- o currently transmitted channel power
- o currently received channel power
- o currently received total power

2.6. WSS/Filter

WSS separates the incoming light input spectrally as well as spatially, then chooses the wavelength that is of interest by deflecting it from the original optical path and then couple it to another optical fibre port. WSS/Filter is internal to ROADM. So this document does not model the inside of ROADM.

2.7. Optical Fiber

There are various optical fiber types defined by ITU-T. There are several fiber-level parameters that need to be factored in, such as, fiber-type, length, loss coefficient, pmd, connectors (in/out).

ITU-T G.652 defines Standard Singlemode Fiber; G.654 Cutoff Shifted Fiber; G.655 Non-Zero Dispersion Shifted Fiber; G.656 Non-Zero Dispersion for Wideband Optical Transport; G.657 Bend-Insensitive Fiber. There may be other fiber-types that need to be considered.

2.8. ROADM Node Architectures

The ROADM node architectures in today's dense wavelength division multiplexing (DWDM) networks can be categorized as follows:

- o Integrated ROADM architecture with integrated optical transponders
- o Integrated ROADM architecture with integrated optical transponders and single channel add/drop ports for remote optical transponders
- o Disaggregated ROADM architecture where the ROADM is subdivided into degree, add/drop, and optical transponder subsystems handled as separate network elements

The TE topology YANG model augmentations including optical impairments for DWDM networks defined below intend to cover all the 3 categories of ROADM architectures listed above. In the case of a disaggregated ROADM architecture, it is assumed that optical domain controller already performs some form of abstraction and presents the TE-node representing the disaggregated ROADM in the same way as an integrated ROADM with integrated optical transponders if the optical transponder subsystems and the add/drop subsystems are collocated (short fiber links not imposing significant optical impairments).

The different ROADM architectures are briefly described and illustrated in the following subsections.

[Editor's note: The modeling of remote optical transponders located for example in the client device with a single channel link between the OT and the add/drop port of the ROADM requires further investigations and will be addressed in a future revision of this document.]

2.8.1. Integrated ROADM Architecture with Integrated Optical Transponders

Figure 2 and Figure 6 below show the typical architecture of an integrated ROADM node, which contains the optical transponders as an integral part of the ROADM node. Such an integrated ROADM node provides DWDM interfaces as external interfaces for interconnecting the device with its neighboring ROADMs (see OTS link above). The number of these interfaces denote also the degree of the ROADM. A degree 3 ROADM for example has 3 DWDM links that interconnect the ROADM node with 3 neighboring ROADMs. Additionally, the ROADM provides client interfaces for interconnecting the ROADM with client devices such as IP routers or Ethernet switches. These client interfaces are the client interfaces of the integrated optical transponders.

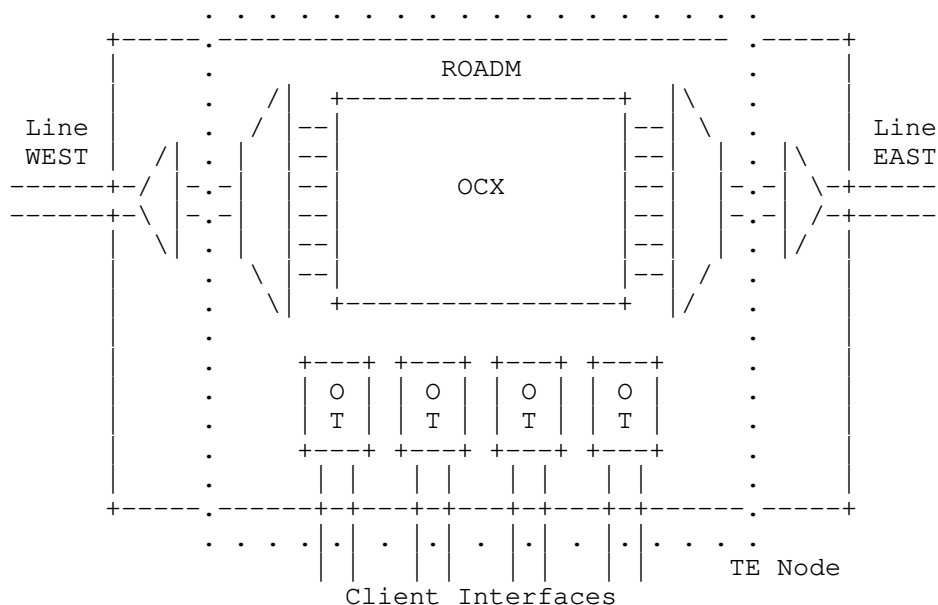


Figure 6: ROADM Architectiure with Integrated Transponders

2.8.2. Integrated ROADMs with Integrated Optical Transponders and Single Channel Add/Drop Interfaces for Remote Optical Transponders

Figure 7 below shows the extreme case where all optical transponders are not integral parts of the ROADM but are separate devices that are interconnected with add/drop ports of the ROADM. If the optical transponders and the ROADM are collocated and if short single channel fiber links are used to interconnect the optical transponders with an add/drop port of the ROADM, the optical domain controller may present these optical transponders in the same way as integrated optical transponders. If, however, the optical impairments of the single channel fiber link between the optical transponder and the add/drop port of the ROADM cannot be neglected, it is necessary to represent the fiber link with its optical impairments in the topology model. This also implies that the optical transponders belong to a separate TE node.

[Editor's note: this requires further study].

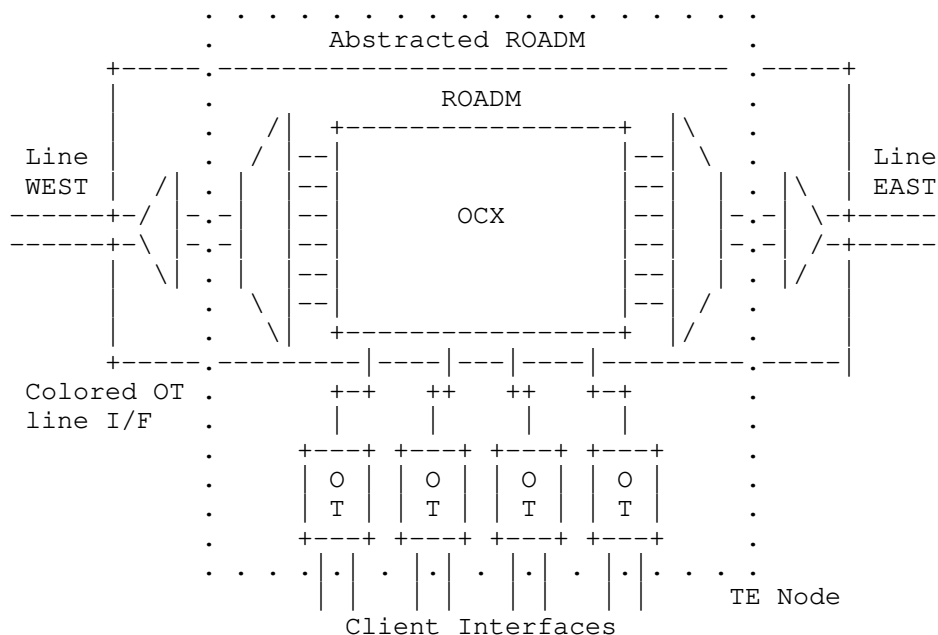


Figure 7: ROADM Architectiure with Remote Transponders

2.8.3. Disaggregated ROADMs Subdivided into Degree, Add/Drop, and Optical Transponder Subsystems

Recently, some DWDM network operators started demanding ROADM subsystems from their vendors. An example is the OpenROADM project where multiple operators and vendors are developing related YANG models. The subsystems of a disaggregated ROADM are: single degree subsystems, add/drop subsystems and optical transponder subsystems. These subsystems separate network elements and each network element provides a separate management and control interface. The subsystems are typically interconnected using short fiber patch cables and form together a disaggregated ROADM node. This disaggregated ROADM architecture is depicted in Figure 8 below.

As this document defines TE topology YANG model augmentations [I-D.ietf-teas-yang-te-topo] for the TE topology YANG model provided at the north-bound interface of the optical domain controller, it is a valid assumption that the optical domain controller abstracts the subsystems of a disaggregated ROADM and presents the disaggregated ROADM in the same way as an integrated ROADM hiding all the interconnects that are not relevant from an external TE topology view.

