YANG Data Models for requesting Path Computation in Optical Networks
draft-gbb-ccamp-optical-path-computation-yang-01

Abstract

This document describes YANG data models for Remote Procedure Calls (RPCs) to request Path Computation in Optical Networks (OTN, WSON and Flexi-grid).

The YANG data models defined in this document conforms to the Network Management Datastore Architecture (NMDA).

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1. Introduction

[I-D.ietf-teas-yang-path-computation] describes key use cases, where a client needs to request underlying SDN controllers for path computation. In some of these use cases, the underlying SDN controller can control a single-layer optical technologies, including Optical Transport Network (OTN), Wavelength Switched Optical Networks (WSON), Flexi-grid, and multi-layer Optical network.

This document defines YANG data models, which augment the generic Path Computation RPC defined in [I-D.ietf-teas-yang-path-computation], with technology-specific augmentations required to request path computation to an underlying Optical SDN controller. These models allow a client to delegate path computation tasks to the underlying Optical SDN controller without
having to obtain optical-layer information from the controller and performing feasible path computation itself. This is especially helpful in cases where computing optically-feasible paths require knowledge of physical-layer states, such as optical impairments, which are visible only to the Optical controller.

The YANG data model defined in this document conforms to the Network Management Datastore Architecture [RFC8342].

1.1. Terminology and Notations

Refer to [RFC7446] and [RFC7581] for the key terms used in this document. The following terms are defined in [RFC7950] and are not redefined here:

* client
* server
* augment
* data model
* data node

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

* configuration data
* 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 3 of this document. The meaning of the symbols in these diagrams is defined in [RFC8340].

1.3. 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, as shown in Table 1.
2. YANG Data Models for Optical Path Computation

2.1. YANG Models Overview

The YANG data models for requesting WSON, Flexi-grid and OTN path computation are defined as augmentations of the generic Path Computation RPC defined in [I-D.ietf-teas-yang-path-computation], as shown in Figure 1.
The entities and Traffic Engineering (TE) attributes, such as requested path and tunnel attributes, defined in [I-D.ietf-teas-yang-path-computation], are still applicable when requesting WSON, Flexi-grid and OTN path computation and the models defined in this document only specifies the additional technology-specific attributes/information, using the attributes defined in [RFC9093], [I-D.ietf-ccamp-layer0-types-ext] and [I-D.ietf-ccamp-layer1-types].

The YANG modules ietf-wson-path-computation, ietf-flexi-grid-path-computation and ietf-otn-path-computation defined in this document conforms to the Network Management Datastore Architecture (NMDA) defined in [RFC8342].

2.2. Attributes Augmentation

The common characteristics for layer 0 (WSON and Flexi-grid) tunnels are under definition in [I-D.ietf-ccamp-layer0-types-ext] and re-used in the ietf-wson-path-computation and ietf-flexi-grid-path-computation YANG models.
2.3. Bandwidth Augmentation

As described in Section 4.2 of [RFC7699], there is some overlap between bandwidth and label in layer0.

The WSON and flexi-grid label resource information described in Section 2.4, is sufficient to describe also the spectrum resources within WSON and flexi-grid networks. Therefore, the model does not define any augmentation for the te-bandwidth containers defined in [I-D.ietf-teas-yang-path-computation].

The OTN path computation model augments all the occurrences of the te-bandwidth container with the OTN technology-specific attributes using the otn-link-bandwidth and otn-path-bandwidth groupings defined in [I-D.ietf-ccamp-layer1-types].

2.4. Label Augmentations

The models augment all the occurrences of the label-restriction list with WSON, Flexi-grid and OTN technology-specific attributes using the 10-label-range-info and flexi-grid-label-range-info groupings defined in [RFC9093] and the otn-label-range-info grouping defined in [I-D.ietf-ccamp-layer1-types].

Moreover, the models augment all the occurrences of the te-label container with the WSON, Flexi-grid and OTN technology-specific attributes using the wson-label-start-end, wson-label-hop, wson-label-step, flexi-grid-label-start-end, flexi-grid-label-hop and flexi-grid-label-step defined in [RFC9093] and the otn-label-start-end, otn-label-hop and otn-label-step groupings defined in [I-D.ietf-ccamp-layer1-types].

3. Optical Path Computation Tree Diagrams

3.1. WSON Path Computation Tree Diagrams

Figure 2 below shows the tree diagram of the YANG data model defined in module ietf-wson-path-computation.yang.

```
module: ietf-wson-path-computation

augment /te:tunnels-path-compute/te:input/te:path-compute-info
 /tepc:path-request:
   +++ fec-type? identityref
   +++ termination-type? identityref
   +++ bit-stuffing? boolean
   +++ wavelength-assignment? identityref
   +++ gsnr-margin? snr
```
augment /te:tunnels-path-compute/te:output/te:path-compute-result
  /tepc:response/tepc:computed-paths-properties
  /tepc:computed-path-properties/tepc:path-properties:
  +--ro estimated-gsnr?   snr
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /tepc:path-request/tepc:optimizations/tepc:algorithm
  /tepc:metric/tepc:optimization-metric
  /tepc:explicit-route-exclude-objects
  /tepc:route-object-exclude-object/tepc:type:
  +--:(oms-element)
    +-- oms-element-uid?   string
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /tepc:path-request/tepc:optimizations/tepc:algorithm
  /tepc:metric/tepc:optimization-metric
  /tepc:explicit-route-include-objects
  /tepc:route-object-include-object/tepc:type:
  +--:(oms-element)
    +-- oms-element-uid?   string
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /tepc:path-request/tepc:explicit-route-objects-always
  /tepc:route-object-exclude-objects-always/tepc:type:
  +--:(oms-element)
    +-- oms-element-uid?   string
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /tepc:path-request/tepc:explicit-route-objects-always
  /tepc:route-object-exclude-exclude/tepc:type:
  +--:(oms-element)
    +-- oms-element-uid?   string
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /tepc:path-request/tepc:explicit-route-objects-always
  /tepc:route-object-exclude-always/tepc:type:
  +--:(oms-element)
    +-- oms-element-uid?   string
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /tepc:synchronization/tepc:exclude-objects/tepc:excludes
  /tepc:type:
  +--:(oms-element)
    +-- oms-element-uid?   string
augment /te:tunnels-path-compute/te:output/te:path-compute-result
  /tepc:response/tepc:computed-paths-properties
  /tepc:computed-path-properties/tepc:path-properties
  /tepc:path-route-objects/tepc:path-route-object
  /tepc:type:
  +--:(oms-element)
    +-- ro oms-element-uid?   string
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /tepc:path-request/tepc:path-in-segment
  /tepc:label-restrictions/tepc:label-restriction:
  +-- grid-type?   identityref
  +-- priority?    uint8
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /tepc:path-request/tepc:path-out-segment
  /tepc:label-restrictions/tepc:label-restriction:
++-- grid-type? identityref
++-- priority? uint8
augment /te:tunnels-path-compute/te:input/te:path-compute-info
    /tepc:path-request/tepc:optimizations/tepc:algorithm
    /tepc:metric/tepc:optimization-metric
    /tepc:explicit-route-exclude-objects
    /tepc:route-object-exclude-object/tepc:type/tepc:label
    /tepc:label-hop/tepc:te-label/tepc:technology:
++-- (wson)
++-- (grid-type)?
++-- (single-or-super-channel)?
++-- (single)
    | ++-- dwdm-n? 10-types:dwdm-n
++-- (super)
    | ++-- subcarrier-dwdm-n* 10-types:dwdm-n
++-- (cwdm)
    ++-- cwm-n? 10-types:cwm-n
augment /te:tunnels-path-compute/te:input/te:path-compute-info
    /tepc:path-request/tepc:optimizations/tepc:algorithm
    /tepc:metric/tepc:optimization-metric
    /tepc:explicit-route-include-objects
    /tepc:route-object-include-object/tepc:type/tepc:label
    /tepc:label-hop/tepc:te-label/tepc:technology:
++-- (wson)
++-- (grid-type)?
++-- (single-or-super-channel)?
++-- (single)
    | ++-- dwdm-n? 10-types:dwdm-n
++-- (super)
    | ++-- subcarrier-dwdm-n* 10-types:dwdm-n
++-- (cwdm)
    ++-- cwm-n? 10-types:cwm-n
augment /te:tunnels-path-compute/te:input/te:path-compute-info
    /tepc:path-request/tepc:explicit-route-objects-always
    /tepc:route-object-exclude-always/tepc:type/tepc:label
    /tepc:label-hop/tepc:te-label/tepc:technology:
++-- (wson)
++-- (grid-type)?
++-- (single-or-super-channel)?
++-- (single)
    | ++-- dwdm-n? 10-types:dwdm-n
++-- (super)
    | ++-- subcarrier-dwdm-n* 10-types:dwdm-n
++-- (cwdm)
    ++-- cwm-n? 10-types:cwm-n
augment /te:tunnels-path-compute/te:input/te:path-compute-info
 /tepc:path-request/tepc:explicit-route-objects-always
 /tepc:route-object-include-exclude/tepc:type/tepc:label
 /tepc:label-hop/tepc:te-label/tepc:technology:
  +--:(wson)
   +-- (grid-type)?
    +--:(dwdm)
     |   +-- (single-or-super-channel)?
      |     +--:(single)
      |     |   +-- dwdm-n?  10-types:dwdm-n
      |     +--:(super)
      |     |   +-- subcarrier-dwdm-n*  10-types:dwdm-n
      +--:(cwdm)
       +-- cwdm-n?  10-types:cwdm-n
augment /te:tunnels-path-compute/te:input/te:path-compute-info
 /tepc:path-request/tepc:path-in-segment
 /tepc:label-restrictions/tepc:label-restriction
 /tepc:label-start/tepc:te-label/tepc:technology:
  +--:(wson)
   +-- (grid-type)?
    +--:(dwdm)
     |   +-- dwdm-n?  10-types:dwdm-n
    +--:(cwdm)
     +-- cwdm-n?  10-types:cwdm-n
augment /te:tunnels-path-compute/te:input/te:path-compute-info
 /tepc:path-request/tepc:path-in-segment
 /tepc:label-restrictions/tepc:label-restriction
 /tepc:label-end/tepc:te-label/tepc:technology:
  +--:(wson)
   +-- (grid-type)?
    +--:(dwdm)
     |   +-- dwdm-n?  10-types:dwdm-n
    +--:(cwdm)
     +-- cwdm-n?  10-types:cwdm-n
augment /te:tunnels-path-compute/te:input/te:path-compute-info
 /tepc:path-request/tepc:path-in-segment
 /tepc:label-restrictions/tepc:label-restriction
 /tepc:label-step/tepc:technology:
  +--:(wson)
   +-- (grid-type)?
    +--:(dwdm)
     |   +-- dwdm-n?  10-types:dwdm-n
    +--:(cwdm)
     +-- cwdm-n?  10-types:cwdm-n
augment /te:tunnels-path-compute/te:input/te:path-compute-info
 /tepc:path-request/tepc:path-in-segment
 /tepc:label-restrictions/tepc:label-restriction
 /tepc:label-step/tepc:technology:
  +--:(wson)
   +-- (10-grid-type)?
    +--:(dwdm)
     |   +-- wson-dwdm-channel-spacing?  identityref
    +--:(cwdm)
     +-- wson-cwdm-channel-spacing?  identityref
augment /te:tunnels-path-compute/te:input/te:path-compute-info
 /tepc:path-request/tepc:path-out-segment
 /tepc:label-restrictions/tepc:label-restriction
 /tepc:label-start/tepc:te-label/tepc:technology:
3.2. Flexi-grid Path Computation Tree Diagrams

Figure 3 below shows the tree diagram of the YANG data model defined in module ietf-flexi-grid-path-computation.yang.

module: ietf-flexi-grid-path-computation

augment /te:tunnels-path-compute/te:input/te:path-compute-info
tepc:path-request:
  --- fec-type? identityref
  --- termination-type? identityref
  --- bit-stuffing? boolean
  --- wavelength-assignment? identityref
  --- gsnr-margin? snr
augment /te:tunnels-path-compute/te:output/te:path-compute-result
tepc:response/tepc:computed-paths-properties/tepc:computed-path-properties:
  ---ro estimated-gsnr? snr
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  ---ro oms-element-uid? string
augment /te:tunnels-path-compute/te:input/te:path-compute-info
tepc:optimizations/tepc:algorithm/tepc:metric/tepc:optimization-metric/tepc:explicit-route-include-objects/tepc:type:
  ---ro oms-element-uid? string
augment /te:tunnels-path-compute/te:input/te:path-compute-info
tepc:explicit-route-objects-always/tepc:route-object-exclude-always/tepc:type:
  ---ro oms-element-uid? string
augment /te:tunnels-path-compute/te:input/te:path-compute-info
/tepc:path-request/tepc:explicit-route-objects-always
/tepc:route-object-include-exclude/tepc:type:
  ++:(oms-element)
    ++ oms-element-uid?  string
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /tepc:synchronization/tepc:exclude-objects/tepc:excludes
  /tepc:type:
    ++:(oms-element)
    ++ oms-element-uid?  string
augment /te:tunnels-path-compute/te:output/te:path-compute-result
  /tepc:response/tepc:computed-paths-properties
  /tepc:computed-path-properties/tepc:path-properties
  /tepc:path-route-objects/tepc:path-route-object
  /tepc:type:
    ++:(oms-element)
    ++ ro oms-element-uid?  string
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /tepc:path-request/tepc:path-in-segment
  /tepc:label-restrictions/tepc:label-restriction:
    ++ grid-type?  identityref
    ++ priority?   uint8
    ++ flexi-grid
      ++ slot-width-granularity?  identityref
      ++ min-slot-width-factor?   uint16
      ++ max-slot-width-factor?   uint16
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /tepc:path-request/tepc:path-out-segment
  /tepc:label-restrictions/tepc:label-restriction:
    ++ grid-type?  identityref
    ++ priority?   uint8
    ++ flexi-grid
      ++ slot-width-granularity?  identityref
      ++ min-slot-width-factor?   uint16
      ++ max-slot-width-factor?   uint16
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /tepc:path-request/tepc:optimizations/tepc:algorithm
  /tepc:metric/tepc:optimization-metric
  /tepc:explicit-route-exclude-objects
  /tepc:route-object-exclude-object/tepc:type/tepc:label
  /tepc:label-hop/tepc:te-label/tepc:technology:
  +--:(flexi-grid)
    ++ (single-or-super-channel)?
      +--:(single)
        ++ flexi-n?  10-types:flexi-n
        ++ flexi-m?  10-types:flexi-m
      +--:(super)
        ++ subcarrier-flexi-n*  [flexi-n]
          ++ flexi-n  10-types:flexi-n
augment /te:tunnels-path-compute/te:input/te:path-compute-info
   /tepc:path-request/tepc:optimizations/tepc:algorithm
   /tepc:metric/tepc:optimization-metric
   /tepc:explicit-route-include-objects
   /tepc:route-object-include-object/tepc:type/tepc:label
   /tepc:label-hop/tepc:te-label/tepc:technology:
   +-- (flexi-grid)
      +-- (single-or-super-channel)?
         +-- (single)
            |   +-- flexi-n?   10-types:flexi-n
            |   +-- flexi-m?   10-types:flexi-m
         +-- (super)
            +-- subcarrier-flexi-n* [flexi-n]
               +-- flexi-n   10-types:flexi-n
               +-- flexi-m?   10-types:flexi-m

augment /te:tunnels-path-compute/te:input/te:path-compute-info
   /tepc:path-request/tepc:explicit-route-objects-always
   /tepc:route-object-exclude-always/tepc:type/tepc:label
   /tepc:label-hop/tepc:te-label/tepc:technology:
   +-- (flexi-grid)
      +-- (single-or-super-channel)?
         +-- (single)
            |   +-- flexi-n?   10-types:flexi-n
            |   +-- flexi-m?   10-types:flexi-m
         +-- (super)
            +-- subcarrier-flexi-n* [flexi-n]
               +-- flexi-n   10-types:flexi-n
               +-- flexi-m?   10-types:flexi-m

data-import /te:tunnels-path-compute/te:input/te:path-compute-info
   /tepc:path-request/tepc:explicit-route-objects-always
   /tepc:route-object-exclude-always/tepc:type/tepc:label
   /tepc:label-hop/tepc:te-label/tepc:technology:
   +-- (flexi-grid)
      +-- (single-or-super-channel)?
         +-- (single)
            |   +-- flexi-n?   10-types:flexi-n
            |   +-- flexi-m?   10-types:flexi-m
         +-- (super)
            +-- subcarrier-flexi-n* [flexi-n]
               +-- flexi-n   10-types:flexi-n
               +-- flexi-m?   10-types:flexi-m