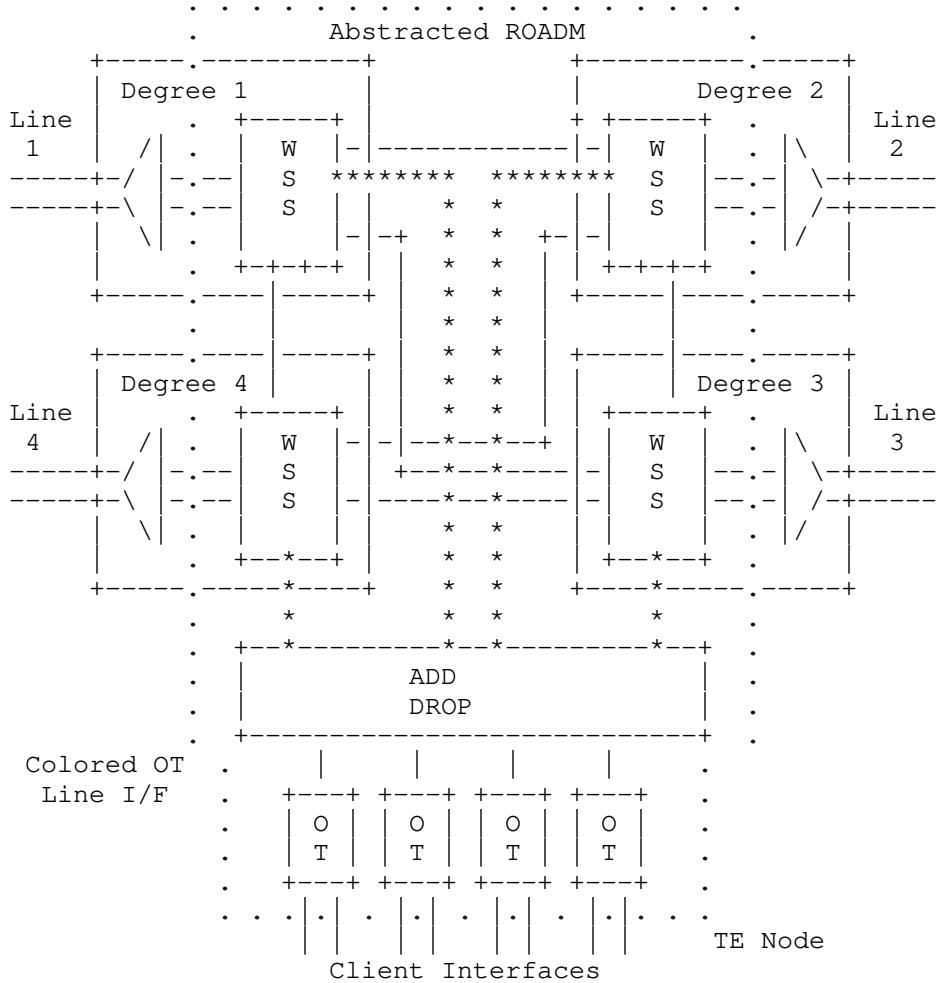


Figure 8: Disaggregated ROADM Architecture with Remote Transponders

2.8.4. Optical Impairments Imposed by ROADM Nodes

When an optical OTSi signal traverses a ROADM node, optical impairments are imposed on the signal by various passive or active optical components inside the ROADM node. Examples of optical impairments are:

- o Chromatic dispersion (CD)
- o Polarization mode dispersion (PMD)
- o Polarization dependent loss (PDL)

- o Optical amplifier noise due to amplified spontaneous emission (ASE)
- o In-band cross-talk
- o Filtering effects (for further study)

A ROADM node contains a wavelength selective photonic switching function (WSS) that is capable of switching media channels (MCs) described in Section 2.3.4. These MCs can be established between two line ports of the ROADM or between a line port and an Add/Drop port of the ROADM. The Add/Drop ports of a ROADM are those ports to which optical transponders are connected. Typically, this is a single channel signal (single OTSi), but principally this could also be a group of OTSi signals. The optical impairments associated with these MCs are different and the paths of the MCs inside the ROADM node can be categorized as follows:

- o Express path: MC path between two line ports of the ROADM (unidirectional)
- o Add Path: MC path from an Add port to a line port of the ROADM
- o Drop path: MC path from a line port to a Drop port of the ROADM

Due to the symmetrical architecture of the ROADM node, the optical impairments associated with the express path are typically the same between any two line ports of the ROADM whereas the optical impairments for the add and drop paths are different and therefore have to be modeled separately.

The optical impairments associated with each of the three types of ROADM-node-internal paths described above are modeled as optical impairment parameter sets. These parameter sets are modeled as an augmentation of the te-node-attributes defined in [I-D.ietf-teas-yang-te-topo]. The te-node-attributes are augmented with a list of roadm-path-impairments for the three ROADM path types distinguished by the impairment-type. Each roadm-path-impairments list entry contains the set of optical impairment parameters for one of the three path types indicated by the impairment-type. For the optical feasibility calculation based on the optical impairments, it is necessary to know whether the optical power of the OTSi stays within a certain power window. This is reflected by some optical power related parameters such as loss parameters or power parameters, which are included in the optical impairment parameter sets (see tree view in Section 3).

[I-D.ietf-teas-yang-te-topo] defines a connectivity matrix and a local link connectivity list for the TE node. The connectivity matrix describes the connectivity for the express paths between the

different lines of the ROADM and the local link connectivity list describes the connectivity for the Add and Drop paths of the ROADM. These matrices are augmented with a new `roadm-path-impairment` matrix element, an `add-path-impairment`, and `drop-path-impairment` matrix element, respectively, which are defined as a pointer to the corresponding entry in the `roadm-path-impairments` list (`leaf-ref`).

[Editor's note: this section is still work in progress]

3. YANG Model (Tree Structure)

```

module: ietf-optical-impairment-topology
augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
  +--rw optical-impairment-topology!
augment /nw:networks/nw:network/nt:link/tet:te
  /tet:te-link-attributes:
    +--ro OMS-attributes
      +--ro generalized-snr?                10-types-ext:snr
      +--ro equalization-mode                identityref
      +--ro (power-param)?
        | +--:(channel-power)
        | | +--ro nominal-channel-power?    decimal64
        | +--:(power-spectral-density)
        | | +--ro nominal-power-spectral-density? decimal64
      +--ro media-channel-group* [i]
        | +--ro i                          int16
        | +--ro media-channels* [flexi-n]
        | | +--ro flexi-n                  10-types:flexi-n
        | | +--ro flexi-m?                  10-types:flexi-m
        | | +--ro OTSiG-ref?                leafref
        | | +--ro OTSi-ref?                leafref
      +--ro OMS-elements* [elt-index]
        | +--ro elt-index                  uint16
        | +--ro uid?                      string
        | +--ro type                      identityref
        | +--ro element
        | | +--ro (element)?
        | | | +--:(amplifier)
        | | | | +--ro amplifier
        | | | | | +--ro type-variety        string
        | | | | | +--ro operational
        | | | | | | +--ro actual-gain
        | | | | | | | decimal64
        | | | | | | +--ro tilt-target
        | | | | | | | decimal64
        | | | | | | +--ro out-voa
        | | | | | | | decimal64
        | | | | | | +--ro in-voa

```



```

    |
    |         decimal64
    +--ro (power-param)?
    |   +--:(channel-power)
    |   |   +--ro nominal-channel-power?
    |   |   |       decimal64
    |   +--:(power-spectral-density)
    |   |   +--ro nominal-power-spectral-density?
    |   |   |       decimal64
    +--:(fiber)
    |   +--ro fiber
    |   |   +--ro type-variety      string
    |   |   +--ro length            decimal64
    |   |   +--ro loss-coef         decimal64
    |   |   +--ro total-loss        decimal64
    |   |   +--ro pmd?              decimal64
    |   |   +--ro conn-in?          decimal64
    |   |   +--ro conn-out?         decimal64
    +--:(concentratedloss)
    |   +--ro concentratedloss
    |   |   +--ro loss?             decimal64
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point:
    +--ro otsi-group* [otsi-group-id]
    |   +--ro otsi-group-id      int16
    |   +--ro otsi* [otsi-carrier-id]
    |   |   +--ro otsi-carrier-id      int16
    |   |   +--ro transponder-ref?     leafref
    |   |   +--ro transceiver-ref?     leafref
    |   |   +--ro configured-mode?     leafref
    |   |   +--ro OTSi-carrier-frequency? frequency-thz
    |   |   +--ro tx-channel-power?    dbm-t
    |   |   +--ro rx-channel-power?    dbm-t
    |   |   +--ro rx-total-power?      dbm-t
    +--ro transponder* [transponder-id]
    |   +--ro transponder-id      uint32
    +--ro transceiver* [transceiver-id]
    |   +--ro transceiver-id      uint32
    |   +--ro supported-modes
    |   |   +--ro supported-mode* [mode-id]
    |   |   |   +--ro mode-id          string
    |   |   +--ro (mode)
    |   |   |   +--:(G.698.2)
    |   |   |   |   +--ro standard-mode?      standard-mode
    |   |   +--:(organizational-mode)
    |   |   |   +--ro organizational-mode
    |   |   |   |   +--ro operational-mode?
    |   |   |   |   |   operational-mode
    |   |   +--ro organization-identifier?