data-import /te:tunnels-path-compute/te:input/te:path-compute-info
   /tepc:path-request/tepc:explicit-route-objects-exclude/tepc:type/tepc:label
   /tepc:label-start/tepc:te-label/tepc:technology:
   +-- (flexi-grid)
      +-- flexi-n?   10-types:flexi-n
augment /te:tunnels-path-compute/te:input/te:path-compute-info
   /tepc:path-request/tepc:path-in-segment
   /tepc:label-restrictions/tepc:label-restriction
   /tepc:label-end/tepc:te-label/tepc:technology:
     +=:(flexi-grid)
     ++ flexi-n?  10-types:flexi-n
augment /te:tunnels-path-compute/te:input/te:path-compute-info
   /tepc:path-request/tepc:path-in-segment
   /tepc:label-restrictions/tepc:label-restriction
   /tepc:label-step/tepc:technology:
     +=:(flexi-grid)
     ++ flexi-grid-channel-spacing?  identityref
     ++ flexi-n-step?  uint8
augment /te:tunnels-path-compute/te:input/te:path-compute-info
   /tepc:path-request/tepc:path-out-segment
   /tepc:label-restrictions/tepc:label-restriction
   /tepc:label-start/tepc:te-label/tepc:technology:
     +=:(flexi-grid)
     ++ flexi-n?  10-types:flexi-n
augment /te:tunnels-path-compute/te:input/te:path-compute-info
   /tepc:path-request/tepc:path-out-segment
   /tepc:label-restrictions/tepc:label-restriction
   /tepc:label-step/tepc:technology:
     +=:(flexi-grid)
     ++ flexi-n?  10-types:flexi-n
augment /te:tunnels-path-compute/te:input/te:path-compute-info
   /tepc:path-request/tepc:path-out-segment
   /tepc:label-restrictions/tepc:label-restriction
   /tepc:label-end/tepc:te-label/tepc:technology:
     +=:(flexi-grid)
     ++ flexi-grid-channel-spacing?  identityref
     ++ flexi-n-step?  uint8
augment /te:tunnels-path-compute/te:input/te:path-compute-info
   /tepc:synchronization/tepc:exclude-objects/tepc:excludes
   /tepc:type/tepc:label/tepc:label-hop/tepc:te-label
   /tepc:technology:
     +=:(flexi-grid)
     ++ (single-or-super-channel)?
      +=:(single)
       ++ flexi-n?  10-types:flexi-n
       ++ flexi-m?  10-types:flexi-m
     +=:(super)
       ++ subcarrier-flexi-n*  [flexi-n]
       ++ flexi-n  10-types:flexi-n
       ++ flexi-m?  10-types:flexi-m
augment /te:tunnels-path-compute/te:output/te:path-compute-result
   /tepc:response/tepc:computed-paths-properties
   /tepc:computed-path-properties/tepc:path-properties
3.3. OTN Path Computation Tree Diagrams

Figure 4 below shows the tree diagram of the YANG data model defined in module ietf-otn-path-computation.yang.

module: ietf-otn-path-computation

augment /te:tunnels-path-compute/te:input/te:path-compute-info /tepc:path-request/tepc:te-bandwidth/tepc:technology:
  +++:(otn)
    ++ otu
      ++ odu-type? identityref
      ++ (oduflex-type)?
        +++:(generic)
          | ++ nominal-bit-rate uint64
        +++:(cbr)
          | ++ client-type identityref
        +++:(gfp-n-k)
          | ++ gfp-n uint8
          | ++ gfp-k? gfp-k
        +++:(flexe-client)
          | ++ flexe-client flexe-client-rate
        +++:(flexe-aware)
          | ++ flexe-aware-n uint16
        +++:(packet)
          ++ opuflex-payload-rate uint64
augment /te:tunnels-path-compute/te:input/te:path-compute-info /tepc:tunnel-attributes/tepc:te-bandwidth /tepc:technology:
  +++:(otn)
    ++ otu
      ++ odu-type? identityref
      ++ (oduflex-type)?
        +++:(generic)
|  +-- nominal-bit-rate        uint64
  +--:(cbr)
  |  +-- client-type             identityref
  +--:(gfp-n-k)
  |  +-- gfp-n                   uint8
  |  +-- gfp-k?                  gfp-k
  +--:(flexe-client)
  |  +-- flexe-client            flexe-client-rate
  +--:(flexe-aware)
  |  +-- flexe-aware-n           uint16
  +--:(packet)
  |  +-- opuflex-payload-rate    uint64

augment /te:tunnels-path-compute/te:output/te:path-compute-result
  /tepc:response/tepc:computed-paths-properties
  /tepc:computed-path-properties/tepc:path-properties
  /tepc:te-bandwidth/tepc:technology:
  +--:(otn)
  ++-ro otn
  +++-ro odu-type?               identityref
  +++-ro (oduflex-type)?
  +--:(generic)
  |  +++-ro nominal-bit-rate       uint64
  +--:(cbr)
  |  +++-ro client-type            identityref
  +--:(gfp-n-k)
  |  +++-ro gfp-n                  uint8
  |  +++-ro gfp-k?                 gfp-k
  +--:(flexe-client)
  |  +++-ro flexe-client           flexe-client-rate
  +--:(flexe-aware)
  |  +++-ro flexe-aware-n          uint16
  +--:(packet)
  |  +++-ro opuflex-payload-rate   uint64

augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /tepc:path-request/tepc:path-in-segment
  /tepc:label-restrictions/tepc:label-restriction:
  +++ range-type?                otn-label-range-type
  +++ tsg?                        identityref
  +++ odu-type-list*              identityref
  +++ priority?                   uint8

augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /tepc:path-request/tepc:path-out-segment
  /tepc:label-restrictions/tepc:label-restriction:
  +++ range-type?                otn-label-range-type
  +++ tsg?                        identityref
  +++ odu-type-list*              identityref
  +++ priority?                   uint8
/tepc:path-request/tepc:optimizations/tepc:algorithm
/tepc:metric/tepc:optimization-metric
/tepc:explicit-route-exclude-objects
/tepc:route-object-exclude-object/tepc:type/tepc:label
/tepc:label-hop/tepc:te-label/tepc:technology:
  +++:(otn)
    +-- otn-tpn?  otn-tpn
    +-- tsg?       identityref
    +-- ts-list?   string
augment /te:tunnels-path-compute/te:input/te:path-compute-info
/tepc:path-request/tepc:optimizations/tepc:algorithm
/tepc:metric/tepc:optimization-metric
/tepc:explicit-route-include-objects
/tepc:route-object-include-object/tepc:type/tepc:label
/tepc:label-hop/tepc:te-label/tepc:technology:
  +++:(otn)
    +-- otn-tpn?  otn-tpn
    +-- tsg?       identityref
    +-- ts-list?   string
augment /te:tunnels-path-compute/te:input/te:path-compute-info
/tepc:path-request/tepc:explicit-route-objects-always
/tepc:route-object-exclude-always/tepc:type/tepc:label
/tepc:label-hop/tepc:te-label/tepc:technology:
  +++:(otn)
    +-- otn-tpn?  otn-tpn
    +-- tsg?       identityref
    +-- ts-list?   string
augment /te:tunnels-path-compute/te:input/te:path-compute-info
/tepc:path-request/tepc:explicit-route-objects-always
/tepc:route-object-include-exclude/tepc:type/tepc:label
/tepc:label-hop/tepc:te-label/tepc:technology:
  +++:(otn)
    +-- otn-tpn?  otn-tpn
    +-- tsg?       identityref
    +-- ts-list?   string
augment /te:tunnels-path-compute/te:input/te:path-compute-info
/tepc:path-request/tepc:path-in-segment
/tepc:label-restrictions/tepc:label-restriction
/tepc:label-start/tepc:te-label/tepc:technology:
  +++:(otn)
    +-- (range-type)?
      +--:(trib-port)
        |  +-- otn-tpn?  otn-tpn
      +--:(trib-slot)
        +-- otn-ts?    otn-ts
augment /te:tunnels-path-compute/te:input/te:path-compute-info
/tepc:path-request/tepc:path-in-segment
/tepc:label-restrictions/tepc:label-restriction
/tepc:label-end/tepc:te-label/tepc:technology:
++-:(otn)
  ++- (range-type)?
  +--:(trib-port)
   |   ++- otn-tpn?  otn-tpn
  ++-:(trib-slot)
   ++- otn-ts?  otn-ts
augment /te:tunnels-path-compute/te:input/te:path-compute-info
   /tepc:path-request/tepc:path-in-segment
   /tepc:label-restrictions/tepc:label-restriction
   /tepc:label-step/tepc:technology:
++-:(otn)
  ++- (range-type)?
  +--:(trib-port)
   |   ++- otn-tpn?  otn-tpn
  ++-:(trib-slot)
   ++- otn-ts?  otn-ts
augment /te:tunnels-path-compute/te:input/te:path-compute-info
   /tepc:path-request/tepc:path-out-segment
   /tepc:label-restrictions/tepc:label-restriction
   /tepc:label-end/tepc:te-label/tepc:technology:
++-:(otn)
  ++- (range-type)?
  +--:(trib-port)
   |   ++- otn-tpn?  otn-tpn
  ++-:(trib-slot)
   ++- otn-ts?  otn-ts
augment /te:tunnels-path-compute/te:input/te:path-compute-info
   /tepc:path-request/tepc:path-out-segment
   /tepc:label-restrictions/tepc:label-restriction
   /tepc:label-end/tepc:te-label/tepc:technology:
++-:(otn)
  ++- (range-type)?
  +--:(trib-port)
   |   ++- otn-tpn?  otn-tpn
  ++-:(trib-slot)
   ++- otn-ts?  otn-ts
augment /te:tunnels-path-compute/te:input/te:path-compute-info
   /tepc:path-request/tepc:path-out-segment
   /tepc:label-restrictions/tepc:label-restriction
   /tepc:label-end/tepc:te-label/tepc:technology:
Figure 4: OTN path computation tree diagram

4. YANG Models for Optical Path Computation

4.1. YANG Model for WSON Path Computation

<CODE BEGINS> file "ietf-wson-path-computation@2022-03-07.yang"
module ietf-wson-path-computation {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-wson-path-computation";
  prefix "wson-pc";

  import ietf-te-path-computation {
    prefix "tepc";
    revision-date "2021-09-06";
    reference
      "I-D.ietf-teas-yang-path-computation-14: Yang model for requesting Path Computation.";
  }

  import ietf-te {
    prefix "te";
    revision-date "2021-02-20";
    reference
      "I-D.ietf-teas-yang-te-19: A YANG Data Model for Traffic Engineering Tunnels and Interfaces. ";
  }

  import ietf-layer0-types {
    prefix "10-types";
  }
}
This module defines a model for requesting WSON Path Computation. The model fully conforms to the Network Management Datastore Architecture (NMDA).

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

revision "2022-03-07" {
    description
        "Initial version.";
    reference
        "RFC XXXX: YANG Model for OTN and Optical Path Computation";
        // RFC Ed.: replace XXXX with actual RFC number, update date
        // information and remove this note
}

/*
 * Data nodes
 */
augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
   + "tepc:path-request" {  
   description
   "Augment with additional constraints for WSON paths.";
   uses l0-types:l0-tunnel-attributes;
   uses l0-types:l0-path-constraints;
 }

augment "/te:tunnels-path-compute/te:output/"
   + "te:path-compute-result/tepc:response/
   + "tepc:computed-paths-properties/
   + "tepc:computed-path-properties/tepc:path-properties" {  
   description
   "Augment with additional properties for WSON paths.";
   uses l0-types:l0-path-properties;
 }

/*
 * Augment Route Hop
 */

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
   + "tepc:path-request/tepc:optimizations/tepc:algorithm/
   + "tepc:metric/tepc:optimization-metric/
   + "tepc:explicit-route-exclude-objects/
   + "tepc:route-object-exclude-object/tepc:type" {  
   description
   "Augment the route hop for the optimization of the explicit
   route objects excluded by the path computation of the requested
   path.";
   case oms-element {
   leaf oms-element-uid {
   type string;
   description
   "The unique id of the OMS element.";
   }
   description
   "The OMS element route hop type";
   }
 }

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
   + "tepc:path-request/tepc:optimizations/tepc:algorithm/
   + "tepc:metric/tepc:optimization-metric/
   + "tepc:explicit-route-include-objects/
   + "tepc:route-object-include-object/tepc:type" {  
   description
   "Augment the route hop for the optimization of the explicit
   route objects included by the path computation of the requested
   path.";
   case oms-element {
   leaf oms-element-uid {
   type string;
   description
   "The unique id of the OMS element.";
   }
   description
   "The OMS element route hop type";
   }
 }
route objects included by the path computation of the requested path.

```yang
case oms-element {
  leaf oms-element-uid {
    type string;
    description
      "The unique id of the OMS element.";
  };
  description
    "The OMS element route hop type";
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "tepc:path-request/tepc:explicit-route-objects-always/
    + "tepc:route-object-exclude-always/tepc:type" {
  description
    "Augment the route hop for the explicit route objects always excluded by the path computation of the requested path.";
  case oms-element {
    leaf oms-element-uid {
      type string;
      description
        "The unique id of the OMS element.";
    };
    description
      "The OMS element route hop type";
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "tepc:path-request/tepc:explicit-route-objects-always/
    + "tepc:route-object-exclude/include/tepc:type" {
  description
    "Augment the route hop for the explicit route objects included or excluded by the path computation of the requested path.";
  case oms-element {
    leaf oms-element-uid {
      type string;
      description
        "The unique id of the OMS element.";
    };
    description
      "The OMS element route hop type";
  }
}
```

```
description
"Augment the route hop for the explicit route objects to always
exclude from synchronized path computation."
}
case oms-element {
leaf oms-element-uid {
  type string;
description
"The unique id of the OMS element.";
}
description
"The OMS element route hop type";
}
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "te:path-compute-result/tepc:response/
  + "tepc:computed-paths-properties/
  + "tepc:computed-path-properties/tepc:path-properties/
  + "tepc:path-route-objects/tepc:path-route-object/
  + "tepc:type" {
  description
"Augment the route hop for the route object of the computed path.";
  case oms-element {
  leaf oms-element-uid {
    type string;
description
"The unique id of the OMS element.";
  }
description
"The OMS element route hop type";
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "te:path-request/tepc:path-in-segment/
  + "tepc:label-restrictions/tepc:label-restriction" {
  description
"Augment TE label range information for the ingress segment
of the requested path.";
  uses l0-types:l0-label-range-info;
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"  
+ "tepc:path-request/tepc:path-out-segment/"  
+ "tepc:label-restrictions/tepc:label-restriction" {  
description  
"Augment TE label range information for the egress segment  
of the requested path.";  
uses 10-types:10-label-range-info;  
}  

/*  
* Augment TE label.  
*/

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"  
+ "tepc:path-request/tepc:optimizations/tepc:algorithm/"  
+ "tepc:metric/tepc:optimization-metric/"  
+ "tepc:explicit-route-exclude-objects/"  
+ "tepc:route-object-exclude-object/tepc:type/tepc:label/"  
+ "tepc:label-hop/tepc:te-label/tepc:technology" {  
description  
"Augment TE label hop for the optimization of the explicit  
route objects excluded by the path computation of the requested  
path.";  
case wson {  
uses 10-types:wson-label-hop;  
}  
}  

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"  
+ "tepc:path-request/tepc:optimizations/tepc:algorithm/"  
+ "tepc:metric/tepc:optimization-metric/"  
+ "tepc:explicit-route-include-objects/"  
+ "tepc:route-object-include-object/tepc:type/tepc:label/"  
+ "tepc:label-hop/tepc:te-label/tepc:technology" {  
description  
"Augment TE label hop for the optimization of the explicit  
route objects included by the path computation of the requested  
path.";  
case wson {  
uses 10-types:wson-label-hop;  
}  
}  

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"  
+ "tepc:path-request/tepc:explicit-route-objects-always/"  
+ "tepc:route-object-exclude-always/tepc:type/tepc:label/"  
+ "tepc:label-hop/tepc:te-label/tepc:technology" {  
description
"Augment TE label hop for the explicit route objects always excluded by the path computation of the requested path."
case wson {
  uses 10-types:wson-label-hop;
}
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "tepc:path-request/tepc:explicit-route-objects-always/
    + "tepc:route-object-include-exclude/tepc:te-label/
      + "tepc:label-hop/tepc:te-label/tepc:technology" { 
    description
    "Augment TE label hop for the explicit route objects included or excluded by the path computation of the requested path.";
    case wson {
      uses 10-types:wson-label-hop;
    }
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "tepc:path-request/tepc:path-in-segment/
    + "tepc:label-restrictions/tepc:label-restriction/
      + "tepc:label-start/tepc:te-label/tepc:technology" { 
    description
    "Augment TE label range start for the ingress segment of the requested path.";
    case wson {
      uses 10-types:wson-label-start-end;
    }
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "tepc:path-request/tepc:path-in-segment/
    + "tepc:label-restrictions/tepc:label-restriction/
      + "tepc:label-end/tepc:te-label/tepc:technology" { 
    description
    "Augment TE label range end for the ingress segment of the requested path.";
    case wson {
      uses 10-types:wson-label-start-end;
    }
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "tepc:path-request/tepc:path-in-segment/
    + "tepc:label-restrictions/tepc:label-restriction/
      + "tepc:label-step/tepc:technology" { 
    description
"Augment TE label range step for the ingress segment of the requested path."
  case wson {
    uses 10-types:wson-label-step;
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "tepc:path-request/tepc:path-out-segment/
  + "tepc:label-restrictions/tepc:label-restriction/"
  + "tepc:label-start/tepc:te-label/tepc:technology" {
  description
  "Augment TE label range start for the egress segment of the requested path."
  case wson {
    uses 10-types:wson-label-start-end;
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "tepc:path-request/tepc:path-out-segment/
  + "tepc:label-restrictions/tepc:label-restriction/"
  + "tepc:label-end/tepc:te-label/tepc:technology" {
  description
  "Augment TE label range end for the egress segment of the requested path."
  case wson {
    uses 10-types:wson-label-start-end;
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "tepc:path-request/tepc:path-out-segment/
  + "tepc:label-restrictions/tepc:label-restriction/"
  + "tepc:label-step/tepc:technology" {
  description
  "Augment TE label range end for the egress segment of the requested path."
  case wson {
    uses 10-types:wson-label-step;
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "tepc:synchronization/tepc:exclude-objects/tepc:excludes/
  + "tepc:type/tepc:label/tepc:label-hop/
  + "tepc:te-label/tepc:technology" {
  description
"Augment TE label hop for the explicit route objects to always exclude from synchronized path computation."

    case wson {
        uses 10-types:wson-label-hop;
    }

} augment "/te:tunnels-path-compute/te:output/"
+ "te:path-compute-result/tepc:response/
+ "tepc:computed-paths-properties/"
+ "tepc:computed-path-properties/tepc:path-properties/"
+ "tepc:path-route-objects/tepc:path-route-object/"
+ "tepc:type/tepc:label/"
+ "tepc:label-hop/tepc:te-label/tepc:technology" {
    description
        "Augment TE label hop for the route object of the computed path.";
    case wson {
        uses 10-types:wson-label-hop;
    }
} <CODE ENDS>

Figure 5: WSON path computation YANG module

4.2. YANG Model for Flexi-grid Path Computation

<CODE BEGINS> file "ietf-flexi-grid-path-computation@2022-03-07.yang"
module ietf-flexi-grid-path-computation {
    yang-version 1.1;
    namespace
    prefix "flexg-pc";

    import ietf-te-path-computation {
        prefix "tepc";
        revision-date "2021-09-06";
        reference
            "I-D.ietf-teas-yang-path-computation-14: Yang model for requesting Path Computation.";
    }

    import ietf-te {
        prefix "te";
        revision-date "2021-02-20";
        reference
            "I-D.ietf-teas-yang-te-19: A YANG Data Model for Traffic
import ietf-layer0-types {
    prefix "l0-types";
}

organization "IETF CCAMP Working Group";
contact "WG Web: <http://tools.ietf.org/wg/ccamp/>
       WG List: <mailto:ccamp@ietf.org>
       Editor: Aihua Guo <mailto:aihuaguo.ietf@gmail.com>
       Editor: Italo Busi <mailto:italo.busi@huawei.com>
       Editor: Sergio Belotti <mailto:sergio.belotti@nokia.com>";

description "This module defines a model for requesting Flexi-grid Path Computation.

The model fully conforms to the Network Management Datastore Architecture (NMDA).

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

revision "2022-03-07" {
    description "Initial version.";
    reference "RFC XXXX: YANG Model for OTN and Optical Path Computation";
    // RFC Ed.: replace XXXX with actual RFC number, update date
augment "/te:tunnels-path-compute/te:input/te:path-compute-info/" 
  + "tepc:path-request" { 
    description 
    "Augment with additional constraints flexi-grid media channel.";
    uses 10-types:10-tunnel-attributes;
    uses 10-types:10-path-constraints;
  }

augment "/te:tunnels-path-compute/te:output/" 
  + "te:path-compute-result/tepc:response/
  + "tepc:computed-paths-properties/"
  + "tepc:computed-path-properties/tepc:path-properties" { 
    description 
    "Augment with additional properties for Flexi-grid paths.";
    uses 10-types:10-path-properties;
  }

/*
 * Augment Route Hop
 */

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/" 
  + "tepc:path-request/tepc:optimizations/tepc:algorithm/"
  + "tepc:metric/tepc:optimization-metric/"
  + "tepc:explicit-route-exclude-objects/"
  + "tepc:route-object-exclude-object/tepc:type" { 
    description 
    "Augment the route hop for the optimization of the explicit route objects excluded by the path computation of the requested path.";
    case oms-element {
      leaf oms-element-uid {
        type string;
        description 
        "The unique id of the OMS element.";
      }
      description 
      "The OMS element route hop type";
    }
  }
augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
 + "tepc:path-request/tepc:optimizations/tepc:algorithm/"
 + "tepc:metric/tepc:optimization-metric/
 + "tepc:explicit-route-include-objects/"
 + "tepc:route-object-include-object/tepc:type" {
   description
   "Augment the route hop for the optimization of the explicit
   route objects included by the path computation of the requested
   path.";
   case oms-element {
     leaf oms-element-uid {
       type string;
       description
       "The unique id of the OMS element.";
     }
     description
     "The OMS element route hop type";
   }
 }

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
 + "tepc:path-request/tepc:explicit-route-objects-always/"
 + "tepc:route-object-exclude-always/tepc:type" {
   description
   "Augment the route hop for the explicit route objects always
   excluded by the path computation of the requested path.";
   case oms-element {
     leaf oms-element-uid {
       type string;
       description
       "The unique id of the OMS element.";
     }
     description
     "The OMS element route hop type";
   }
 }

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
 + "tepc:path-request/tepc:explicit-route-objects-always/"
 + "tepc:route-object-exclude-exclude/tepc:type" {
   description
   "Augment the route hop for the explicit route objects included
   or excluded by the path computation of the requested path.";
   case oms-element {
     leaf oms-element-uid {
       type string;
       description
       "The unique id of the OMS element.";
     }
     description
     "The OMS element route hop type";
   }
 }
augment "/te:tunnels-path-compute/te:input/te:path-compute-info/" 
  + "tepc:synchronization/tepc:exclude-objects/tepc:excludes/" 
  + "tepc:type" {
  description
  "Augment the route hop for the explicit route objects to always 
  exclude from synchronized path computation.";
  case oms-element {
    leaf oms-element-uid {
      type string;
      description
      "The unique id of the OMS element.";
    }
  }
  description
  "The OMS element route hop type";
}
}

augment "/te:tunnels-path-compute/te:output/" 
  + "te:path-compute-result/tepc:response/" 
  + "tepc:computed-paths-properties/" 
  + "tepc:computed-path-properties/tepc:path-properties/" 
  + "tepc:path-route-objects/tepc:path-route-object/" 
  + "tepc:type" {
  description
  "Augment the route hop for the route object of the computed 
  path.";
  case oms-element {
    leaf oms-element-uid {
      type string;
      description
      "The unique id of the OMS element.";
    }
  }
  description
  "The OMS element route hop type";
}
}
/*
* Augment TE label range information
*/

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
+ "tepc:path-request/tepc:path-in-segment/"
+ "tepc:label-restrictions/tepc:label-restriction" {
  description
  "Augment TE label range information for the ingress segment
  of the requested path.";
  uses 10-types:flexi-grid-label-range-info;
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "tepc:path-request/tepc:path-out-segment/
  + "tepc:label-restrictions/tepc:label-restriction" {
  description
  "Augment TE label range information for the egress segment
  of the requested path.";
  uses 10-types:flexi-grid-label-range-info;
}

/*
 * Augment TE label.
 */

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "tepc:path-request/tepc:optimizations/tepc:algorithm/
  + "tepc:metric/tepc:optimization-metric/
  + "tepc:explicit-route-exclude-objects/
  + "tepc:route-object-exclude-object/tepc:type/tepc:label/
  + "tepc:label-hop/tepc:te-label/tepc:technology" {
  description
  "Augment TE label hop for the optimization of the explicit
  route objects excluded by the path computation of the requested
  path.";
  case flexi-grid {
    uses 10-types:flexi-grid-label-hop;
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "tepc:path-request/tepc:optimizations/tepc:algorithm/
  + "tepc:metric/tepc:optimization-metric/
  + "tepc:explicit-route-include-objects/
  + "tepc:route-object-include-object/tepc:type/tepc:label/
  + "tepc:label-hop/tepc:te-label/tepc:technology" {
  description
  "Augment TE label hop for the optimization of the explicit
  route objects included by the path computation of the requested
  path.";
  case flexi-grid {
    uses 10-types:flexi-grid-label-hop;
  }
augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
  + "tepc:path-request/tepc:explicit-route-objects-always/"
  + "tepc:route-object-exclude-always/tepc:type/tepc:label/
  + "tepc:label-hop/tepc:te-label/tepc:technology" { 
description
"Augment TE label hop for the explicit route objects always
excluded by the path computation of the requested path.";
  case flexi-grid {
    uses 10-types:flexi-grid-label-hop;
  }
} 

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
  + "tepc:path-request/tepc:explicit-route-objects-always/"
  + "tepc:route-object-exclude-exclude/tepc:type/tepc:label/
  + "tepc:label-hop/tepc:te-label/tepc:technology" { 
description
"Augment TE label hop for the explicit route objects included
or excluded by the path computation of the requested path.";
  case flexi-grid {
    uses 10-types:flexi-grid-label-hop;
  }
} 

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
  + "tepc:path-request/tepc:path-in-segment/"
  + "tepc:label-restrictions/tepc:label-restriction/
  + "tepc:label-start/tepc:te-label/tepc:technology" { 
description
"Augment TE label range start for the ingress segment
of the requested path.";
  case flexi-grid {
    uses 10-types:flexi-grid-label-start-end;
  }
} 

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
  + "tepc:path-request/tepc:path-in-segment/"
  + "tepc:label-restrictions/tepc:label-restriction/
  + "tepc:label-end/tepc:te-label/tepc:technology" { 
description
"Augment TE label range end for the ingress segment
of the requested path.";
  case flexi-grid {
    uses 10-types:flexi-grid-label-start-end;
  }
augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
  + "tepc:path-request/tepc:path-in-segment/"
  + "tepc:label-restrictions/tepc:label-restriction/
    + "tepc:label-step/tepc:technology" { 
    description
    "Augment TE label range step for the ingress segment
    of the requested path.";
    case flexi-grid {
      uses 10-types:flexi-grid-label-step;
    }
  }

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
  + "tepc:path-request/tepc:path-out-segment/"
  + "tepc:label-restrictions/tepc:label-restriction/
    + "tepc:label-start/tepc:te-label/tepc:technology" { 
    description
    "Augment TE label range start for the egress segment
    of the requested path.";
    case flexi-grid {
      uses 10-types:flexi-grid-label-start-end;
    }
  }

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
  + "tepc:path-request/tepc:path-out-segment/"
  + "tepc:label-restrictions/tepc:label-restriction/
    + "tepc:label-end/tepc:te-label/tepc:technology" { 
    description
    "Augment TE label range end for the egress segment
    of the requested path.";
    case flexi-grid {
      uses 10-types:flexi-grid-label-start-end;
    }
  }

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
  + "tepc:path-request/tepc:path-out-segment/"
  + "tepc:label-restrictions/tepc:label-restriction/
    + "tepc:label-step/tepc:technology" { 
    description
    "Augment TE label range end for the egress segment
    of the requested path.";
    case flexi-grid {
      uses 10-types:flexi-grid-label-step;
augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
+ "tepc:synchronization/tepc:exclude-objects/tepc:excludes/"
+ "tepc:type/tepc:label/tepc:label-hop/
+ "tepc:te-label/tepc:technology" {
  description
    "Augment TE label hop for the explicit route objects to always
     exclude from synchronized path computation.";
  case flexi-grid {
    uses 10-types:flexi-grid-label-hop;
  }
}

augment "/te:tunnels-path-compute/te:output/"
+ "te:path-compute-result/tepc:response/"
+ "tepc:computed-paths-properties/"
+ "tepc:computed-path-properties/tepc:path-properties/"
+ "tepc:path-route-objects/tepc:path-route-object/"
+ "tepc:type/tepc:label/
+ "tepc:label-hop/tepc:te-label/tepc:technology" {
  description
    "Augment TE label hop for the route object of the computed
     path.";
  case flexi-grid {
    uses 10-types:flexi-grid-label-hop;
  }
}

Figure 6: Flexi-grid path computation YANG module

4.3. YANG Model for OTN Path Computation

<CODE BEGINS> file "ietf-otn-path-computation@2021-10-07.yang"
module ietf-otn-path-computation {
  yang-version 1.1;
namespace "urn:ietf:params:xml:ns:yang:ietf-otn-path-computation";
  prefix "otn-pc";

  import ietf-te-path-computation {
    prefix "tepc";
    revision-date "2021-09-06";
    reference
      "I-D.ietf-teas-yang-path-computation-14: Yang model
       for requesting Path Computation.";
  }

import ietf-te {
  prefix "te";
  revision-date "2021-02-20";
  reference
    "I-D.ietf-teas-yang-te-19: A YANG Data Model for Traffic Engineering Tunnels and Interfaces. ";
}

import ietf-layer1-types {
  prefix "l1-types";
  reference
    "I-D.ietf-ccamp-layer1-types: A YANG Data Model for Layer 1 Types. ";
}

organization
  "IETF CCAMP Working Group";

contact
  "WG Web: <http://tools.ietf.org/wg/ccamp/>
  WG List: <mailto:ccamp@ietf.org>
  Editor: Aihua Guo
    <mailto:aihuaguo.ietf@gmail.com>
  Editor: Italo Busi
    <mailto:italo.busi@huawei.com>
  Editor: Sergio Belotti
    <mailto:sergio.belotti@nokia.com>"

description
  "This module defines a model for requesting OTN Path Computation.

  The model fully conforms to the Network Management Datastore Architecture (NMDA).

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

revision "2021-10-07" {
  description
    "Initial version.";
  reference
    "RFC XXXX: YANG Model for OTN and Optical Path Computation";
    // RFC Ed.: replace XXXX with actual RFC number, update date
    // information and remove this note
}

/*
 * Data nodes
 */

/*
 * Augment TE bandwidth
 */

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
   + "tepc:path-request/tepc:te-bandwidth/tepc:technology" {
  description
    "Augment TE bandwidth of the requested path.";
  case otn {
    uses l1-types:otn-path-bandwidth;
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
   + "tepc:tunnel-attributes/tepc:te-bandwidth/
   + "tepc:technology" {
  description
    "Augment TE bandwidth of the requested tunnel attributes.";
  case otn {
    uses l1-types:otn-path-bandwidth;
  }
}

augment "/te:tunnels-path-compute/te:output/
   + "te:path-compute-result/tepc:response/
   + "tepc:computed-paths-properties/
   + "tepc:computed-path-properties/tepc:path-properties/
   + "tepc:te-bandwidth/tepc:technology" {
  description
    "Augment TE bandwidth of the computed path properties.";
  case otn {
    uses l1-types:otn-path-bandwidth;
  }
}
augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
  + "tepc:path-request/tepc:path-in-segment/
  + "tepc:label-restrictions/tepc:label-restriction" {
    description
    "Augment TE label range information for the ingress segment of the requested path.";
    uses l1-types:otn-label-range-info;
  }

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
  + "tepc:path-request/tepc:path-out-segment/
  + "tepc:label-restrictions/tepc:label-restriction" {
    description
    "Augment TE label range information for the egress segment of the requested path.";
    uses l1-types:otn-label-range-info;
  }

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
  + "tepc:path-request/tepc:optimizations/tepc:algorithm/
  + "tepc:metric/tepc:optimization-metric"
  + "tepc:explicit-route-exclude-objects/
  + "tepc:route-object-exclude-object/tepc:type/tepc:label/
  + "tepc:label-hop/tepc:te-label/tepc:technology" {
    description
    "Augment TE label hop for the optimization of the explicit route objects excluded by the path computation of the requested path.";
    case otn {
      uses l1-types:otn-label-hop;
    }
  }

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
  + "tepc:path-request/tepc:optimizations/tepc:algorithm/
  + "tepc:metric/tepc:optimization-metric"
  + "tepc:explicit-route-include-objects/"
+ "tepc:route-object-include-object/tepc:type/tepc:label/"
+ "tepc:label-hop/tepc:te-label/tepc:technology" { 
  description
  "Augment TE label hop for the optimization of the explicit
  route objects included by the path computation of the requested
  path.";
  case otn {
    uses li-types:otn-label-hop;
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
+ "tepc:path-request/tepc:explicit-route-objects-always/"
+ "tepc:route-object-exclude-always/tepc:type/tepc:label/"
+ "tepc:label-hop/tepc:te-label/tepc:technology" { 
  description
  "Augment TE label hop for the explicit route objects always
  excluded by the path computation of the requested path.";
  case otn {
    uses li-types:otn-label-hop;
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
+ "tepc:path-request/tepc:explicit-route-objects-always/"
+ "tepc:route-object-include-exclude/tepc:type/tepc:label/"
+ "tepc:label-hop/tepc:te-label/tepc:technology" { 
  description
  "Augment TE label hop for the explicit route objects included
  or excluded by the path computation of the requested path.";
  case otn {
    uses li-types:otn-label-hop;
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
+ "tepc:path-request/tepc:path-in-segment/"
+ "tepc:label-restrictions/tepc:label-restriction/"
+ "tepc:label-start/tepc:te-label/tepc:technology" { 
  description
  "Augment TE label range start for the ingress segment
  of the requested path.";
  case otn {
    uses li-types:otn-label-start-end;
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
+ "tepc:path-request/tepc:path-in-segment/
+ "tepc:label-restrictions/tepc:label-restriction/
+ "tepc:label-end/tepc:te-label/tepc:technology" {
  description
  "Augment TE label range end for the ingress segment
  of the requested path."
  case otn {
    uses l1-types:otn-label-start-end;
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "tepc:path-request/tepc:path-in-segment/
  + "tepc:label-restrictions/tepc:label-restriction/
  + "tepc:label-step/tepc:technology" {
  description
  "Augment TE label range step for the ingress segment
  of the requested path."
  case otn {
    uses l1-types:otn-label-step;
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "tepc:path-request/tepc:path-out-segment/
  + "tepc:label-restrictions/tepc:label-restriction/
  + "tepc:label-start/tepc:te-label/tepc:technology" {
  description
  "Augment TE label range start for the egress segment
  of the requested path."
  case otn {
    uses l1-types:otn-label-start-end;
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "tepc:path-request/tepc:path-out-segment/
  + "tepc:label-restrictions/tepc:label-restriction/
  + "tepc:label-end/tepc:te-label/tepc:technology" {
  description
  "Augment TE label range end for the egress segment
  of the requested path."
  case otn {
    uses l1-types:otn-label-start-end;
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
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+ "tepc:path-request/tepc:path-out-segment/
+ "tepc:label-restrictions/tepc:label-restriction/
+ "tepc:label-step/tepc:technology" {
  description
  "Augment TE label range end for the egress segment
  of the requested path.";
  case otn {
    uses l1-types:otn-label-step;
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "tepc:synchronization/tepc:exclude-objects/tepc:excludes/
  + "tepc:type/tepc:label/tepc:label-hop/
  + "tepc:te-label/tepc:technology" {
  description
  "Augment TE label hop for the explicit route objects to always
  exclude from synchronized path computation.";
  case otn {
    uses l1-types:otn-label-hop;
  }
}

augment "/te:tunnels-path-compute/te:output/
  + "te:path-compute-result/tepc:response/
  + "tepc:computed-paths-properties/
  + "tepc:computed-path-properties/tepc:path-properties/
  + "tepc:path-route-objects/tepc:path-route-object/
  + "tepc:type/tepc:label/
  + "tepc:label-hop/tepc:te-label/tepc:technology" {
  description
  "Augment TE label hop for the route object of the computed
  path.";
  case otn {
    uses l1-types:otn-label-hop;
  }
}

<CODE ENDS>

Figure 7: OTN path computation YANG module

5. Manageability Considerations

  TBD.
6. Security Considerations
   <Add any security considerations>

7. IANA Considerations

This document registers the following URIs in the "ns" subregistry within the "IETF XML registry" [RFC3688].

       Registrant Contact: The IESG.
       XML: N/A, the requested URI is an XML namespace.

       Registrant Contact: The IESG.
       XML: N/A, the requested URI is an XML namespace.

       Registrant Contact: The IESG.
       XML: N/A, the requested URI is an XML namespace.

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

   name:      ietf-otn-path-computation
   prefix:    otn-pc
   reference: this document

   name:      ietf-wson-path-computation
   prefix:    wson-pc
   reference: this document

   name:      ietf-flexi-grid-path-computation
   prefix:    flexg-pc
   reference: this document

8. References

8.1. Normative References
[I-D.ietf-ccamp-layer0-types-ext]

[I-D.ietf-ccamp-layer1-types]

[I-D.ietf-teas-yang-path-computation]

[I-D.ietf-teas-yang-te]


8.2. Informative References

[I-D.ietf-ccamp-flexigrid-tunnel-yang]

[I-D.ietf-ccamp-wson-tunnel-model]

[I-D.ietf-teas-actn-poi-applicability]
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This document was prepared using kramdown.

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This document describes a YANG data model for a Remote Procedure Calls (RPC) to request Path Computation in an Optical Transport Network (OTN).

The YANG data models defined in this document conforms to the Network Management Datastore Architecture (NMDA).

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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1. Introduction

[I-D.ietf-teas-yang-path-computation] describes key use cases, where
a client needs to request underlying SDN controllers for path
computation. In some of these use cases, the underlying SDN
controller can control an Optical Transport Network (OTN).

This document defines a YANG data model, which augment the generic
Path Computation RPC defined in
[I-D.ietf-teas-yang-path-computation], with OTN technology-specific
augmentations required to request path computation to an underlying
OTN SDN controller. These models allow a client to delegate path
computation tasks to the underlying SDN controller without having to
obtain OTN detailed information from the controller and performing
feasible path computation itself.

The YANG data model defined in this document conforms to the Network
Management Datastore Architecture [RFC8342].
1.1. Terminology and Notations

Refer to [I-D.ietf-ccamp-otn-topo-yang] and [I-D.ietf-ccamp-layer1-types] for the OTN specific terms used in this document.

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

* client
* server
* augment
* data model
* data node

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

* configuration data
* 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 3 of this document. The meaning of the symbols in these diagrams is defined in [RFC8340].

1.3. 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, as shown in Table 1.
Table 1: Prefixes and corresponding YANG modules

RFC Editor Note: Please replace XXXX with the RFC number assigned to this document. Please replace YYY with the RFC number assigned to [I-D.ietf-ccamp-layer1-types]. Please replace ZZZZ with the RFC number assigned to [I-D.ietf-teas-yang-te]. Please replace KKKK with the RFC number assigned to [I-D.ietf-teas-yang-path-computation]. Please remove this note.

2. YANG Data Model for OTN Path Computation

2.1. YANG Model Overview

The YANG data model for requesting OTN path computation is defined as an augmentation of the generic Path Computation RPC defined in [I-D.ietf-teas-yang-path-computation], as shown in Figure 1.