```

```

|         organization-identifier
+--ro min-central-frequency?
|         frequency-thz
+--ro max-central-frequency?
|         frequency-thz
+--ro minimum-channel-spacing?
|         frequency-ghz
+--ro tx-channel-power-min?          dbm-t
+--ro tx-channel-power-max?          dbm-t
+--ro rx-channel-power-min?          dbm-t
+--ro rx-channel-power-max?          dbm-t
+--ro rx-total-power-max?            dbm-t
+--:(explicit-mode)
+--ro explicit-mode
+--ro supported-modes
|   +--ro supported-application-codes*
|   |   -> ../../mode-id
|   +--ro supported-organizational-modes*
|   |   -> ../../mode-id
+--ro line-coding-bitrate?
|   identityref
+--ro max-polarization-mode-dispersion?
|   decimal64
+--ro max-chromatic-dispersion?
|   decimal64
+--ro chromatic-and-polarization-dispersion-penalty* []
|   +--ro chromatic-dispersion
|   |   decimal64
|   +--ro polarization-mode-dispersion
|   |   decimal64
|   +--ro penalty
|   |   decimal64
+--ro max-diff-group-delay?
|   int32
+--ro max-polarization-dependent-loss?
|   decimal64
+--ro available-modulation-type?
|   identityref
+--ro OTSi-carrier-bandwidth?
|   frequency-ghz
+--ro min-OSNR?
|   snr
+--ro min-Q-factor?
|   int32
+--ro available-baud-rate?
|   uint32
+--ro available-FEC-type?
|   identityref

```

```

        +---ro FEC-code-rate?
        |   decimal64
        +---ro FEC-threshold?
        |   decimal64
        +---ro min-central-frequency?
        |   frequency-thz
        +---ro max-central-frequency?
        |   frequency-thz
        +---ro minimum-channel-spacing?
        |   frequency-ghz
        +---ro tx-channel-power-min?
        |   dbm-t
        +---ro tx-channel-power-max?
        |   dbm-t
        +---ro rx-channel-power-min?
        |   dbm-t
        +---ro rx-channel-power-max?
        |   dbm-t
        +---ro rx-total-power-max?
        |   dbm-t
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point:
    +---ro sliceable-transponder-list* [carrier-id]
    +---ro carrier-id      uint32
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:te-node-attributes:
    +---ro roadm-path-impairments* [roadm-path-impairments-id]
    +---ro roadm-path-impairments-id      uint32
    +---ro (impairment-type)?
    +---:(roadm-express-path)
    |   +---ro roadm-express-path
    |   |   +---ro roadm-pmd?          decimal64
    |   |   +---ro roadm-cd?          decimal64
    |   |   +---ro roadm-pdl?         decimal64
    |   |   +---ro roadm-inband-crosstalk? decimal64
    |   |   +---ro roadm-maxloss?     decimal64
    +---:(roadm-add-path)
    |   +---ro roadm-add-path
    |   |   +---ro roadm-pmd?          decimal64
    |   |   +---ro roadm-cd?          decimal64
    |   |   +---ro roadm-pdl?         decimal64
    |   |   +---ro roadm-inband-crosstalk? decimal64
    |   |   +---ro roadm-maxloss?     decimal64
    |   |   +---ro roadm-pmax?        decimal64
    |   |   +---ro roadm-osnr?        10-types-ext:snr
    |   |   +---ro roadm-noise-figure? decimal64
    +---:(roadm-drop-path)
    |   +---ro roadm-drop-path

```

```

        +--ro roadm-pmd?                decimal64
        +--ro roadm-cd?                 decimal64
        +--ro roadm-pdl?                decimal64
        +--ro roadm-inband-crosstalk?   decimal64
        +--ro roadm-maxloss?            decimal64
        +--ro roadm-minloss?            decimal64
        +--ro roadm-typlloss?           decimal64
        +--ro roadm-pmin?               decimal64
        +--ro roadm-pmax?               decimal64
        +--ro roadm-ptyp?               decimal64
        +--ro roadm-osnr?               10-types-ext:snr
        +--ro roadm-noise-figure?       decimal64
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:information-source-entry/tet:connectivity-matrices:
    +--ro roadm-path-impairments? leafref
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:information-source-entry/tet:connectivity-matrices
    /tet:connectivity-matrix:
    +--ro roadm-path-impairments? leafref
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices:
    +--ro roadm-path-impairments?
    -> ../../roadm-path-impairments/roadm-path-impairments-id
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
    /tet:connectivity-matrix:
    +--ro roadm-path-impairments? leafref
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point
    /tet:local-link-connectivities:
    +--ro add-path-impairments? leafref
    +--ro drop-path-impairments? leafref
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point
    /tet:local-link-connectivities
    /tet:local-link-connectivity:
    +--ro add-path-impairments? leafref
    +--ro drop-path-impairments? leafref

```

4. Optical Impairment Topology YANG Model

[Editor's note: YANG code below may have to be updated before submission!]

<CODE BEGINS>

```

module ietf-optical-impairment-topology {
  yang-version 1.1;

```

```
namespace "urn:ietf:params:xml"
+ ":ns:yang:ietf-optical-impairment-topology";

prefix "optical-imp-topo";

import ietf-network {
  prefix "nw";
}

import ietf-network-topology {
  prefix "nt";
}

import ietf-te-topology {
  prefix "tet";
}

import ietf-layer0-types {
  prefix "l0-types";
}

import ietf-layer0-types-ext {
  prefix "l0-types-ext";
}

organization
  "IETF CCAMP Working Group";

contact
  "Editor:   Young Lee <younglee.tx@gmail.com>
   Editor:   Haomian Zheng <zhenghaomian@huawei.com>
   Editor:   Nicola Sambo <nicosambo@gmail.com>
   Editor:   Victor Lopez <victor.lopezalvarez@telefonica.com>
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   Editor:   Sergio Belotti <Sergio.belotti@nokia.com>
   Editor:   Griseri Enrico <enrico.griseri@nokia.com>
   Editor:   Gert Grammel <ggrammel@juniper.net>";

description
  "This module contains a collection of YANG definitions for
   impairment-aware optical networks."
```