```
+--------------------------+    o: augment
| TE generic              | ietf-te-path-computation |
+--------------------------+--------------------------+
|                          |                          |
|                          |                           |
+--------------------------+    o
| OTN                     | ietf-otn-path-computation|
+--------------------------+--------------------------+
```

Figure 1: Relationship between OTN and TE path computation models
The entities and Traffic Engineering (TE) attributes, such as requested path and tunnel attributes, defined in [I-D.ietf-teas-yang-path-computation], are still applicable when requesting OTN path computation and the models defined in this document only specifies the additional OTN technology-specific attributes/information, using the attributes defined in [I-D.ietf-ccamp-layer1-types].

The YANG module ietf-otn-path-computation defined in this document conforms to the Network Management Datastore Architecture (NMDA) defined in [RFC8342].

2.2. Bandwidth Augmentation

The OTN path computation model augments all the occurrences of the te-bandwidth container with the OTN technology-specific attributes using the otn-link-bandwidth and otn-path-bandwidth groupings defined in [I-D.ietf-ccamp-layer1-types].

2.3. Label Augmentations

The OTN path computation model augments all the occurrences of the label-restriction list with OTN technology-specific attributes using the otn-label-range-info grouping defined in [I-D.ietf-ccamp-layer1-types].

Moreover, the model augments all the occurrences of the te-label container with the OTN technology-specific attributes using the otn-label-start-end, otn-label-hop and otn-label-step groupings defined in [I-D.ietf-ccamp-layer1-types].

3. OTN Path Computation Tree Diagram

Figure 2 below shows the tree diagram of the YANG data model defined in module ietf-otn-path-computation.yang.

```yang
data-module ietf-otn-path-computation
  namespace "host:example.com"

  augment /te:tunnels-path-compute/te:input/te:path-compute-info/
    /te-pc:path-request/te-pc:te-bandwidth/te-pc:technology:
      += (otn)
      += otn
        += odu-type? identityref
        += (oduflex-type)?
          += (generic)
            += nominal-bit-rate
            += l1-types:bandwidth-scientific-notation
          += (cbr)
```
| ++- cbr-client-type       identityref  
++-:(gfp-n-k)             
  | ++- gfp-n                uint8     
  | ++- gfp-k?               gfp-k      
+++:(flexe-client)        
  | ++- flexe-client         flexe-client-rate 
+++:(flexe-aware)         
  | ++- flexe-aware-n        uint16     
+++:(packet)              
  | ++- opuflex-payload-rate  
    11-types:bandwidth-scientific-notation 
  | augment /te:tunnels-path-compute/te:input/te:path-compute-info 
  |/te-pc:tunnel-attributes/te-pc:te-bandwidth 
  |/te-pc:technology:        
+++:(otn)                 
  ++- otn                  
    | ++- odu-type?           identityref   
    | | ++- (oduflex-type)?    
    | |    | ++-:(generic)         
    | |    |    | ++- nominal-bit-rate   
    | |    |    |    11-types:bandwidth-scientific-notation 
    | |    |    |+++:(cbr)             
    | |    |    | | ++- cbr-client-type    identityref   
    | |    |    |+++:(gfp-n-k)         
    | |    |    |    | ++- gfp-n              uint8     
    | |    |    |    | ++- gfp-k?             gfp-k      
    | |    |    |+++:(flexe-client)     
    | |    |    | | ++- flexe-client       flexe-client-rate 
    | |    |    |+++:(flexe-aware)      
    | |    |    | | ++- flexe-aware-n      uint16     
    | |    |    |+++:(packet)           
    | |    |    | | ++- opuflex-payload-rate  
    | |    |    | |    11-types:bandwidth-scientific-notation 
    | |    |    | | augment /te:tunnels-path-compute/te:output/te:path-compute-result 
    | |    |    | |/te-pc:response/te-pc:computed-paths-properties 
    | |    |    | |/te-pc:computed-path-properties/te-pc:path-properties 
    | |    |    | |/te-pc:te-bandwidth/te-pc:technology: 
+++:(otn)                 
  | ++- ro otn               
    | ++- ro odu-type?         identityref   
    |+++:(generic)            
    | | ++- ro nominal-bit-rate  
    | |    11-types:bandwidth-scientific-notation 
    |+++:(cbr)                
    | | ++- ro cbr-client-type  identityref   
    |+++:(gfp-n-k)            
    | | ++- ro gfp-n            uint8
|  +--ro gfp-k?                        gfp-k
++--:(flexe-client)  
|  +--ro flexe-client      flexe-client-rate
++--:(flexe-aware)       
|  +--ro flexe-aware-n     uint16
++--:(packet)
  +--ro opuflex-payload-rate
     l1-types:bandwidth-scientific-notation
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /te-pc:path-request/te-pc:path-in-segment
  /te-pc:label-restrictions/te-pc:label-restriction:
  +++ otn-label-range
  ++-- range-type?          otn-label-range-type
  ++-- tsg?                 identityref
  ++-- odu-type-list*       identityref
  ++-- priority?            uint8
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /te-pc:path-request/te-pc:path-out-segment
  /te-pc:label-restrictions/te-pc:label-restriction:
  +++ otn-label-range
  ++-- range-type?          otn-label-range-type
  ++-- tsg?                 identityref
  ++-- odu-type-list*       identityref
  ++-- priority?            uint8
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /te-pc:path-request/te-pc:optimizations/te-pc:algorithm
  /te-pc:metric/te-pc:optimization-metric
  /te-pc:explicit-route-exclude-objects
  /te-pc:route-object-exclude-object/te-pc:type/te-pc:label
  /te-pc:label-hop/te-pc:te-label/te-pc:technology:
  +++:(otn)
  ++-- otn
  ++-- tpn?                 otn-tpn
  ++-- tsg?                 identityref
  ++-- ts-list?             string
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /te-pc:path-request/te-pc:optimizations/te-pc:algorithm
  /te-pc:metric/te-pc:optimization-metric
  /te-pc:explicit-route-include-objects
  /te-pc:route-object-include-object/te-pc:type/te-pc:label
  /te-pc:label-hop/te-pc:te-label/te-pc:technology:
  +++:(otn)
  ++-- otn
  ++-- tpn?                 otn-tpn
  ++-- tsg?                 identityref
  ++-- ts-list?             string
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /te-pc:path-request/te-pc:explicit-route-objects-always
augment /te:tunnels-path-compute/te:input/te:path-compute-info
/te-pc:path-request/te-pc:explicit-route-objects-always
/te-pc:route-object-include-exclude/te-pc:type
/te-pc:label/te-pc:label-hop/te-pc:te-label
/te-pc:technology:
++++:(otn)
++ ottn
+++ tpn?       otn-tpn
+++ tsg?       identityref
+++ ts-list?   string
augment /te:tunnels-path-compute/te:input/te:path-compute-info
/te-pc:path-request/te-pc:path-in-segment
/te-pc:label-restrictions/te-pc:label-restriction
/te-pc:label-start/te-pc:te-label/te-pc:technology:
++++:(otn)
++ ottn
+++ (range-type)?
++++:(trib-port)
| +++ tpn?       otn-tpn
++++:(trib-slot)
| +++ ts?       otn-ts
augment /te:tunnels-path-compute/te:input/te:path-compute-info
/te-pc:path-request/te-pc:path-in-segment
/te-pc:label-restrictions/te-pc:label-restriction
/te-pc:label-end/te-pc:te-label/te-pc:technology:
++++:(otn)
++ ottn
+++ (range-type)?
++++:(trib-port)
| +++ tpn?       otn-tpn
++++:(trib-slot)
| +++ ts?       otn-ts
augment /te:tunnels-path-compute/te:input/te:path-compute-info
/te-pc:path-request/te-pc:path-in-segment
/te-pc:label-restrictions/te-pc:label-restriction
/te-pc:label-step/te-pc:technology:
++++:(otn)
++ ottn
+++ (range-type)?
++++:(trib-port)
| +++ tpn?       otn-tpn
++++:(trib-slot)
| +++ ts?       otn-ts
++-- (trib-slot)
  ++ ts?  otn-ts
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /te-pc:path-request/te-pc:path-out-segment
  /te-pc:label-restrictions/te-pc:label-restriction
  /te-pc:label-start/te-pc:te-label/te-pc:technology:
  ++-- (otn)
    ++ otn
      ++-- (range-type)?
      ++-- (trib-port)
      | ++ tpn?  otn-tpn
      ++-- (trib-slot)
      ++ ts?  otn-ts
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /te-pc:path-request/te-pc:path-out-segment
  /te-pc:label-restrictions/te-pc:label-restriction
  /te-pc:label-end/te-pc:te-label/te-pc:technology:
  ++-- (otn)
    ++ otn
      ++-- (range-type)?
      ++-- (trib-port)
      | ++ tpn?  otn-tpn
      ++-- (trib-slot)
      ++ ts?  otn-ts
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /te-pc:path-request/te-pc:path-out-segment
  /te-pc:label-restrictions/te-pc:label-restriction
  /te-pc:label-step/te-pc:technology:
  ++-- (otn)
    ++ otn
      ++-- (range-type)?
      ++-- (trib-port)
      | ++ tpn?  otn-tpn
      ++-- (trib-slot)
      ++ ts?  otn-ts
augment /te:tunnels-path-compute/te:input/te:path-compute-info
  /te-pc:synchronization/te-pc:exclude-objects
  /te-pc:te-label/te-pc:technology:
  ++-- (otn)
    ++ otn
      ++-- tpn?  otn-tpn
      ++-- tsg?  identityref
      ++-- ts-list?  string
augment /te:tunnels-path-compute/te:output/te:path-compute-result
  /te-pc:response/te-pc:computed-paths-properties
  /te-pc:computed-path-properties/te-pc:path-properties
  /te-pc:path-route-objects/te-pc:path-route-object
4. YANG Model for OTN Path Computation

<CODE BEGINS> file "ietf-otn-path-computation@2022-07-10.yang"
module ietf-otn-path-computation {  
  yang-version 1.1;  
  namespace "urn:ietf:params:xml:ns:yang:ietf-otn-path-computation";  
  prefix "otn-pc";  

  import ietf-te-path-computation {  
    prefix "te-pc";  
    revision-date "2021-09-06";  
    reference  
      "I-D.ietf-teas-yang-path-computation-14: Yang model for requesting Path Computation.";  
  }  

  import ietf-te {  
    prefix "te";  
    revision-date "2021-02-20";  
    reference  
      "I-D.ietf-teas-yang-te-19: A YANG Data Model for Traffic Engineering Tunnels and Interfaces.";  
  }  

  import ietf-layer1-types {  
    prefix "l1-types";  
    reference  
      "I-D.ietf-ccamp-layer1-types: A YANG Data Model for Layer 1 Types.";  
  }  

  organization  
    "IETF CCAMP Working Group";  
  contact  
    "WG Web: <https://datatracker.ietf.org/wg/ccamp/>"  
    "WG List: <mailto:ccamp@ietf.org>"  
    "Editor: Aihua Guo"
This module defines a model for requesting OTN Path Computation.

The model fully conforms to the Network Management Datastore Architecture (NMDA).

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

revision "2022-07-10" {
  description
    "Initial version.";
  reference
      "RFC XXXX: YANG Model for OTN and Optical Path Computation";
  // RFC Ed.: replace XXXX with actual RFC number, update date
  // information and remove this note
}

/*
 * Data nodes
 */

/*
 * Augment TE bandwidth
 */

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
    + "te-pc:path-request/te-pc:te-bandwidth/te-pc:technology" {
  description
"Augment TE bandwidth of the requested path."
  case otn {
    uses l1-types:otn-path-bandwidth;
  }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
  + "te-pc:tunnel-attributes/te-pc:te-bandwidth/
  + "te-pc:technology" {
  description
    "Augment TE bandwidth of the requested tunnel attributes."
  case otn {
    uses l1-types:otn-path-bandwidth;
  }
}

augment "/te:tunnels-path-compute/te:output/
  + "te:path-compute-result/te-pc:response/
  + "te-pc:computed-paths-properties/
  + "te-pc:computed-path-properties/te-pc:path-properties/
  + "te-pc:te-bandwidth/te-pc:technology" {
  description
    "Augment TE bandwidth of the computed path properties."
  case otn {
    uses l1-types:otn-path-bandwidth;
  }
}

/*
 * Augment TE label range information
 */

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "te-pc:path-request/te-pc:path-in-segment/
  + "te-pc:label-restrictions/te-pc:label-restriction" {
  description
    "Augment TE label range information for the ingress segment of the requested path.";
  uses l1-types:otn-label-range-info;
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/
  + "te-pc:path-request/te-pc:path-out-segment/
  + "te-pc:label-restrictions/te-pc:label-restriction" {
  description
    "Augment TE label range information for the egress segment of the requested path.";
  uses l1-types:otn-label-range-info;
}
augment "/te:tunnels-path-compute/te:input/te:path-compute-info/" 
+ "te-pc:path-request/te-pc:optimizations/te-pc:algorithm/"
+ "te-pc:metric/te-pc:optimization-metric/"
+ "te-pc:explicit-route-exclude-objects/"
+ "te-pc:route-object-exclude-object/te-pc:type/te-pc:label/"
+ "te-pc:label-hop/te-pc:te-label/te-pc:technology" {
  description
  "Augment TE label hop for the optimization of the explicit 
  route objects excluded by the path computation of the requested 
  path.";
  case otn {
    uses l1-types:otn-label-hop;
  }
}
augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
 + "te-pc:path-request/te-pc:explicit-route-objects-always/
 + "te-pc:route-object-include-exclude/te-pc:type/
 + "te-pc:technology" {
    description
    "Augment TE label hop for the explicit route objects included or excluded by the path computation of the requested path.";
    case otn {
        uses l1-types:otn-label-hop;
    }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
 + "te-pc:path-request/te-pc:path-in-segment/
 + "te-pc:label-restrictions/te-pc:label-restriction/
 + "te-pc:label-start/te-pc:te-label/te-pc:technology" {
    description
    "Augment TE label range start for the ingress segment of the requested path.";
    case otn {
        uses l1-types:otn-label-start-end;
    }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
 + "te-pc:path-request/te-pc:path-in-segment/
 + "te-pc:label-restrictions/te-pc:label-restriction/
 + "te-pc:label-end/te-pc:te-label/te-pc:technology" {
    description
    "Augment TE label range end for the ingress segment of the requested path.";
    case otn {
        uses l1-types:otn-label-start-end;
    }
}

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
 + "te-pc:path-request/te-pc:path-in-segment/
 + "te-pc:label-restrictions/te-pc:label-restriction/
 + "te-pc:label-step/te-pc:technology" {
    description
    "Augment TE label range step for the ingress segment of the requested path.";
    case otn {
        uses l1-types:otn-label-step;
    }
}
augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
  + "te-pc:path-request/te-pc:path-out-segment/"
  + "te-pc:label-restrictions/te-pc:label-restriction/"
  + "te-pc:label-start/te-pc:te-label/te-pc:technology" { 
    description
      "Augment TE label range start for the egress segment
      of the requested path.";
    case otn {
      uses li-types:otn-label-start-end;
    }
  }

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
  + "te-pc:path-request/te-pc:path-out-segment/"
  + "te-pc:label-restrictions/te-pc:label-restriction/"
  + "te-pc:label-end/te-pc:te-label/te-pc:technology" { 
    description
      "Augment TE label range end for the egress segment
      of the requested path.";
    case otn {
      uses li-types:otn-label-start-end;
    }
  }

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
  + "te-pc:path-request/te-pc:path-out-segment/"
  + "te-pc:label-restrictions/te-pc:label-restriction/"
  + "te-pc:label-step/te-pc:technology" { 
    description
      "Augment TE label range end for the egress segment
      of the requested path.";
    case otn {
      uses li-types:otn-label-step;
    }
  }

augment "/te:tunnels-path-compute/te:input/te:path-compute-info/"
  + "te-pc:synchronization/te-pc:exclude-objects/"
  + "te-pc:excludes/te-pc:type/te-pc:label/te-pc:label-hop/"
  + "te-pc:te-label/te-pc:technology" { 
    description
      "Augment TE label hop for the explicit route objects to always
      exclude from synchronized path computation.";
    case otn {
      uses li-types:otn-label-hop;
    }
  }

augment "/te:tunnels-path-compute/te:output/
    + "te:path-compute-result/te-pc:response/
    + "te-pc:computed-paths-properties/
    + "te-pc:computed-path-properties/te-pc:path-properties/"
    + "te-pc:path-route-objects/te-pc:path-route-object/
    + "te-pc:type/te-pc:label/
    + "te-pc:label-hop/te-pc:te-label/te-pc:technology" {
    description
        "Augment TE label hop for the route object of the computed path.";
    case otn {
        uses l1-types:otn-label-hop;
    }
}

Figure 3: OTN path computation YANG module

5. Manageability Considerations

TBD.

6. Security Considerations

<Add any security considerations>

7. IANA Considerations

This document registers the following URIs in the "ns" subregistry within the "IETF XML registry" [RFC3688].

Registrant Contact: The IESG.
XML: N/A, the requested URI is an XML namespace.

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

name:     ietf-otn-path-computation
prefix:   otn-pc
reference: this document

8. References

8.1. Normative References
8.2. Informative References

Acknowledgments

The authors of this document would like to thank the authors of [I-D.ietf-teas-actn-poi-applicability] for having identified the gap and requirements to trigger this work.

This document was prepared using kramdown.

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A YANG Data Model for L1 Connectivity Service Model (L1CSM)
draft-ietf-ccamp-l1csm-yang-17

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.
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:

* client
* server
* augment
* data model
* data node

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

* configuration data
* 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.

<table>
<thead>
<tr>
<th>Prefix</th>
<th>YANG module</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>l1csm</td>
<td>ietf-l1csm</td>
<td>[RFC XXXX]</td>
</tr>
<tr>
<td>11-types</td>
<td>ietf-layer1-types</td>
<td>[I-D.ietf-ccamp-layer1-types]</td>
</tr>
<tr>
<td>yang</td>
<td>ietf-yang-types</td>
<td>[RFC6991]</td>
</tr>
</tbody>
</table>

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-l1csm
  +++rw l1-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 leafref
       +++rw endpoint-2
           +++rw id string
           +++rw uni leafref
       +++rw start-time? yang:date-and-time
       +++rw time-interval? uint32
       +++rw performance-metric* identityref

4. L1CSM YANG Code

<CODE BEGINS>
file "ietf-l1csm@2021-12-13.yang"
module ietf-l1csm {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-l1csm";
  prefix "l1csm";

  import ietf-yang-types {
    prefix "yang";
    reference
    "RFC6991: Common YANG Data Types";
  }

  import ietf-layer1-types {
    prefix "l1-types";
    reference
    "RFCYYYY: A YANG Data Model for Layer 1 Types";
  }

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.

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

revision "2021-12-13" {
  description
    "Initial revision.";
  reference
    "RFC XXXX: A Yang Data Model for L1 Connectivity Service Model (L1CSM)";
  // Note: The RFC Editor will replace XXXX/YYYY with the number assigned to the RFC once this draft becomes an RFC.
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 "The time elapsed from the reception of the first bit of the ingress until the reception of the first bit of the egress.";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
}

identity one-way-errored-second {
    base service-performance-metric;
    description "One second in the available time with at least one errored block, but not a severely errored second.";
    reference "MEF63: Subscriber Layer 1 Service Attributes";
}

identity one-way-severely-errored-second {
    base service-performance-metric;
    description "One second which contains more than 15 percent errored info, or contains a defect (e.g., loss of signal)."
    reference "MEF63: Subscriber Layer 1 Service Attributes";
}

identity one-way-unavailable-second {
    base service-performance-metric;
    description "One second during unavailable time."
    reference "MEF63: Subscriber Layer 1 Service Attributes";
}
identity one-way-availability {
  base service-performance-metric;
  description
    "The percentage of available time over a given interval.";
  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
    "MEF63: Subscriber Layer 1 Service Attributes";

  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-l1vc-sls-service-attributes {
  description
      "A set of service attributes on L1VC Service Level Specification (SLS) that are agreed between the service provider and the subscriber.";
  reference
      "MEF63: Subscriber Layer 1 Service Attributes";

  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 uint32;
    units seconds;
    description
      "A time interval (e.g., 2,419,200 seconds which is 28 days) that is used in conjunction with 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-l1vc-endpoint-attributes {
  description
    "Subscriber layer 1 connection endpoint attributes";
  reference
    "MEF63: Subscriber Layer 1 Service Attributes";

  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;
        must '. != ../../endpoint-1/id' {
            error-message
                "The two end points must not be equal to each other. ";
        }
        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 (llcs)";
}

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
         "A unique identifier of a subscriber L1VC service";
      leaf service-id {
         type string;
         description
            "A unique service identifier for subscriber L1VC.";
      }
   }
}
5. 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.

6. IANA Considerations

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

   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-l1csm
   prefix:       l1csm
   reference:    RFC XXXX

7. Acknowledgements

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9. References

9.1. Normative References
9.2. Informative References


Appendix A. 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 is 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 "  
                    }  
                ]  
            }  
        }  
    }  
}

Authors’ Addresses
A YANG Data Model for Microwave Topology
draft-ietf-ccamp-mw-topo-yang-03

Abstract

This document defines three YANG data models to describe topologies
of microwave/millimeter radio links and bandwidth availability for a
link in general, as well as to reference interface management
information from a termination point.

Discussion Venues

This note is to be removed before publishing as an RFC.

Source for this draft and an issue tracker can be found at

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Authors’ Addresses

1. Introduction

This document defines three YANG data models to describe topologies of microwave/millimeter wave (hereafter microwave is used to simplify the text). The first YANG data model describes radio links, supporting carrier(s) and the associated termination points. A carrier is a description of a link providing transport capacity over the air by a single carrier. It is typically defined by its transmitting and receiving frequencies. A radio link is a link providing the aggregated transport capacity of the supporting carriers in aggregated and/or protected configurations, which can be used to carry traffic on higher topology layers such as Ethernet and TDM. A second YANG data model describes bandwidth availability for a link. It is an important characteristic of a microwave radio link, but it could also be applicable for other types of links. A third YANG data model introduces a way to reference the information in a YANG data model for interface management [RFC8343] from a termination point, which is useful for microwave termination points, but which could also be useful for other types of termination points. All three models augment "YANG Data Model for Traffic Engineering (TE) Topologies" defined in [RFC8795], which is based on "A YANG Data Model for Network Topologies" defined in [RFC8345].