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This version of this YANG module is part of RFC XXXX; see the RFC itself for full legal notices.";

```
// RFC Ed.: replace XXXX with actual RFC number and remove
// this note
```

```
// replace the revision date with the module publication date
// the format is (year-month-day)
```

```
revision 2020-10-13 {
  description
    "Initial Version";
  reference
    "RFC XXXX: A Yang Data Model for Impairment-aware
    Optical Networks";
}
```

```
// identity
```

```
identity modulation {
  description "base identity for modulation type";
}
```

```
identity QPSK {
  base modulation;
  description
    "QPSK (Quadrature Phase Shift Keying) modulation";
}
```

```
identity DP-QPSK {
  base modulation;
  description
    "DP-QPSK (Dual Polarization Quadrature
    Phase Shift Keying) modulation";
}
```

```
identity QAM8 {
  base modulation;
  description
```

```
    "8QAM (8-State Quadrature Amplitude Modulation) modulation";
  }
  identity QAM16 {
    base modulation;
    description
      "QAM16 (Quadrature Amplitude Modulation)";
  }
  identity DP-QAM8 {
    base modulation;
    description
      "DP-QAM8 (Dual Polarization Quadrature Amplitude Modulation)";
  }
  identity DC-DP-QAM8 {
    base modulation;
    description
      "DC DP-QAM8 (Dual Polarization Quadrature Amplitude Modulation)";
  }
  identity DP-QAM16 {
    base modulation;
    description
      "DP-QAM16 (Dual Polarization Quadrature Amplitude Modulation)";
  }
  identity DC-DP-QAM16 {
    base modulation;
    description
      "DC DP-QAM16 (Dual Polarization Quadrature
      Amplitude Modulation)";
  }

  identity FEC {
    description
      "Enumeration that defines the type of
      Forward Error Correction";
  }
  identity reed-solomon {
    base FEC;
    description
      "Reed-Solomon error correction";
  }
  identity hamming-code {
    base FEC;
    description
      "Hamming Code error correction";
  }
  identity golay {
    base FEC;
    description "Golay error correction";
  }
}
```

```
// typedef

typedef fiber-type {
  type enumeration {
    enum G.652 {
      description "G.652 Standard Singlemode Fiber";
    }
    enum G.654 {
      description "G.654 Cutoff Shifted Fiber";
    }
    enum G.653 {
      description "G.653 Dispersion Shifted Fiber";
    }
    enum G.655 {
      description "G.655 Non-Zero Dispersion Shifted Fiber";
    }
    enum G.656 {
      description "G.656 Non-Zero Dispersion for Wideband
        Optical Transport";
    }
    enum G.657 {
      description "G.657 Bend-Insensitive Fiber";
    }
  }
  description
    "ITU-T based fiber-types";
}

// grouping

grouping transponder-attributes {
  description "Configuration of an optical transponder";

  leaf-list available-modulation-types {
    type identityref {
      base modulation;
    }
    config false;
  }
  description
    "List of modulation types the OTSi supports";
}

leaf configured-modulation-type {
  type identityref {
    base modulation;
  }
  config false;
  description
```



```
    "Currently configured OTSi modulation type";
}

leaf-list available-baud-rates {
  type uint32;
  units Bd;
  config false;
  description
    "list of available baud-rates.
    Baud-rate is the unit for
    symbol rate or modulation rate
    in symbols per second or
    pulses per second.
    It is the number of distinct symbol
    changes (signal events) made to the
    transmission medium
    per second in a digitally
    modulated signal or a line code";
}

leaf configured-baud-rate {
  type uint32;
  units Bd;
  config false;
  description "configured baud-rate";
}

leaf-list available-FEC-types {
  type identityref {
    base FEC;
  }
  config false;
  description "List determining all the available FEC";
}

leaf configured-FEC-type {
  type identityref {
    base FEC;
  }
  config false;
  description
    "FEC type configured for the transponder";
}

leaf FEC-code-rate {
  type decimal64 {
    fraction-digits 8;
    range "0..max";
  }
}
```

```
    }
    config false;
    description "FEC-code-rate";
  }

  leaf FEC-threshold {
    type decimal64 {
      fraction-digits 8;
      range "0..max";
    }
    config false;
    description
      "Threshold on the BER, for which FEC
       is able to correct errors";
  }
}

grouping sliceable-transponder-attributes {
  description
    "Configuration of a sliceable transponder.";
  list sliceable-transponder-list {
    key "carrier-id";
    config false;
    description "List of carriers";
    leaf carrier-id {
      type uint32;
      config false;
      description "Identifier of the carrier";
    }
  }
}

grouping optical-fiber-data {
  description
    "optical link (fiber) attributes with impairment data";
  leaf fiber-type {
    type fiber-type;
    config false;
    description "fiber-type";
  }

  leaf span-length {
    type decimal64 {
      fraction-digits 2;
    }
    units "km";
    config false;
  }
}
```

```
    description "the lenght of the fiber span in km";
  }

  leaf input-power {
    type decimal64 {
      fraction-digits 2;
    }
    units "dBm";
    config false;
    description
      "Average input power level estimated at the receiver
       of the link";
  }

  leaf output-power {
    type decimal64 {
      fraction-digits 2;
    }
    units "dBm";
    description
      "Mean launched power at the transmitter of the link";
  }

  leaf pmd {
    type decimal64 {
      fraction-digits 8;
      range "0..max";
    }
    units "ps/(km)^0.5";
    config false;
    description
      "Polarization Mode Dispersion";
  }

  leaf cd {
    type decimal64 {
      fraction-digits 5;
    }
    units "ps/nm/km";
    config false;
    description
      "Cromatic Dispersion";
  }

  leaf osnr {
    type 10-types-ext:snr;
    config false;
    description
```

```
    "Optical Signal-to-Noise Ratio (OSNR) estimated
      at the receiver";
  }

  leaf sigma {
    type decimal64 {
      fraction-digits 5;
    }
    units "dB";
    config false;
    description
      "sigma in the Gaussian Noise Model";
  }
}

grouping optical-channel-data {
  description
    "optical impairment data per channel/wavelength";
  leaf bit-rate {
    type decimal64 {
      fraction-digits 8;
      range "0..max";
    }
    units "Gbit/s";
    config false;
    description
      "Gross bit rate";
  }

  leaf BER {
    type decimal64 {
      fraction-digits 18;
      range "0..max";
    }
    config false;
    description
      "BER (Bit Error Rate)";
  }

  leaf ch-input-power {
    type decimal64 {
      fraction-digits 2;
    }
    units "dBm";
    config false;
    description
      "Per channel average input power level
        estimated at the receiver of the link";
  }
}
```

```
    }

    leaf ch-pmd {
      type decimal64 {
        fraction-digits 8;
        range "0..max";
      }
      units "ps/(km)^0.5";
      config false;
      description
        "per channel Polarization Mode Dispersion";
    }

    leaf ch-cd {
      type decimal64 {
        fraction-digits 5;
      }
      units "ps/nm/km";
      config false;
      description
        "per channel Chromatic Dispersion";
    }

    leaf ch-osnr {
      type 10-types-ext:snr;
      config false;
      description
        "per channel Optical Signal-to-Noise Ratio
        (OSNR) estimated at the receiver";
    }

    leaf q-factor {
      type decimal64 {
        fraction-digits 5;
      }
      units "dB";
      config false;
      description
        "q-factor estimated at the receiver";
    }
  }

  /*
  * Identities
  */
  identity type-element {
    description
      "Base identity for element type";
  }
```

```
    }

    identity Fiber {
      base type-element;
      description
        "Fiber element";
    }

    identity Roadm {
      base type-element;
      description
        "Roadm element";
    }

    identity Edfa {
      base type-element;
      description
        "Edfa element";
    }

    identity Concentratedloss {
      base type-element;
      description
        "Concentratedloss element";
    }

    identity type-power-mode {
      description
        "power equalization mode used within the
        OMS and its elements";
    }

    identity power-spectral-density {
      base type-power-mode;
      description
        "all elements must use power spectral density (W/Hz)";
    }

    identity channel-power {
      base type-power-mode;
      description
        "all elements must use power (dBm)";
    }

    /*
     * Groupings
     */
    grouping amplifier-params {
```

```
description "describes parameters for an amplifier";
container amplifier{
description "amplifier type, operational parameters
            are described";
  leaf type-variety {
    type string ;
    mandatory true ;
    description
      "String identifier of amplifier type referencing
       a specification in a separate equipment catalog";
  }
  container operational {
    description "amplifier operationnal parameters";
    leaf actual-gain {
      type decimal64 {
        fraction-digits 2;
      }
      units dB ;
      mandatory true ;
      description "..";
    }
    leaf tilt-target {
      type decimal64 {
        fraction-digits 2;
      }
      mandatory true ;
      description "..";
    }
    leaf out-voa {
      type decimal64 {
        fraction-digits 2;
      }
      units dB;
      mandatory true;
      description "..";
    }
    leaf in-voa {
      type decimal64 {
        fraction-digits 2;
      }
      units dB;
      mandatory true;
      description "..";
    }
    uses power-param;
  }
}
```

```
grouping fiber-params {
  description
    "String identifier of fiber type referencing a
    specification in a separate equipment catalog";
  container fiber {
    description "fiber characteristics";
    leaf type-variety {
      type string ;
    }
    mandatory true ;
    description "fiber type";
  }
  leaf length {
    type decimal64 {
      fraction-digits 2;
    }
    units km;
    mandatory true ;
    description "length of fiber";
  }
  leaf loss-coef {
    type decimal64 {
      fraction-digits 2;
    }
    units dB/km;
    mandatory true ;
    description "loss coefficient of the fiber";
  }
  leaf total-loss {
    type decimal64 {
      fraction-digits 2;
    }
    units dB;
    mandatory true ;
    description
      "includes all losses: fiber loss and conn-in and
      conn-out losses";
  }
  leaf pmd{
    type decimal64 {
      fraction-digits 2;
    }
    units sqrt(ps);
    description "pmd of the fiber";
  }
  leaf conn-in{
    type decimal64 {
      fraction-digits 2;
    }
  }
}
```



```
        units dB;
    description "connector-in";
    }
    leaf conn-out{
        type decimal64 {
            fraction-digits 2;
        }
        units dB;
    description "connector-out";
    }
}
}
```

```
grouping roadm-express-path {
    description "roadm express path optical impairments";

    container roadm-express-path {
        description "roadm parameters per express path";

        leaf roadm-pmd {
            type decimal64 {
                fraction-digits 8;
                range "0..max";
            }
            units "ps/(km)^0.5";
            description
                "Polarization Mode Dispersion";
        }
        leaf roadm-cd {
            type decimal64 {
                fraction-digits 5;
            }
            units "ps/nm";
            description "Chromatic Dispersion";
        }
        leaf roadm-pdl {
            type decimal64 {
                fraction-digits 2;
            }
            units dB ;
            description "Polarization dependent loss";
        }
        leaf roadm-inband-crosstalk {
            type decimal64 {
                fraction-digits 2;
            }
        }
    }
}
```

```
        units dB;
        description
            "In-band crosstalk, or coherent crosstalk, can occur in
            components that can have multiple same wavelength inputs
            with the inputs either routed to different output ports,
            or all but 1 blocked";
    }
    leaf roadm-maxloss {
        type decimal64 {
            fraction-digits 2;
        }
        units dB;
        description
            "This is the maximum expected add path loss from the
            ROADM ingress to the ROADM egress
            assuming no additional add path loss is added";
    }
}

grouping roadm-add-path {
    description "roadm add block path optical impairments";

    container roadm-add-path {
        description "roadm optical impairment parameters
        per add path";

        leaf roadm-pmd {
            type decimal64 {
                fraction-digits 8;
                range "0..max";
            }
            units "ps";
            description
                "Polarization Mode Dispersion";
        }
        leaf roadm-cd {
            type decimal64 {
                fraction-digits 5;
            }
            units "ps/nm";
            description "Cromatic Dispersion";
        }
        leaf roadm-pdl {
            type decimal64 {
                fraction-digits 2;
            }
            units dB ;
        }
    }
}
```

```
    description "Polarization dependent loss";
  }
  leaf roadm-inband-crosstalk {
    type decimal64 {
      fraction-digits 2;
    }
    units dB ;
    description
      "In-band crosstalk, or coherent crosstalk,
       can occur in components that can have multiple same
       wavelength inputs, with the inputs either
       routed to different output ports,
       or all but 1 blocked.
       In the case of add path it is the total
       of the add block
       + egress WSS crosstalk contributions.";
  }
  leaf roadm-maxloss {
    type decimal64 {
      fraction-digits 2;
    }
    units dB ;
    description
      "This is the maximum expected add path loss from
       the add/drop port input to the ROADM egress,
       assuming no additional add path loss is added.
       This is used to establish the minimum required
       transponder output power required
       to hit the ROADM egress target power
       levels and preventing
       to hit the WSS attenuation limits.
       If the add path contains an internal amplifier
       this loss value should be based
       on worst case expected amplifier gain due to
       ripple or gain uncertainty";
  }
  leaf roadm-pmax {
    type decimal64 {
      fraction-digits 2;
    }
    units dBm ;
    description
      "This is the maximum (per carrier) power level
       permitted at the add block input ports,
       that can be handled by the ROADM node.
       This may reflect either add amplifier power
       constraints or WSS adjustment limits.
       Higher power transponders would need to have
```

```
        their launch power reduced
        to this value or lower";
    }
    leaf roadm-osnr {
        type 10-types-ext:snr;
        description
            "Optical Signal-to-Noise Ratio (OSNR).
            If the add path contains the ability to adjust the
            carrier power levels into an add path amplifier
            (if present) to a target value,
            this reflects the OSNR contribution of the
            add amplifier assuming this target value is obtained.
            The worst case OSNR based on the input power and
            NF calculation method, and this value, should be used
            (if both are defined).";
    }
    leaf roadm-noise-figure {
        type decimal64 {
            fraction-digits 5;
        }
        units "dB";
        description
            "Noise Figure. If the add path contains an amplifier,
            this is the noise figure of that amplifier inferred
            to the add port.
            This permits add path OSNR calculation based
            on the input power levels to the add block
            without knowing the ROADM path losses to
            the add amplifier.";
    }
}

grouping roadm-drop-path {
    description "roadm drop block path optical impairments";

    container roadm-drop-path {
        description "roadm optical impairment parameters
        per drop path";

        leaf roadm-pmd {
            type decimal64 {
                fraction-digits 8;
                range "0..max";
            }
            units "ps/(km)^0.5";
            description
                "Polarization Mode Dispersion";
        }
    }
}
```

```
}
leaf roadm-cd {
  type decimal64 {
    fraction-digits 5;
  }
  units "ps/nm";
  description "Chromatic Dispersion";
}
leaf roadm-pdl {
  type decimal64 {
    fraction-digits 2;
  }
  units dB ;
  description "Polarization dependent loss";
}
leaf roadm-inband-crosstalk {
  type decimal64 {
    fraction-digits 2;
  }
  units dB;
  description
    "In-band crosstalk, or coherent crosstalk, can occur in
    components that can have multiple same wavelength
    inputs, with the inputs either routed to different
    output ports, or all but 1 blocked.
    In the case of drop path it is the total
    of the ingress
    to drop e.g. WSS and drop block crosstalk
    contributions.";
}
leaf roadm-maxloss {
  type decimal64 {
    fraction-digits 2;
  }
  units dB ;
  description
    "The net loss from the ROADM input, to the output
    of the drop block.
    If ROADM ingress to drop path includes an amplifier,
    the amplifier gain reduces the net loss.
    This is before any additional drop path attenuation
    that may be required
    due to drop amplifier power constraints.
    The max value correspond to worst case expected loss,
    including amplifier gain ripple or uncertainty.
    It is the maximum output power of the drop
    amplifier.";
}
```

```
leaf roadm-minloss {
  type decimal64 {
    fraction-digits 2;
  }
  units dB ;
  description
    "The net loss from the ROADM input, to the
    output of the drop block.
    If this ROADM ingress to drop path includes
    an amplifier, the amplifier gain reduces the net loss.
    This is before any additional drop path attenuation
    that may be required due to drop amplifier power
    constraints.
    The min value correspond to best case expected loss,
    including amplifier gain ripple or uncertainty.";
}
leaf roadm-typlloss {
  type decimal64 {
    fraction-digits 2;
  }
  units dB ;
  description
    "The net loss from the ROADM input,
    to the output of the drop block.
    If this ROADM ingress to drop path
    includes an amplifier,
    the amplifier gain reduces the net loss.
    This is before any additional drop path
    attenuation
    that may be required due to drop amplifier
    power constraints.
    The typ value correspond to typical case
    expected loss.";
}
leaf roadm-pmin {
  type decimal64 {
    fraction-digits 2;
  }
  units dBm ;
  description
    "If the drop path has additional loss
    that is added, for example,
    to hit target power levels into a
    drop path amplifier, or simply, to reduce the
    power of a "strong" carrier
    (due to ripple, for example),
    then the use of the ROADM input power levels and
    the above drop losses is not appropriate."
```

```
        This parameter corresponds to the min per
        carrier power levels
        expected at the output of the drop block.
        A detail example of the comparison using
        these parameters is
        detailed in section xxx of the document yyy.";
    }
    leaf roadm-pmax {
        type decimal64 {
            fraction-digits 2;
        }
        units dBm ;
        description
            "If the drop path has additional loss that is added,
            for example, to hit target power levels into a
            drop path amplifier, or simply, to reduce the power
            of a "strong" carrier (due to ripple, for example),
            then the use of the ROADM input power levels and the
            above drop losses is not appropriate.
            This parameter corresponds to the best case per
            carrier power levels expected at the output of the
            drop block.
            A detail example of the comparison using
            these parameters
            is detailed in section xxx of the document yyy";
    }
    leaf roadm-ptyp {
        type decimal64 {
            fraction-digits 2;
        }
        units dBm ;
        description
            "If the drop path has additional loss that is added,
            for example, to hit target power levels into a
            drop path amplifier, or simply, to reduce the
            power of a "strong" carrier (due to ripple, for example),
            then the use of the ROADM input power levels and
            the above drop losses is not appropriate.
            This parameter corresponds to the typical case
            per carrier power levels expected
            at the output of the drop block.";
    }
    leaf roadm-osnr {
        type 10-types-ext:snr;
        description
            "Optical Signal-to-Noise Ratio (OSNR).
            Expected OSNR contribution of the drop path
            amplifier (if present)";
    }
```

```

        for the case of additional drop path loss
        (before this amplifier)
        in order to hit a target power level (per carrier).
        If both, the OSNR based on the ROADM
        input power level
        (Pcarrier =
        Pref+10Log(carrier-baudrate/ref-baud) + delta-power)
        and the input inferred NF(NF.drop),
        and this OSNR value, are defined,
        the minimum value between these two should be used";
    }
    leaf roadm-noise-figure {
        type decimal64 {
            fraction-digits 5;
        }
        units "dB";
        description
            "Drop path Noise Figure.
            If the drop path contains an amplifier,
            this is the noise figure
            of that amplifier, inferred to the
            ROADM ingress port.
            This permits to determine
            amplifier OSNR contribution
            without having to specify the
            ROADM node's losses to that amplifier.
            This applies for the case of no
            additional drop path loss,
            before the amplifier, in order to reduce the power
            of the carriers to a target value";
    }
}

grouping concentratedloss-params{
    description "concentrated loss";
    container concentratedloss{
        description "concentrated loss";
        leaf loss {
            type decimal64 {
                fraction-digits 2;
            }
            units dB ;
            description "..";
        }
    }
}