The microwave point-to-point radio technology provides connectivity on L0/L1 over a radio link between two termination points, using one or several supporting carriers in aggregated or protected configurations. That application of microwave technology cannot be used to perform cross-connection or switching of the traffic to create network connectivity across multiple microwave radio links.
Instead, a payload of traffic on higher topology layers, normally L2 Ethernet, is carried over the microwave radio link and when the microwave radio link is terminated at the endpoints, cross-connection and switching can be performed on that higher layer creating connectivity across multiple supporting microwave radio links.

The microwave topology, the bandwidth availability, and the interface reference models are expected to be used between a Provisioning Network Controller (PNC) and a Multi Domain Service Coordinator (MDSC) [RFC8453]. Examples of use cases that can be supported are:

1. Correlation between microwave radio links and the supported links on higher topology layers. e.g. an L2 Ethernet topology. This information can be used to understand how changes in the performance/status of a microwave radio link affects traffic on higher layers.

2. Propagation of relevant characteristics of a microwave radio link, such as bandwidth, to higher topology layers, where it e.g. could be used as a criterion when configuring and optimizing a path for a connection/service through the network end to end.

3. Optimization of the microwave radio link configurations on a network level, e.g. with the purpose to minimize overall interference and/or maximize the overall capacity provided by the links.

4. A microwave radio link could dynamically adjust its bandwidth according to changes in the signal conditions. [RFC8330] defines a mechanism to report bandwidth-availability information through OSPF-TE, but it could also be useful for a controller to access such bandwidth-availability information as part of the topology model when performing a path/route computation.

Different use cases require access to different attributes and in order not to restrict what use cases can be supported, all attributes supported by the microwave radio link interface management model is accessible from the topology model.

1.1. Terminology and Definitions

The following acronyms are used in this document:

PNC Provisioning Network Controller

MDSC Multi Domain Service Coordinator

1.2. Tree Structure

A simplified graphical representation of the data models is used in chapters 3.1, 4.1, and 5.1 of this document. The meaning of the symbols in these diagrams is defined in [RFC8340].

2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

3. Microwave Topology YANG Data Model
3.1. YANG Tree

module: ietf-microwave-topology

augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
  ++--rw mw-topology!
augment /nw:networks/nw:network/nw:node/nt:termination-point/tet:te:
  ++--rw mw-tp-choice
    ++--rw (mw-tp-option)?
      ++--:(microwave-rltp)
      |   ++--rw microwave-rltp!
      ++--:(microwave-ctp)
      ++--rw microwave-ctp!

augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes:
  ++--rw mw-link-choice
    ++--rw (mw-link-option)?
      ++--:(microwave-radio-link)
      |    ++--rw microwave-radio-link!
      |    ++--rw mode? identityref
      ++--:(microwave-carrier)
        ++--rw microwave-carrier!
          ++--rw tx-frequency?                       uint32
          ++--rw rx-frequency?                       uint32
          ++--rw channel-separation?                 uint32
          ++--ro actual-tx-cm?                       identityref
          ++--ro actual-snir?                        decimal64
          ++--ro actual-transmitted-level?           power

augment /nw:networks/nw:network/nt:link/tet:te/
  tet:te-link-attributes/tet:max-link-bandwidth/
  tet:technology:
    ++--:(microwave)
      ++--ro mw-bandwidth?                      uint64

3.2. Relationship between radio links and carriers

A microwave radio link is always an aggregate of one or multiple carries, in various configurations/modes. The supporting carriers are identified by its termination points and are listed in the container bundled-links as part of the te-link-config in the YANG Data Model for Traffic Engineering (TE) Topologies [RFC8795] for a radio-link. The exact configuration of the included carriers is further specified in the leaf mode (1+0, 2+0, 1+1, etc.) for the radio-link. Appendix A includes an JSON example of how such a relationship can be modelled.

3.3. Relationship with client topology model

A microwave radio link carries a payload of traffic on higher topology layers, normally L2 Ethernet. The leafs supporting-network, supporting-node, supporting-link, and supporting-termination-point in the generic YANG module for Network Topologies [RFC8345] are expected to be used to model a relationship/dependency from higher topology layers to a supporting microwave radio link topology layer. Appendix A includes an JSON example of an L2 Ethernet link transported over one supporting microwave link.

3.4. Applicability of the Data Model for Traffic Engineering (TE) Topologies

Since microwave is a point-to-point radio technology providing
connectivity on L0/L1 over a radio link between two termination points and cannot be used to perform cross-connection or switching of the traffic to create network connectivity across multiple microwave radio links, a majority of the leaves in the Data Model for Traffic Engineering (TE) Topologies augmented by the microwave topology model are not applicable. An example of which leaves are considered applicable can be found in appendix "Examples of the application of the Topology Models" in this document. Appendix A

More specifically, admin-status and oper-status are recommended to be reported for links only. Status for termination points can be used when links are inter-domain and when the status of only one side of link is known, but since microwave is a point-to-point technology where both ends normally belong to the same domain it is not expected to be applicable in normal cases. Furthermore, admin-status is not applicable for microwave radio links. Enable and disable of a radio link is instead done in the constituent carriers.

3.5. Model applicability to other technology

TBD

3.6. Microwave Topology YANG Module

<CODE BEGINS> file "ietf-microwave-topology@2021-10-20.yang"
module ietf-microwave-topology { 
  yang-version "1.1";
  namespace 
  "urn:ietf:params:xml:ns:yang:ietf-microwave-topology";
  prefix "mwtopo";

  import ietf-network { 
    prefix "nw";
    reference "RFC 8345: A YANG Data Model for Network Topologies";
  }

  import ietf-network-topology { 
    prefix "nt";
    reference "RFC 8345: A YANG Data Model for Network Topologies";
  }

  import ietf-te-topology { 
    prefix "tet";
    reference "RFC 8795: YANG Data Model for Traffic Engineering (TE) Topologies";
  }

  import ietf-microwave-types { 
    prefix mw-types;
    reference "RFC 8561";
  }

  organization 
  "Internet Engineering Task Force (IETF) CCAMP WG";
  contact 
  "WG List: <mailto:ccamp@ietf.org>

  //JonasA Who would like to be on the list of editors/contributors?
  Editor: Jonas Ahlberg
  <mailto:jonas.ahlberg@ericsson.com>
  Editor: Scott Mansfield
description "This is a module for microwave topology."

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revision 2021-10-20 {
  description "Draft to be used as a basis for the continued microwave team discussions";
  reference "";
}

/*
 * Typedefs
 */
typedef power {
  type decimal64 {
    fraction-digits 1;
  }
  description "Type used for the power values 'selected' and 'measured'.";
}

/*
 * Groupings
 */
grouping microwave-rltp-attributes {
  description "Grouping used for attributes describing a microwave radio link termination point.";

  //Any attributes to be included?
}

grouping microwave-ctp-attributes {
  description "Grouping used for attributes describing a microwave carrier termination point.";
}
grouping microwave-radio-link-attributes {
    description "Grouping used for attributes describing a microwave radio link.";
    leaf mode {
        type identityref {
            base mw-types:rlt-mode;
        }
        description
            "A description of the mode in which the radio link is configured. The format is X plus Y.
            X represents the number of bonded carriers.
            Y represents the number of protecting carriers.
            Related to the data node rlt-mode in RFC 8561.";
        reference
            "RFC 8561: A YANG Data Model for Microwave Radio Link";
    }
}

// Any other attributes to be included?

grouping microwave-carrier-attributes {
    description "Grouping used for attributes describing a microwave carrier.";
    leaf tx-frequency {
        type uint32;
        units "kHz";
        description
            "Selected transmitter frequency. Related to the data node tx-frequency in RFC 8561.";
        reference
            "RFC 8561: A YANG Data Model for Microwave Radio Link";
    }
    leaf rx-frequency {
        type uint32;
        units "kHz";
        description
            "Selected receiver frequency. Related to the data node actual-rx-frequency in RFC 8561.";
        reference
            "RFC 8561: A YANG Data Model for Microwave Radio Link";
    }
    leaf channel-separation {
        type uint32;
        units "kHz";
        description
            "The amount of bandwidth allocated to a carrier. The distance between adjacent channels in a radio frequency channels arrangement. Related to the data node channel-separation in RFC 8561.";
        reference
            "ETSI EN 302 217-1 and RFC 8561: A YANG Data Model for Microwave Radio Link";
    }
    leaf actual-tx-cm {
        type identityref {
            base mw-types:coding-modulation;
        }
        config false;
        description
            "Actual coding/modulation in transmitting direction.";
    }
}
Related to the data node actual-tx-cm in RFC 8561.

leaf actual-snir {
  type decimal64 {
    fraction-digits 1;
    range "0..99";
  }
  units "dB";
  config false;
  description
  "Actual signal to noise plus the interference ratio
   (0.1 dB resolution).
   Related to the data node actual-snir in RFC 8561.";
  reference
  "RFC 8561: A YANG Data Model for Microwave Radio Link";
}

leaf actual-transmitted-level {
  type power {
    range "-99..99";
  }
  units "dBm";
  config false;
  description
  "Actual transmitted power level (0.1 dBm resolution).
   Related to the data node actual-transmitted-level
   in RFC 8561.";
  reference
  "ETSI EN 301 129 and
   RFC 8561: A YANG Data Model for Microwave Radio Link";
}

//Any other attributes to be included?

grouping microwave-bandwidth {
  description "Grouping used for microwave bandwidth.";
  leaf mw-bandwidth {
    type uint64;
    units "Kbps";
    config false;
    description
    "Nominal microwave radio link and carrier bandwidth.";
  }
}

/*
 * Data nodes
 */

augment "/nw:networks/nw:network/nw:network-types/"
  + "tet:te-topology" {
  description
  "Augment network types to define a microwave network
topology type.";
  container mw-topology {
    presence "Indicates a topology type of microwave.";
    description "Microwave topology type";
  }
}

augment "/nw:networks/nw:network/nw:node/nt:termination-point/"
description
"Augmentation parameters apply only for networks with an microwave network topology type.");
}

description
"Augmentation to add microwave technology specific characteristics to a termination point.");
container mw-tp-choice {
  description "Specification of type of termination point.");
  choice mw-tp-option {
    description "Selection of type of termination point.");
    case microwave-rltp {
      container "microwave-rltp" {
        presence
        "Denotes a microwave radio link termination point. It corresponds to a microwave RLT interface as defined in RFC 8561.";
        uses microwave-rltp-attributes;
        description
        "Denotes and describes a microwave radio link termination point.");
      }
    }
    case microwave-ctp {
      container "microwave-ctp" {
        presence
        "Denotes a microwave carrier termination point. It corresponds to a microwave CT interface as defined in RFC 8561.";
        uses microwave-ctp-attributes;
        description
        "Denotes and describes a microwave carrier termination point.");
      }
    }
  }
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:te-link-attributes" {
    when ’../../../../nw:network-types/tet:te-topology/’
    + ’mwtopo:mw-topology’ {
      description
      "Augmentation parameters apply only for networks with an microwave network topology type.");
    }
    description
    "Augmentation to add microwave technology specific characteristics to a link.");
    container mw-link-choice {
      description "Specification of type of link.");
      choice mw-link-option {
        description "Selection of type of link.");
        case microwave-radio-link {
          container "microwave-radio-link" {
            presence
            "Denotes a microwave radio link";
            uses microwave-radio-link-attributes;
description
  "Denotes and describes a microwave radio link";
}
}
case microwave-carrier {
  container "microwave-carrier" {
    presence "Denotes a microwave carrier";
    uses microwave-carrier-attributes;
    description "Denotes and describes a microwave carrier";
  }
}
}

  + "tet:te-link-attributes/
  + "tet:max-link-bandwidth/
  + "tet:te-bandwidth/tet:technology" {
    when '../../../../nw:network-types/tet:te-topology/
    + 'mwtopo:mw-topology' {
      description
        "Augmentation parameters apply only for networks with an
        microwave network topology type.";
    }
    description
      "Augmentation for TE bandwidth.";
    case microwave {
      uses microwave-bandwidth;
    }
  }
}

<CODE ENDS>

4. Bandwidth Availability Topology YANG Data Model

4.1. YANG Tree

module: ietf-bandwidth-availability-topology

augment
  /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes:
    +--rw link-availability* [availability]
    |  +--rw availability  decimal64
    |  +--rw link-bandwidth?  uint64
    +--ro actual-bandwidth?  yang:gauge64

4.2. Bandwidth Availability Topology YANG Data Module

<CODE BEGINS> file "ietf-bandwidth-availability-topology.yang"
module ietf-bandwidth-availability-topology {
  yang-version "1.1";
  namespace
  prefix "bwatopo";

  import ietf-yang-types {
    prefix yang;
    reference
      "RFC 6991";
  }
import ietf-network {
    prefix "nw";
    reference "RFC 8345: A YANG Data Model for Network Topologies";
}

import ietf-network-topology {
    prefix "nt";
    reference "RFC 8345: A YANG Data Model for Network Topologies";
}

import ietf-te-topology {
    prefix "tet";
    reference "RFC 8795: YANG Data Model for Traffic Engineering (TE) Topologies";
}

organization
    "Internet Engineering Task Force (IETF) CCAMP WG";
contact
    "WG List: <mailto:ccamp@ietf.org>
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// Note to RFC Editor: replace XXXX with actual RFC number and
// remove this note.
description
    "This is a module for defining bandwidth availability matrix,
for links in a topology. It is intended to be used in
conjunction with an instance of ietf-network-topology and its
augmentations.
Example use cases include:
- Defining bandwidth availability matrix for a microwave link
- Defining bandwidth availability matrix for a LAG link
    comprising of two or more member links

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Relating to IETF Documents
(http://trustee.ietf.org/license-info).
This version of this YANG module is part of RFC XXXX
(https://tools.ietf.org/html/rfcXXXX); see the RFC itself for
full legal notices.";

revision 2021-10-20 {
null
5.1. YANG Tree

module: ietf-tp-interface-reference-topology

augment /nw:networks/nw:network/nw:node/nt:termination-point/tet:te:
   +--rw tp-to-interface-path?   -> /if:interfaces/interface/name

5.2. Termination Point to Interface Reference YANG Data Module

<CODE BEGINS> file "ietf-tp-interface-reference-topology.yang"
module ietf-tp-interface-reference-topology {
   yang-version "1.1";
   prefix "ifref";

   import ietf-network {
      prefix "nw";
      reference "RFC 8345: A YANG Data Model for Network Topologies";
   }

   import ietf-network-topology {
      prefix "nt";
      reference "RFC 8345: A YANG Data Model for Network Topologies";
   }

   import ietf-te-topology {
      prefix "tet";
      reference "RFC 8795: YANG Data Model for Traffic Engineering (TE) Topologies";
   }

   import ietf-interfaces {
      prefix if;
      reference "RFC 8343";
   }

   organization
      "Internet Engineering Task Force (IETF) CCAMP WG";
   contact
      "WG List: <mailto:ccamp@ietf.org>

   //[JonasA] Who would like to be on the list of editors/contributors?
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      <mailto:daniela.spreafigco@nokia.com>

   // Note to RFC Editor: replace XXXX with actual RFC number and
   // remove this note.
description
"This is a module for defining a reference from a termination point in a te topology to a list element in interfaces as defined in RFC 8343.

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revision 2021-10-20 {
    description
    "First rough draft."
    reference ""

    /*
     * Groupings
     */
    grouping tp-to-interface-ref {
        description
        "Grouping used for reference between a termination point and an interface."
        leaf tp-to-interface-path {
            type leafref {
                path '/if:interfaces/if:interface/if:name';
            }
            description
            "Leafref expression referencing a list element, identified by its name, in interfaces as defined in RFC 8343."
        }
    }

    /*
     * Data nodes
     */
    augment "/nw:networks/nw:network/nw:node/nt:termination-point/" + "tet:te" {
        description
        "Augmentation to add possibility to reference an element in the list of interfaces as defined by RFC 8343."
        uses tp-to-interface-ref;
    }
}

6. Security Considerations

The YANG modules specified in this document define schemas 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 modules specified in this document import and augment the ietf-network and ietf-network-topology models defined in [RFC8345]. The security considerations from [RFC8345] are applicable to the modules in this document.

There are several data nodes defined in these YANG modules that are writable/creatable/deletable (i.e., config true, which is the default). These 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. These are the subtrees and data nodes and their sensitivity/vulnerability:

In the "ietf-microwave-topology" module:

* rlt-interface-path: A malicious client could set an arbitrary xpath that could allow a client to retrieve incorrect information. Troubleshooting would be difficult because the bad path would not be detectable until the client tries to use the leaf to identify to radio link terminal.

In the "ietf-bandwidth-availability-topology" module:

* availability: A malicious client could attempt to modify the availability level which could modify the intended behavior.

* link-bandwidth: A malicious client could attempt to modify the link bandwidth which could either provide more or less link bandwidth at the indicated availability level, changing the resource allocation in unintended ways.

7. IANA Considerations

IANA is asked to assign a new URI from the "IETF XML Registry" [RFC3688] as follows:

Registrant Contact: The IESG
XML: N/A; the requested URI is an XML namespace.

Registrant Contact: The IESG
XML: N/A; the requested URI is an XML namespace.

It is proposed that IANA should record YANG module names in the "YANG Module Names" registry [RFC6020] as follows:

Name: ietf-microwave-topology
Maintained by IANA?: N
Prefix: mwtopo
Reference: RFC XXXX
8. References

8.1. Normative References


8.2. Informative References


Appendix A. Examples of the application of the Topology Models

This appendix provides some examples and illustrations of how the Microwave Topology Model and the Bandwidth Availability Topology Model can be used. There is one extended tree to illustrate the complete Microwave Topology Model and a JSON based instantiation of the Microwave Topology Model for a small network example.

A.1. A tree for a complete Microwave Topology Model

The tree below shows the leafs for a complete Microwave Topology Model including the augmented Network Topology Model defined in [RFC8345], Traffic Engineering (TE) Topologies model defined in [RFC8795] and the associated Bandwidth Availability Model.