```



```
grouping power-param{
  description
    "optical power or PSD after the ROADM or after the out-voa";
  choice power-param {
    description
      "select the mode: channel power or power spectral density";
    case channel-power {
/*      when "equalization-mode='channel-power'"; */
      leaf nominal-channel-power{
        type decimal64 {
          fraction-digits 1;
        }
        units dBm ;
        description
          " Reference channel power after the ROADM or after
            the out-voa. ";
      }
    }
    case power-spectral-density{
/*      when "equalization-mode='power-spectral-density'"; */
      leaf nominal-power-spectral-density{
        type decimal64 {
          fraction-digits 16;
        }
        units W/Hz ;
        description
          " Reference power spectral density after
            the ROADM or after the out-voa.
            Typical value : 3.9 E-14, resolution 0.1nW/MHz";
      }
    }
  }
}

grouping oms-general-optical-params {
  description "OMS link optical parameters";
  leaf generalized-snr {
    type 10-types-ext:snr;
    description "generalized snr";
  }
  leaf equalization-mode{
    type identityref {
      base type-power-mode;
    }
    mandatory true;
    description "equalization mode";
  }
  uses power-param;
}
```

```
    }

    grouping OTSiG {
      description "OTSiG definition , representing client
        digital information stream supported by 1 or more OTSi";

      list otsi {
        key "otsi-carrier-id";
        config false;
        description
          "list of OTSi contained in 1 OTSiG.
          The list could also be of only 1 element";
        leaf otsi-carrier-id {
          type int16;
          description "OTSi carrier-id";
        }
      }

      /*any OTSi as signal generated by transceiver and*/
      /* attached to a transponder.*/

      leaf transponder-ref {
        type leafref {
          path "/nw:networks/nw:network/nw:node/tet:te" +
            "/tet:tunnel-termination-point" +
            "/transponder/transponder-id";
        }
        description
          "Reference to the configured transponder";
      }

      leaf transceiver-ref {
        type leafref {
          path "/nw:networks/nw:network/nw:node/tet:te" +
            "/tet:tunnel-termination-point/"
            +"transponder[transponder-id=current ()]"
            +"../transponder-ref]/"
            + "transceiver/transceiver-id" ;
        }
        description
          "Reference to the configured transceiver " ;
      }

      leaf configured-mode {
        type leafref {
          path "/nw:networks/nw:network/nw:node/tet:te" +
            "/tet:tunnel-termination-point/"
            +"transponder[transponder-id=current ()]"
            +"../transponder-ref]/"+
            "transceiver[transceiver-id=current ()]/"+
```

```

        "../transceiver-ref]/supported-modes/" +
        "supported-mode/mode-id";
    }
    description
        "Reference to the configured mode for transceiver
        compatibility approach";
    }
    uses 10-types-ext:common-transceiver-configured-param;
  } // OTSi list
} // OTSiG grouping

grouping media-channel-groups {
  description "media channel groups";
  list media-channel-group {
    key "i";
    description
        "list of media channel groups";
    leaf i {
      type int16;
      description "index of media channel group member";
    }

    list media-channels {
      key "flexi-n";
      description
          "list of media channels represented as (n,m)";

      // this grouping add both n.m values
      uses 10-types:flexi-grid-frequency-slot;

      leaf OTSiG-ref {
        type leafref {
          path "/nw:networks/nw:network/nw:node/tet:te" +
            "/tet:tunnel-termination-point" +
            "/otsi-group/otsi-group-id" ;
        }
        description
            "Reference to the otsi-group list to get otsi-group
            identifier of the
            OTSiG carried by this media channel
            that reports the transient stat";
      }
      leaf OTSi-ref {
        type leafref {
          path "/nw:networks/nw:network/nw:node/tet:te" +
            "/tet:tunnel-termination-point/"
            +"otsi-group[otsi-group-id=current()]"

```

```

        + "../OTSiG-ref]/"
        + "otsi/otsi-carrier-id" ;
    }
    description
        "Reference to the otsi list supporting
        the related OTSiG to get otsi identifier";
}

} // media channels list
} // media-channel-groups list
} // media media-channel-groups grouping

grouping oms-element {
    description "OMS description";
    list OMS-elements {
        key "elt-index";
        description
            "defines the spans and the amplifier blocks of
            the amplified lines";
        leaf elt-index {
            type uint16;
            description
                "ordered list of Index of OMS element
                (whether it's a Fiber, an EDFA or a
                Concentratedloss)";
        }
        leaf uid {
            type string;
            description
                "unique id of the element if it exists";
        }
        leaf type {
            type identityref {
                base type-element;
            }
        }
        mandatory true;
        description "element type";
    }

    container element {
        description "element of the list of elements of the OMS";
        choice element {
            description "OMS element type";
            case amplifier {
                when "type = 'Edfa'"; /*
                    uses amplifier-params ;
                }
            case fiber {

```

```
/*          when "type = 'Fiber'"; */
          uses fiber-params ;
        }
      case concentratedloss {
/*          when "type = 'Concentratedloss'"; */
          uses concentratedloss-params ;
        }
      }
    }
  }

/* Data nodes */

augment "/nw:networks/nw:network/nw:network-types"
+ "/tet:te-topology" {
  description "optical-impairment topology augmented";
  container optical-impairment-topology {
    presence "indicates an impairment-aware topology of
    optical networks";
    description
      "Container to identify impairment-aware topology type";
  }
}

augment "/nw:networks/nw:network/nt:link/tet:te"
+ "/tet:te-link-attributes" {
  when "/nw:networks/nw:network/nw:network-types"
  + "/tet:te-topology/"
  + "optical-imp-topo:optical-impairment-topology" {
    description
      "This augment is only valid for Optical Impairment.";
  }
  description "Optical Link augmentation for impairment data.";
  container OMS-attributes {
    config false;
    description "OMS attributes";
    uses oms-general-optical-params;
    uses media-channel-groups;
    uses oms-element;
  }
}

augment "/nw:networks/nw:network/nw:node/tet:te"
+ "/tet:tunnel-termination-point" {
  when "/nw:networks/nw:network/nw:network-types"
  + "/tet:te-topology/optical-imp-topo:optical-impairment-topology" {
    description
```

```
    "This augment is only valid for Impairment with non-sliceable
      transponder model";
  }
  description
    "Tunnel termination point augmentation for non-sliceable
      transponder model.";

  list otsi-group {
    key "otsi-group-id";
    config false;
    description
      "the list of possible OTSiG representing client digital
        stream";

    leaf otsi-group-id {
      type int16;
      description "index of otsi-group element";
    }
    uses OTSiG;
  } // list of OTSiG

  list transponder {
    key "transponder-id";
    config false;
    description "list of transponder";
    leaf transponder-id {
      type uint32;
      description "transponder identifier";
    }

    list transceiver {
      key "transceiver-id";
      config false;
      description "list of transceiver related to a transponder";
      leaf transceiver-id {
        type uint32;
        description "transceiver identifier";
      }
      uses 10-types-ext:transceiver-capabilities;
    } // end of list of transceiver

  } // end list of transponder

} // end of augment

augment "/nw:networks/nw:network/nw:node/tet:te"
```

```
+ "/tet:tunnel-termination-point" {
when "/nw:networks/nw:network/nw:network-types"
+ "/tet:te-topology/"
+ "optical-imp-topo:optical-impairment-topology" {
description
  "This augment is only valid for optical impairment
  with sliceable transponder model";
}
description
  "Tunnel termination point augmentation for sliceable
  transponder model.";
uses sliceable-transponder-attributes;
}

augment "/nw:networks/nw:network/nw:node/tet:te"
+ "/tet:te-node-attributes" {
when "/nw:networks/nw:network/nw:network-types"
+ "/tet:te-topology"
+ "/optical-imp-topo:optical-impairment-topology" {

description
  "This augment is only valid for Optical Impairment
  topology";
}
description
  "node attributes augmentantion for optical-impairment ROADM
  node";

list roadm-path-impairments {
key "roadm-path-impairments-id";
config false;
description "list of set of optical impairments related
to ROADM ";

leaf roadm-path-impairments-id {
type uint32;
description "index of the ROADM path-impairment list";
}
choice impairment-type {
description "type path impairment";
case roadm-express-path {
uses roadm-express-path;
}
case roadm-add-path {
uses roadm-add-path;
}
case roadm-drop-path {
uses roadm-drop-path;
}
```

```
    }
  }
} // list path impairments
} // augmentation for optical-impairment ROADM

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices"{
  when "/nw:networks/nw:network/nw:network-types"
    + "/tet:te-topology/"
    + "optical-imp-topo:optical-impairment-topology" {
    description
      "This augment is only valid for Optical Impairment
      topology ";
  }

  description
    "Augment default TE node connectivity matrix information
    source.";

  leaf roadm-path-impairments {
    type leafref {
      path "../.../tet:te-node-attributes/"
        + "roadm-path-impairments/roadm-path-impairments-id";
    }
    description "pointer to the list set of ROADM optical
    impairments";
  }
} // augmentation connectivity-matrices information-source

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:connectivity-matrix" {
  when "/nw:networks/nw:network/nw:network-types"
    + "/tet:te-topology/"
    + "optical-imp-topo:optical-impairment-topology" {
    description
      "This augment is only valid for Optical Impairment
      topology ";
  }

  description
    "Augment TE node connectivity matrix entry information
    source.";

  leaf roadm-path-impairments {
    type leafref {
      path "../.../.../tet:te-node-attributes/"
        + "roadm-path-impairments/roadm-path-impairments-id";
    }
  }
```



```
    }
    description "pointer to the list set of ROADM optical
    impairments";
  }
} // augmentation connectivity-matrix information-source

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:te-node-attributes/tet:connectivity-matrices" {
  when "/nw:networks/nw:network/nw:network-types"
  + "/tet:te-topology/"
  + "optical-imp-topo:optical-impairment-topology" {
    description
      "This augment is only valid for Optical Impairment
      topology ";
  }

  description
    "Augment default TE node connectivity matrix.";
  leaf roadm-path-impairments {
    type leafref {
      path "../..//roadm-path-impairments/"
      + "roadm-path-impairments-id";
    }
    config false; /*the identifier in the list */
    /*"roadm-path-impairments" of ROADM optical impairment*/
    /*is read-only as the rest of attributes*/
    description "pointer to the list set of ROADM optical
    impairments";
  }
} // augmentation connectivity-matrices

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:te-node-attributes/"
  + "tet:connectivity-matrices/tet:connectivity-matrix" {
  when "/nw:networks/nw:network/nw:network-types"
  + "/tet:te-topology/"
  + "optical-imp-topo:optical-impairment-topology" {
    description
      "This augment is only valid for
      Optical Impairment topology ";
  }

  description
    "Augment TE node connectivity matrix entry.";

  leaf roadm-path-impairments {
    type leafref {
      path "../..//..//roadm-path-impairments/"
```

```
        + "roadm-path-impairments-id";
    }
    config false;
    description "pointer to the list set of ROADM optical
        impairments";
}
} // augmentation connectivity-matrix

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:tunnel-termination-point/"
    + "tet:local-link-connectivities" {

    when "/nw:networks/nw:network/nw:network-types"
        + "/tet:te-topology/"
        + "optical-imp-topo:optical-impairment-topology" {
        description
            "This augment is only valid for Optical Impairment topology ";
    }

    description
        "Augment default TTP LLC.";
    leaf add-path-impairments {
        type leafref {
            path "../../tet:te-node-attributes/"
                + "roadm-path-impairments/roadm-path-impairments-id" ;
        }
        config false;
        description "pointer to the list set of ROADM optical
            impairments";
    }
    leaf drop-path-impairments {
        type leafref {
            path "../../tet:te-node-attributes/"
                + "roadm-path-impairments/roadm-path-impairments-id" ;
        }
        config false;
        description "pointer to the list set of ROADM
            optical impairments";
    }
} // augmentation local-link-connectivities

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:tunnel-termination-point/"
    + "tet:local-link-connectivities/"
    + "tet:local-link-connectivity" {

    when "/nw:networks/nw:network/nw:network-types"
        + "/tet:te-topology/"
```

```
    + "optical-imp-topo:optical-impairment-topology" {
      description
        "This augment is only valid for
         Optical Impairment topology ";
    }

    description
      "Augment TTP LLC entry.";
    leaf add-path-impairments {
      type leafref {
        path "../../../../../tet:te-node-attributes/"
          + "roadm-path-impairments/roadm-path-impairments-id" ;
      }
      config false;
      description "pointer to the list set of ROADM optical
        impairments";
    }
    leaf drop-path-impairments {
      type leafref {
        path "../../../../../tet:te-node-attributes/"
          + "roadm-path-impairments/roadm-path-impairments-id" ;
      }
      config false;
      description "pointer to the list set of ROADM optical
        impairments";
    }
  } // augmentation local-link-connectivity
}
<CODE ENDS>
```

5. Security Considerations

The configuration, state, and action data defined in this document are designed to be accessed via a management protocol with a secure transport layer, such as NETCONF [RFC6241]. The NETCONF access control model [RFC8341] provides the means to restrict access for particular NETCONF users to a preconfigured subset of all available NETCONF protocol operations and content.

A number of configuration data nodes defined in this document are read-only; however, these data nodes may be considered sensitive or vulnerable in some network environments (TBD).

6. IANA Considerations

This document registers the following namespace URIs in the IETF XML registry [RFC3688]:

URI: urn:ietf:params:xml:ns:yang:ietf-optical-impairment-topology
Registrant Contact: The IESG.
XML: N/A, the requested URI is an XML namespace.

This document registers the following YANG modules in the YANG Module Names registry [RFC7950]:

name: iETF-optical-impairment-topology
namespace: urn:ietf:params:xml:ns:yang:ietf-optical-impairment-topology
prefix: optical-imp-topo
reference: RFC XXXX (TDB)

7. Acknowledgments

We thank Daniele Ceccarelli and Oscar G. De Dios for useful discussions and motivation for this work.

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Framework and Data Model for OTN Network Slicing
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Abstract

The requirement of slicing network resource with desired quality of service is emerging at every network technology, including the Optical Transport Networks (OTN). As a part of the transport network, the OTN has the capability to provide hard pipes with guaranteed data isolation and deterministic low latency, which are highly demanded in the Service Level Agreement (SLA).