```text
module: ietf-network
  +-rw networks
    +-rw network* [network-id]
      |-+rw network-id network-id
      |-+rw network-types
        |-+rw tet:te-topology!
          |-+rw mwtopo:mw-topology!
        |-+rw supporting-network* [network-ref]
          |-+rw network-ref -> /networks/network/network-id
      +-rw node* [node-id]
        |-+rw node-id node-id
        |-+rw supporting-node* [network-ref node-ref]
          |-+rw network-ref
            |-+rw node-ref -> ../../supporting-network/network-ref
            |-+rw network-ref -> /networks/network/node/node-id
        +-rw nt:termination-point* [tp-id]
```
A.2. A topology with single microwave radio link

Microwave is a transport technology which can be used to transport client services, such as L2 Ethernet links. When an L2 link is transported over a single supporting microwave radio link, the topologies could be as shown below. Note that the figure just shows an example, there might be other possibilities to demonstrate such a topology. The example of the instantiation encoded in JSON is using only a selected subset of the leafs from the L2 topology model [RFC8944] and the Microwave Interface Management Model [RFC8561].

```
L2 transported over a (2+0) microwave radio link
```

```
Node N1                              Interfaces
----------------------------------------
  +-----------------+                   +-----------------+
  | L2-N1-TP1      | tp-to-interface-path | +-----------------+
  | +-------------+---------+                   | +-----------------+
  | *             | **                     | *                 |
  | +-------------+---------+                   | +-----------------+
  | mw-N1-CTP1    | * mw-N2-CTP1         | * mw-N2-CTP2      |
  | +-------------+---------+                   | +-----------------+
  | *             | **                     | *                 |
  | +-------------+---------+                   | +-----------------+
  | mw-N1-CTP3    | * mw-N2-CTP3         |                   |
  +-----------------+                   +-----------------+
```

```
Node N2
```

```
----------------------------------------
  +-----------------+                   +-----------------+
  | L2-N1-N-N2      | tp-to-interface-path | +-----------------+
  | +-------------+---------+                   | +-----------------+
  | *             | **                     | *                 |
  | +-------------+---------+                   | +-----------------+
  | mw-N1-mwrl-N2  | * mw-N2-mwrl-N2      | *                 |
  | +-------------+---------+                   | +-----------------+
  | *             | **                     | *                 |
  | +-------------+---------+                   | +-----------------+
  | mw-N1-mwc-N1-N2-A | * mw-N2-mwc-N1-N2-A | * mw-N2-mwc-N2-N2-A |
  +-----------------+                   +-----------------+
```

```
L2-network
```

```
L2 topology
```

```
Supporting
```

```
mw link
```

```
TPs
```

```
MW-network
```

```
Supporting
```

```
TPs
```

```
carriers as bundled links
```

```
---
```
The example above, a L2 network with a supporting microwave network, including microwave-topology (MW) and bandwidth-availability-topology (BWA) models as well as the reference to the associated interface management information, is encoded in JSON as follows:

```
<CODE BEGINS> file "example2plus0-f.json"
=============== NOTE: '\\' line wrapping per RFC 8792 ================
{
    "ietf-network:networks": {
        "network": [
            {
                "network-id": "L2-network",
                "network-types": {
                    "ietf-te-topology:te-topology": {
                        "ietf-eth-te-topology:eth-tran-topology": {
                        }
                    }
                },
                "supporting-network": [
                    {
                        "network-ref": "mw-network"
                    }
                ],
            }
        ]
    }
}
```

This example shows a 2+0 mode for a bonded configuration.

Node N1

```
Topography model information to the associated interface management model information for Node N1
```

```
+-----------+ tp-to-interface-path +-----------+
| mw-N1-RLTP1 | RLT-1                  |
+-----------+------------------------+
| mw-N1-CTP1 | CT-1                   |
+-----------+------------------------+
| mw-N1-CTP3 | CT-3                   |
+-----------+------------------------+
```

Interfaces

```
Topography model information to the associated interface management model information for Node N1
```

```
+-----------+ tp-to-interface-path +-----------+
| L2-N2-TP2 | L2Interface2           |
+-----------+------------------------+
| mw-N2-RLTP2 | RLT-2                  |
+-----------+------------------------+
| mw-N2-CTP2 | CT-2                   |
+-----------+------------------------+
| mw-N2-CTP4 | CT-4                   |
+-----------+------------------------+
```

Node N2

```
Topography model information to the associated interface management model information for Node N2
```

The example above, a L2 network with a supporting microwave network, including microwave-topology (MW) and bandwidth-availability-topology (BWA) models as well as the reference to the associated interface management information, is encoded in JSON as follows:

```
<CODE BEGINS> file "example2plus0-f.json"
=============== NOTE: '\\' line wrapping per RFC 8792 ================
{
    "ietf-network:networks": {
        "network": [
            {
                "network-id": "L2-network",
                "network-types": {
                    "ietf-te-topology:te-topology": {
                        "ietf-eth-te-topology:eth-tran-topology": {
                        }
                    }
                },
                "supporting-network": [
                    {
                        "network-ref": "mw-network"
                    }
                ],
            }
        ]
    }
}
```

This example shows a 2+0 mode for a bonded configuration.
"node": [
  {
    "node-id": "L2-N1",
    "supporting-node": [
      {
        "network-ref": "mw-network",
        "node-ref": "mw-N1"
      }
    ],
    "ietf-network-topology:termination-point": [
      {
        "tp-id": "L2-N1-TP1",
        "supporting-termination-point": [
          {
            "network-ref": "mw-network",
            "node-ref": "mw-N1",
            "tp-ref": "mw-N1-RLTP1"
          }
        ]
      }
    ],
    "node-id": "L2-N2",
    "supporting-node": [
      {
        "network-ref": "mw-network",
        "node-ref": "mw-N2"
      }
    ],
    "ietf-network-topology:termination-point": [
      {
        "tp-id": "L2-N2-TP2",
        "supporting-termination-point": [
          {
            "network-ref": "mw-network",
            "node-ref": "mw-N2",
            "tp-ref": "mw-N2-RLTP2"
          }
        ]
      }
    ],
    "ietf-network-topology:link": [
      {
        "link-id": "L2-N1-N2",
        "source": {
          "source-node": "L2-N1",
          "source-tp": "L2-N1-TP1"
        },
        "destination": {
          "dest-node": "L2-N2",
          "dest-tp": "L2-N2-TP2"
        },
        "supporting-link": [
          {
            "network-ref": "mw-network",
            "link-ref": "mwl-N1-N2"
          }
        ]
      }
    ]
  }
]
"network-id": "mw-network",
"network-types": {
   "ietf-te-topology:te-topology": {
       "ietf-microwave-topology:mw-topology": {
       }
   }
},
"supporting-network": [ {
   "network-ref": "mw-network"
},
"node": [ {
   "node-id": "mw-N1",
   "supporting-node": [ {
      "network-ref": "mw-network",
      "node-ref": "mw-N1"
   } ],
   "ietf-network-topology:termination-point": [ {
      "tp-id": "mw-N1-RLTP1",
      "supporting-termination-point": [ {
         "network-ref": "mw-network",
         "node-ref": "mw-N1",
         "tp-ref": "mw-N1-CTP1"
      },
      "network-ref": "mw-network",
      "node-ref": "mw-N1",
      "tp-ref": "mw-N1-CTP3"
   } ],
   "ietf-te-topology:te-tp-id": "10.10.10.1",
   "ietf-te-topology:te": { "ietf-microwave-topology:mw-tp-choice": { "microwave-rltp": {} },
   "ietf-tp-interface-reference-topology:tp-to-interface-path": "RLT-1"
   },
   "ietf-te-topology:te-tp-id": 1,
   "ietf-te-topology:te": { "ietf-microwave-topology:mw-tp-choice": { "microwave-ctp": {} },
   "ietf-tp-interface-reference-topology:tp-to-interface\ ace-path": "CT-1"
   },
   "tp-id": "mw-N1-CTP3",
   "ietf-te-topology:te-tp-id": 2,
"ietf-te-topology:te": {
    "ietf-microwave-topology:mw-tp-choice": {
    "microwave-ctp": {}  
    },
    "ietf-tp-interface-reference-topology:tp-to-interface-path": "CT-3"
  }
},
},
{
  "node-id": "mw-N2",
  "supporting-node": [
    {
    "network-ref": "mw-network",
    "node-ref": "mw-N2"
    }
  ],
  "ietf-network-topology:termination-point": [
    {
    "tp-id": "mw-N2-RLTP2",
    "supporting-termination-point": [
    {
    "network-ref": "mw-network",
    "node-ref": "mw-N2",
    "tp-ref": "mw-N2-CTP2"
    },
    {  
    "network-ref": "mw-network",
    "node-ref": "mw-N2",
    "tp-ref": "mw-N2-CTP4"
    }   
    ],
    "ietf-te-topology:te-tp-id": "10.10.10.1",
    "ietf-te-topology:te": {
    "ietf-microwave-topology:mw-tp-choice": {
    "microwave-rltp": {} 
    },
    "ietf-tp-interface-reference-topology:tp-to-interface-path": "RLT-2"
    }
  }
},
{
  "tp-id": "mw-N2-CTP2",
  "ietf-te-topology:te-tp-id": 1,
  "ietf-te-topology:te": {
    "ietf-microwave-topology:mw-tp-choice": {
    "microwave-ctp": {} 
    },
    "ietf-tp-interface-reference-topology:tp-to-interface-path": "CT-2"
  }
},
{
  "tp-id": "mw-N2-CTP4",
  "ietf-te-topology:te-tp-id": 2,
  "ietf-te-topology:te": {
    "ietf-microwave-topology:mw-tp-choice": {
    "microwave-ctp": {} 
    },
    "ietf-tp-interface-reference-topology:tp-to-interface-path": "CT-4"
  }
}  
}
{"ietf-network-topology:link": [{
  "link-id": "mwrl-N1-N2",
  "source": {
    "source-node": "mw-N1",
    "source-tp": "mw-N1-RLTP1"
  },
  "destination": {
    "dest-node": "mw-N2",
    "dest-tp": "mw-N2-RLTP2"
  },
  "ietf-te-topology:te": {
    "bundled-links": {
      "bundled-link": [
        {
          "sequence": 1,
          "src-tp-ref": "mw-N1-CTP1",
          "des-tp-ref": "mw-N2-CTP2"
        },
        {
          "sequence": 2,
          "src-tp-ref": "mw-N1-CTP3",
          "des-tp-ref": "mw-N2-CTP4"
        }
      ]
    },
    "te-link-attributes": {
      "ietf-bandwidth-availability-topology:link-availability": [
        {
          "availability": "0.999",
          "link-bandwidth": "1572864"
        },
        {
          "availability": "0.95",
          "link-bandwidth": "2097152"
        }
      ],
      "ietf-microwave-topology:mw-link-choice": {
        "microwave-radio-link": {
          "mode": "ietf-microwave-types:two-plus-zero"
        }
      }
    }
  }
},
{"link-id": "mwc-N1-N2-A",
 "source": {
   "source-node": "mw-N1",
   "source-tp": "mw-N1-CTP1"
 },
 "destination": {
   "dest-node": "mw-N2",
   "dest-tp": "mw-N2-CTP2"
 },
"ietf-te-topology:te": {
    "bundled-links": {
      "bundled-link": [
        {
          "sequence": 1,
          "src-tp-ref": "mw-N1-CTP1",
          "des-tp-ref": "mw-N2-CTP2"
        },
        {
          "sequence": 2,
          "src-tp-ref": "mw-N1-CTP3",
          "des-tp-ref": "mw-N2-CTP4"
        }
      ]
    },
    "te-link-attributes": {
      "ietf-bandwidth-availability-topology:link-availability": [
        {
          "availability": "0.999",
          "link-bandwidth": "1572864"
        },
        {
          "availability": "0.95",
          "link-bandwidth": "2097152"
        }
      ],
      "ietf-microwave-topology:mw-link-choice": {
        "microwave-radio-link": {
          "mode": "ietf-microwave-types:two-plus-zero"
        }
      }
    }
  }
}
"ietf-te-topology:te": {
  "te-link-attributes": {
    "ietf-bandwidth-availability-topology:link-availability": [
      {
        "availability": "0.99",
        "link-bandwidth": "1048576"
      }
    ],
    "ietf-microwave-topology:mw-link-choice": {
      "microwave-carrier": {
        "tx-frequency": 10728000,
        "rx-frequency": 10615000,
        "channel-separation": 28000
      }
    }
  },
  "link-id": "mwc-N1-N2-B",
  "source": {
    "source-node": "mw-N1",
    "source-tp": "mw-N1-CTP3"
  },
  "destination": {
    "dest-node": "mw-N2",
    "dest-tp": "mw-N2-CTP4"
  }
},
"ietf-te-topology:te": {
  "te-link-attributes": {
    "ietf-bandwidth-availability-topology:link-availability": [
      {
        "availability": "0.99",
        "link-bandwidth": "1048576"
      }
    ],
    "ietf-microwave-topology:mw-link-choice": {
      "microwave-carrier": {
        "tx-frequency": 10528000,
        "rx-frequency": 10415000,
        "channel-separation": 28000
      }
    }
  },
  "link-id": "mwc-N1-N2-B",
  "source": {
    "source-node": "mw-N1",
    "source-tp": "mw-N1-CTP3"
  },
  "destination": {
    "dest-node": "mw-N2",
    "dest-tp": "mw-N2-CTP4"
  }
},
"ietf-interfaces:interfaces": {
  "interface": [
    {
      "name": "L2Interface1",
      "description": "Ethernet Interface 1",
      "type": "iana-if-type:ethernetCsmacd"
    }]
}
"name": "L2Interface2",
"description": "Ethernet Interface 2",
"type": "iana-if-type:ethernetCsmacd"
},
{
"name": "RLT-1",
"description": "Radio Link Terminal 1",
"type": "iana-if-type:microwaveRadioLinkTerminal",
"ietf-microwave-radio-link:mode": "ietf-microwave-types:two-plus-zero",
"ietf-microwave-radio-link:carrier-terminations": [
  "CT-1",
  "CT-3"
]
},
{
"name": "RLT-2",
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  "CT-4"
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"ietf-microwave-radio-link:duplex-distance": 644000,
"ietf-microwave-radio-link:channel-separation": 28000,
"ietf-microwave-radio-link:rtpc": {
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}}
This example shows a 1+1 mode for protection.

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        "network-types": {  
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            "ietf-eth-te-topology:eth-tran-topology": {  
            }  
          }  
        },  
        "supporting-network": [  
          {  
            "network-ref": "mw-network"  
          }  
        ],  
        "node": [  
          {  
            "node-id": "L2-N1",  
            "supporting-node": [  
              {  
                "network-ref": "mw-network",  
                "node-ref": "mw-N1"  
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            ],  
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                  }  
                ]  
              }  
            ]  
          }  
        ]  
      }  
    ]  
  }  
}
```

<CODE BEGINS> file "exampleplus1-f.json"

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"
"ietf-microwave-radio-link:single": {
  "selected-cm": "ietf-microwave-types:qam-512"
}
"

<CODE ENDS>
"tp-ref": "mw-N1-RLTP1"
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}
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"supporting-node": [
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"network-ref": "mw-network",
"node-ref": "mw-N2"
}]
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"supporting-termination-point": [
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"node-ref": "mw-N2",
"tp-ref": "mw-N2-RLTP2"
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}
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"link-ref": "mwrl-N1-N2"
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}
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    "supporting-termination-point": [ 
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        "node-ref": "mw-N2",
        "tp-ref": "mw-N2-CTP2"
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        "network-ref": "mw-network",
        "node-ref": "mw-N2",
        "tp-ref": "mw-N2-CTP4"
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]
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    "ietf-microwave-topology:mw-tp-choice": { 
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},
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  "tp-id": "mw-N2-CTP4",
  "ietf-te-topology:te-tp-id": 2,
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      "microwave-ctp": {} 
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  } 
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      "source-tp": "mw-N1-RLTP1"
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    "destination": { 
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      "dest-tp": "mw-N2-RLTP2"
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                "sequence": 2,
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        "ietf-microwave-topology:mw-link-choice": {
            "microwave-radio-link": {
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            }
        }
    }
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"tx-frequency": 10728000,
"rx-frequency": 10615000,
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]
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"channel-separation": 28000
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}
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"destination": {
"dest-node": "mw-N2",
"dest-tp": "mw-N2-CTP4"
}
}]}
"ietf-microwave-radio-link:mode": "ietf-microwave-types:one-plus-one",
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            "CT-4"
          ]
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  "ietf-microwave-radio-link:channel-separation": 28000,
  "ietf-microwave-radio-link:rtpc": {
    "maximum-nominal-power": "20.0"
  },
  "ietf-microwave-radio-link:adaptive": {
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    "selected-max-acm": "ietf-microwave-types:qam-512"
  }
},
{ "name": "CT-2",
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  "ietf-microwave-radio-link:rtpc": {
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  },
  "ietf-microwave-radio-link:adaptive": {
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},

{
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    "ietf-microwave-radio-link:channel-separation": 28000,
    "ietf-microwave-radio-link:rtpc": {
        "maximum-nominal-power": "20.0"
    },
    "ietf-microwave-radio-link:adaptive": {
        "selected-min-acm": "ietf-microwave-types:qam-256",
        "selected-max-acm": "ietf-microwave-types:qam-512"
    }
}


<CODE ENDS>

Note that the examples above show one particular link (unidirectional) and not a complete network topology.

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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.