This document describes a framework for OTN network slicing. A YANG data model augmentation will be defined in a future version of this draft.

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1. Introduction

The requirement of slicing network resource with desired quality of service is emerging at every network technology, including the Optical Transport Networks (OTN). As a part of the transport network, the OTN has the capability to provide hard pipes with guaranteed data

isolation and deterministic low latency, which are highly demanded in the Service Level Agreement (SLA).

This document describes a framework for OTN network slicing. A YANG data model augmentation will be defined in a future version of this draft.

2. Use Cases for OTN Network Slicing

2.1. Leased Line Services with OTN

For large OTT enterprises, leased lines have the advantage of providing high-speed connections with low costs. On the other hand, the traffic control of leased lines is very challenging due to rapid changes of service demands. Carriers are recommended to provide network-level slicing capabilities to meet this demand. Based on such capabilities, private network users have full control over the sliced resources which have allocated to them and which could be used to support their leased lines, when needed. Users may formulate policies based on the demand on services and time to flexibly schedule the network from the perspective of the entire network. For example, the bandwidth between any two points may be established or released based on the time or monitored traffic characteristics, the routing and bandwidth may be adjusted at specific time interval to maximize network resource utilization efficiency.

2.2. Co-construction and Sharing

Co-construction and sharing of a network is becoming a popular mean amongst service providers with the goal of reducing networking building capex. For Co-construction and sharing case, there are typically multiple co-founders for the same network. For example, one founder may provide optical fibres and another founder may provide OTN equipment, while each of them occupies a certain percentage of the usage rights of the network resources. In this scenario, the network O&M is performed by certain founder in each region, where an independent management and control system is usually deployed by the same founder. The other founders of the network use each other's management and control system to provision services remotely. In this scenario, network resources used by different founders need to be automatically (associated) divided, isolated, and visualized. In addition, all founders have independent O&M capabilities, and should be able to perform service-level provisioning in their respective slices.

2.3. Wholesale of optical resources

In the optical resource wholesale market, smaller, local carriers and wireless carriers may rent resources from larger carriers, or infrastructure carriers, instead of building their own networks. Likewise, international carriers may rent resources from respective local carriers and local carriers may lease their owned networks to each other to achieve better network utilization efficiency.

From the perspective of a resource provider, it is crucial that a network slice is timely configured to meet traffic matrix requirements requested by its tenants. The support for multi-tenancy within the resource provider's network demands that the network slices are qualitatively isolated from each other to meet the requirements for transparency, non-interference, and security.

Typically, a resource purchaser expects to flexibly use the leased network resources just like they are self-constructed. Therefore, the purchaser is not only provided with a network slice, but also the full set of functionalities for operating and maintaining the network slice. The purchaser also expects to, in a flexible and independent manner, schedule and maintain physical resources to support their own end-to-end automation using both leased and self-constructed network resources.

2.4. Vertical dedicated network with OTN

Vertical industry slicing is an emerging category of network slicing due to the high demand of private high-speed network interconnects for industrial applications.

In this scenario, the biggest challenge is to implement differentiated optical network slices based on the requirements from different industries. For example, in the financial industry, to support high-frequency transactions, the slice must ensure to provide the minimum latency along with the mechanism for latency management. For the healthcare industry, online diagnosis network and software capabilities to ensure the delivery of HD video without frame loss. For bulk data migration in data centers, network needs to support on-demand, large-bandwidth allocation. In each of the aforementioned vertical industry scenarios, the bandwidth shall be adjusted as required to ensure flexible and efficient network resource usage.

3. Framework for OTN slicing

An OTN slice is a collection of OTN network resources that is used to establish a logically dedicated OTN virtual network over one or more OTN networks. For example, the bandwidth of an OTN slice is described in terms of the number/type of OTN time slots; the labels may be specified as OTN tributary slots and/or tributary ports to allow slice users to interconnect devices with matching specifications.

The relationship between an OTN slice and an IETF network slice [I-D.teas-transport-network-slice-yang] is for further discussions.

To support the configuration of OTN slices, an OTN slice controller (OTN-SC) can be deployed either outside or within the SDN controller.

In the former case, the OTN-SC translates an OTN slice configuration request into a TE topology configuration or a set of TE tunnel configurations, and instantiate it by using the TE topology [RFC8795] or TE tunnel [I-D.ietf-teas-yang-te] interfaces at the MPI, as defined in the ACTN framework [RFC8453].

In the latter case, an Orchestrator or an end-to-end slice controller may request OTN slices directly through the OTN slicing interface provided by the OTN-SC. A higher-level OTN-SC may also designate the creation of OTN slices to a lower-level OTN-SC in a recursive manner.

Figure 1 illustrates the OTN slicing control hierarchy and the positioning of the OTN slicing interfaces.

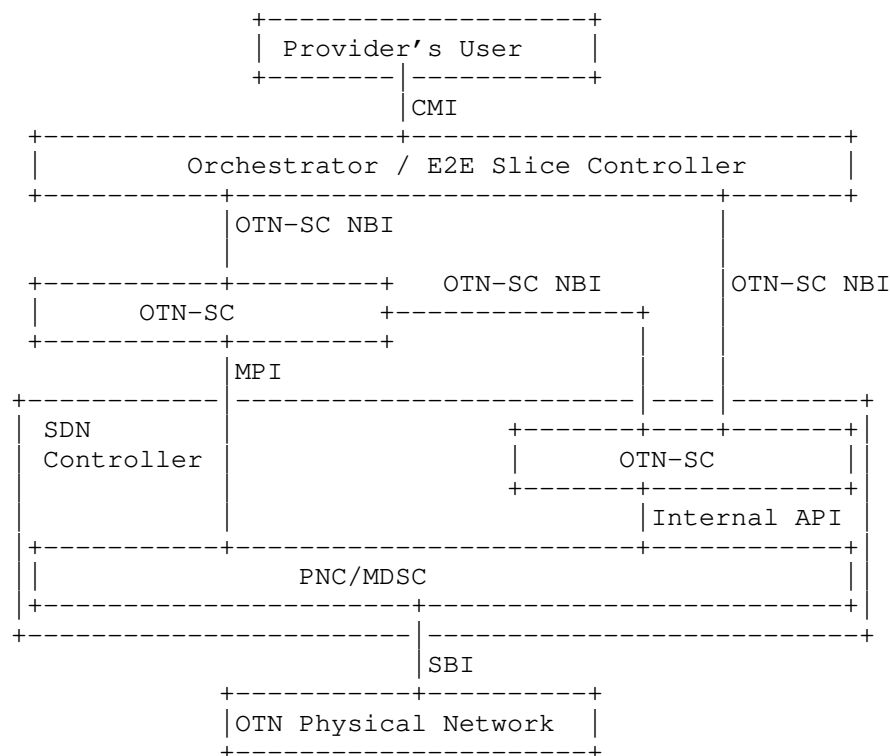


Figure 1 - Positioning of OTN Slicing Interfaces

A particular OTN network resource, such as a port or link, may be sliced in two modes:

- o Link-based slicing, where a link and its associated link termination points (LTPs) are dedicatedly allocated to a particular OTN network slice.
- o Tributary-slot based slicing, where multiple OTN network slices share the same link by allocating different OTN tributary slots in different granularities.

Additionally, since OTN tributary slots are usually switched unconstrained at every node within an OTN network, it is unimportant to which exact tributary slot(s) an OTN slice is allocated, but rather mattered is the number and type of the tributary slots.

4. YANG Model

TBD. The OTN slice YANG model may augment the IETF network slice YANG models, developed in [I-D. teas-transport-network-slice-yang], and/or the TE topology defined in [RFC8795].

5. YANG Tree

TBD.

6. Manageability Considerations

To ensure the security and controllability of physical resource isolation, slice-based independent operation and management are required to achieve management isolation.

Each optical slice typically requires dedicated accounts, permissions, and resources for independent access and O&M. This mechanism is to guarantee the information isolation among slice tenants and to avoid resource conflicts. The access to slice management functions will only be permitted after successful security checks.

7. Security Considerations

<Add any security considerations>

8. IANA Considerations

<Add any IANA considerations>

9. References

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TBD

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