It is worth noting that optical data plane interoperability is a complex topic especially in a multi vendor environment and usually requires joint engineering, which is independent from control plane and management plane capabilities. The YANG data model defined in this draft is providing sufficient information to enable optical impairment aware path computation. Optical data plane interoperability is outside the scope of this draft.
This document augments the generic TE topology YANG model defined in [RFC8795] 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:

* client
* server
* augment
* data model
* data node

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

* configuration data
* state data

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

The term ROADM in this document refers to the term "multi-degree reconfigurable optical add/drop multiplexer (MD-ROADM)" as defined in [G.672]. It does not include local optical transponders, which can be co-located in the same physical device (managed entity).

The term WDM-node refers to a physical device, which is managed as a single network element.

The term WDM-TE-node refers to those parts of a WDM-node (physical device) that are modeled as a TE-node as defined in [RFC8795], which may include a ROADM and/or multiple local optical transponders (OTs). Hence, a WDM-TE-node may only contain OTs.
The term "WDM-TE-network" refers to a set of WDM-TE-nodes as defined above that are interconnected via TE-links carrying WDM signals. These TE-links may include optical amplifiers.

1.2. Tree Diagram

A simplified graphical representation of the data model is used in Section 2 of 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.

<table>
<thead>
<tr>
<th>Prefix</th>
<th>YANG module</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>optical-imp-topo</td>
<td>ietf-optical-impairment-topology</td>
<td>[RFCXXXX]</td>
</tr>
<tr>
<td>layer0-types</td>
<td>ietf-layer0-types</td>
<td>[RFC9093]</td>
</tr>
<tr>
<td>10-types-ext</td>
<td>ietf-layer0-types-ext</td>
<td>[I-D.ietf-ccamp-layer0-types-ext]</td>
</tr>
<tr>
<td>nw</td>
<td>ietf-network</td>
<td>[RFC8345]</td>
</tr>
<tr>
<td>nt</td>
<td>ietf-network-topology</td>
<td>[RFC8345]</td>
</tr>
<tr>
<td>tet</td>
<td>ietf-te-topology</td>
<td>[RFC8795]</td>
</tr>
</tbody>
</table>

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.

The topology model developed in this document is an abstracted topology YANG model that can be used at 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. Optical Transport Network Data Plane

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

Figure 2 shows the reference architecture.

- BA: Booster Amplifier (or egress amplifier)
- PA: Pre-Amplifier (or ingress amplifier)
- ILA: In-Line Amplifier
- MCG: Media Channel Group

Figure 2: Reference Architecture for Optical Transport Network

BA (on the left side WDM-TE-node) is the egress Amplifier and PA (on the right side WDM-TE-node) is the ingress amplifier for the OMS Media Channel Group (MCG) Figure 2.

2.3. OTS and OMS Media Channel Group

According to [G.807] and [G.872], an OTS Media Channel Group (MCG) represents a topological construct between two adjacent amplifiers, such as:

(i) between a WDM-TE-node’s BA and the adjacent ILA,
(ii) between a pair of ILAs,
(iii) between an ILA and the adjacent WDM-TE-node’s PA.
According to [G.807] and [G.872], an OMS Media Channel Group (MCG) represents a topological construct between two WDM-TE-nodes.

Specifically, it originates at the ROADM in the source WDM-TE-node and terminates at the ROADM in the destination WDM-TE-node including the Booster Amplifier (BA) and the Pre-Amplifier (PA) in the WDM-TE-nodes as well as the In-Line Amplifiers (ILAs) between the two WDM-TE-nodes.

An OMS MCG can be decomposed into a sequence of OTS MCGs and amplifiers.

An OMS MCG can be described as a sequence of elements such as BA, fiber section, ILA, PA, and concentrated loss wherever there is an insertion loss caused for example by a fiber connector.

In TE-topology terms, the OMS MCG is modeled as a WDM TE-link interconnecting two WDM-TE-nodes. A network controller can retrieve the optical impairment data for all the WDM TE-link elements defined in the layer-0 topology YANG model.

The optical impairments related to the link between remote optical transponders, located in a different WDM-TE-node (an IP router with integrated optical transponders for example), can also be modeled as a WDM TE-link using the same optical impairments as those defined for a WDM TE-link between WDM-TE-nodes (OMS MCG). In this scenario, the node containing the remote optical transponders can be considered as WDM-TE-node with termination capability only and no no switching capabilities.

An OMS MCG is terminated on both ends by a link termination point (LTP) as defined in [RFC8345]. Links in optical transport networks are typically bidirectional but have to be modeled as a pair of two unidirectional links following the [RFC8345] modeling approach. Unlike TE-links, which are unidirectional, the LTPs on either end of the TE-link pair forming the bidirectional link, are bidirectional as described in [I-D.ietf-teas-te-topo-and-tunnel-modeling] and the pair of unidirectional links are connected to the same bidirectional LTP on either end of the link pair.

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.

Path computation needs to know the existing OTSi signals for each OMS link in the topology to determine the optical impairment impact of the existing OTSi signals on the optical feasibility of a new OTSi signal and vice versa, i.e., the impact of the new OTSi on the existing OTSi signals. For determining the optical feasibility of the new OTSi, it is necessary to know the OTSi properties like carrier frequency, baud rate, and signal power for all existing OTSi signals on each OMS link.

Additionally, it is necessary for each WDM-TE-node in the network to know the OTSi signals that are added to or dropped from an WDM TE-link (OMS MCG) link as well as the optical power of these OTSi signals to check whether the WDM-TE-node’s optical power constraints are met.

The optical impairment-aware topology YANG model below defines the OTSi properties needed for optical impairment-aware path computation including the spectrum occupied by each OTSi signal. The model also defines a pointer (leafref) from the OTSi to the transceiver module terminating the OTSi signal.

The OTSi signals in the YANG model are described by augmenting the network and each OTSi signal is uniquely identified by its otsi-carrier-id, which is unique within the scope the OTSiG [see Section 2.3.2 below] the OTSi belongs to.

2.3.2. Optical Tributary Signal Group (OTSiG)

The OTSiG is defined in ITU-T Recommendation G.807 [G.807] as a "set of optical tributary signals (OTSi) that supports a single digital client". Hence, the OTSiG is an electrical signal that is carried by one or more OTSi’s. The relationship between the OTSiG and the the OTSi’s is described in [G.807], section 10.2. The YANG model below supports both cases: the single OTSi case where the OTSiG contains a single OTSi (see [G.807], Figure 10-2) and the multiple OTSi case where the OTSiG consists of more than one OTSi (see [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.
All OTSiGs are described in the YANG model by augmenting the network and each OTSiG is uniquely identified by its otsi-group-id, which is unique within the network. Each OTSiG also contains a list of the OTSi signals belonging to the OTSiG.

```
    OTSiG
    /\  
   //  
  /   \  
 m=7
```

```
- - - +---------------------------X---------------------------+ - - -
/ / / |                                                       | / / /
/ / /|      OTSi         OTSi         OTSi         OTSi      | / / /
/ / / |        ^            ^            ^            ^       | / / /
/ / / |        |            |            |            |       | / / /
/ / / |        |            |            |            |       | / / /
/ / / |        |            |            |            |       | / / /
-4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12
```

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

2.3.3. Media Channel (MC)

[G.807] defines a "media channel" as "A media association that represents both the topology (i.e., the path through the media) and the resource (i.e., frequency slot or effective frequency slot) that it occupies." In this document, the term "channel" is occasionally used to indicate the resource of an MC (i.e., frequency slot or effective frequency slot), without representing topology.

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.
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 [G.694.1]. In this model, the effective frequency slot as defined in [G.807] is equal to the frequency slot of this end-to-end MC. It is also assumed that ROADM devices 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 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.
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 used in WDM networks for amplifying the optical signal in the optical domain without any optical to electrical and electrical to optical conversion. There are three main optical amplifier technologies:

* Erbium Doped Fiber Amplifiers (EDFAs)

* Raman Amplifiers

* Semiconductor Optical Amplifiers (SOAs)

In today’s WDM networks EDFAs and Raman amplifiers are widely used. Raman amplifiers have become attractive due to their large spectral gain bandwidth, which can be quite flat, with similar or even lower noise figures compared to EDFAs. On the other hand, Raman amplifiers consume more power and are usually more expensive than EDFAs.

Raman amplifiers are distributed amplifiers where an optical pump signal is injected typically in opposite direction to the optical signal that is amplified (backward pump, counter-propagating pump light). Injecting the optical pump signal in the same direction is
also possible (forward pump, co-propagating pump light). For optical amplifiers, the YANG model defines Raman pump light attributes describing the direction (raman-direction) with respect to the signal that is amplified and optical frequency and power for the pump light source(s) contained in the raman-pump list. These Raman amplifier-specific attributes are optional as they are only applicable to Raman amplifiers. For determining the optical amplifier type, i.e., to figure out whether an optical amplifier is a Raman amplifier, the type-variety attribute is used. Due to the distributed nature of the Raman amplifier it is difficult to clearly separate the amplifier from the fiber span into which the pump signal is injected. From a topology modeling perspective, the Raman amplifier is modeled as two OMS line elements:

1. a passive fiber element accounting for the fiber loss only and not the resulting loss including the Raman gain
2. an amplifier element providing all optical amplifier properties (gain, tilt, etc.). On the OMS-link, the amplifier element is placed where the pump is located and the geolocation information also indicates the location of the pump.

Amplifiers can be classified according to their location along the TE-link (OMS MCG). There are three basic amplifier types: In-Line Amplifiers, Pre-Amplifiers and Booster Amplifiers. ILAs are separate physical devices while Pre-Amplifiers and Booster Amplifiers are integral elements of a WDM-node. From a data modeling perspective, node-internal details should not be modeled and should be abstracted as much as possible. For Pre-Amplifiers and Booster Amplifiers, however, a different approach has been taken and they are modeled as TE-link elements as they have the same optical impairments as ILAs.

ILAs are placed at locations where the optical amplification of the WDM signal is required on the TE-link (OMS MCG) between two WDM-TE-nodes nodes. Geolocation information is already defined for TE nodes in [RFC8795] and is also beneficial for ILAs. Therefore, the same geolocation container has been added to the amplifier element on an OMS link containing altitude, latitude, and longitude as optional attributes.

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, Power_in (@ ROADM Booster) = Power_out (@ ROADM Pre-Amplifier) - 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 transceiver modules. A transceiver represents a transmitter/receiver (Tx/Rx) pair as defined in ITU-T Recommendation G.698.2 [G.698.2]. In addition to the transceiver, which is terminating an OTSi signal, a transponder typically provides additional layer 1 functionality like for example aggregation (multiplexing) of client layer signals, which is outside the scope of this document addressing layer 0 aspects of transponders.

The termination of an OTSi signal by a transceiver is modeled as a function of the tunnel termination point (TTP) as defined in [RFC8795]. Due to the fact that optical transport services (TE tunnels) are typically bidirectional, a TTP is also modeled as a bidirectional entity like the LTP described above. Moreover, a TTP can terminate one or several OTSiG signals (tunnels) as described in [I-D.ietf-teas-te-topo-and-tunnel-modeling] and each OTSiG consists of one or multiple OTSi signals as described in Section 2.3.2. Therefore, a TTP may be associated with multiple transceiver modules.

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:

* Standard Modes

* Organizational Modes

* Explicit Modes
2.5.1. Standard Modes

A standard mode is related to an optical specification developed by an SDO organization. Currently, the "Standard Modes" can only be referred to ITU-T G.698.2 [G.698.2] since G.698.2 is the only specification defining "Standard Modes" today. Nothing is precluding, however, to consider other specifications provided by any other SDO in the Standard Mode context as soon as such specifications will be available. An application code as defined in ITU-T G.698.2 [G.698.2] is representing 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. As the characteristics are encoded in the application code, the YANG model in this document only defines a string, which represents that application code.

2.5.2. Organizational Modes

Organizations like operator groups, industry fora, or equipment vendors can define their own optical interface specifications and make use of transceiver capabilities going beyond existing standards.

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. It is the responsibility of the organization to assign operational modes and to ensure that operational modes are unique and unambiguous within the scope of the organization.

Two transceivers can be interconnected, 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 defined by the optical interface specification - these properties are not provided for an operational mode and are therefore not defined in the YANG model. Examples of these properties are:

* FEC type
* Modulation scheme
* Encoding (mapping of bit patterns (code words) to symbols in the constellation diagram)

* Baud rate (symbol rate)

* 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.

An organization may define the operational modes to include the optical power and carrier frequency related properties following the application code approach as defined in ITU-T Recommendation G.698.2 [G.698.2]. In such a case, the explicit optical power and carrier frequency related optional attributes shall be omitted in order to avoid redundant information in the description of the transceiver capabilities. If these attributes are provided in addition to the operational modes including these attribute values implicitly, the parameter values provided explicitly replace the implicit values and take precedence. This shall, however, only be done in exceptional cases and shall be avoided whenever possible. In case an implicitly given range is extended utilizing the explicit optional attributes, a path computation policy rule may be applied to select a value preferably from the range defined implicitly and to only select a value from the extended range if no path can be found for values in the implicitly defined range. Path computation policy is outside the scope of this topology YANG model.
In summary, the optical power and carrier frequency related attributes shall either be described implicitly by the operational mode following the definition provided by that organization or shall be described explicitly when the optical power and carrier frequency related properties are not included in the operational mode definition.

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:

* Supported transmitter tuning range with min/max nominal carrier frequency \([f_{tx\_min}, f_{tx\_max}]\)

* Supported transmitter tunability describing the transmitter’s frequency fine tuning steps (the minimum distance between two adjacent carrier frequencies in GHz)

* Supported transmitter power range \([p_{tx\_min}, p_{tx\_max}]\)
* Supported receiver channel power range \([p_{rx-min}, p_{rx-max}]\)

* 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:

* Pointer to the transponder instance containing the transceiver terminating the OTSi

* Pointer to the transceiver instance terminating the OTSi

* Pointer to the currently configured transceiver mode

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

* current carrier-frequency

* currently transmitted channel power

* currently received channel power

* currently received total power
2.6. 3R Regenerators

Optical transponders are usually used to terminate a layer 0 tunnel (layer 0 service) in the WDM layer. If, however, no optical path can be found from the source transponder to the destination transponder that is optically feasible due to the optical impairments, one or more 3R regenerators are needed for regenerating the optical signal in intermediate nodes. The term "3R" regenerator means: reamplification, reshaping, retiming. As described in [G.807], Appendix IV, a 3R regenerator terminates the OTSi and generates a new OTSi. Depending on the 3R regenerator capabilities, it can provide functions such as carrier frequency translation (carrier-frequency), changes in the modulation scheme (modulation-type) and FEC (FEC-type) while passing through the digital signal except the FEC (the FEC is processed and errors are corrected).

The 3R regenerator function is illustrated in section 10.1 of [G.798.1], and sections 10.3 and 10.4 provide examples of a ROADM architecture and a photonic cross-connect architecture including 3R regenerators. Based on the provided functionality, 3R regenerators are considered as topological layer 0 entities because they are needed for layer 0 path computation in case the optical impairments make it impossible to find an optically feasible end-to-end path from the source transponder to the destination transponder without 3R regeneration. When an end-to-end path includes one or more 3R regenerators, the corresponding layer 0 tunnel is subdivided into 2 or more segments between the source transponder and the destination transponder terminating the layer 0 tunnel.

3R regenerators are usually realized by a pair of optical transponders, which are described in Section 2.5 above. If a pair of optical transponders is used to perform a 3R regenerator function, two different configurations are possible involving the pair of optical transceivers of the two optical transponders:

* The two transponders can be operated in a back-to-back configuration where the transceiver of each optical transponder receives and transmits the optical signal from/to the same segment of the end-to-end tunnel. This means that each transceiver is operated in a bi-directional mode.
* The two transponders can be operated in a configuration where each transponder performs the 3R regeneration function in one direction, one in forward direction (from source to destination) and the other in the reverse direction. In this configuration, the transceiver of each optical transponder receives the signal from one segment and transmits the regenerated optical signal into the adjacent segment. This configuration is also called cross-regeneration and each transceiver is operated in an uni-directional mode.

Implementations may support the change of the carrier frequency where the receiver may operate at a different optical frequency as the transmitter. The transceiver mode is a property of the transceiver and is applied to the transmitter and the receiver. Therefore, the transceiver mode is the same for the two segments on the two sides of the 3R regenerator realised by two transceivers operated in the uni-directional mode.
Due to the fact that 3R regenerators are composed of an optical transponder pair, the capability whether an optical transponder can be used as a 3R regenerator is is added to the transponder capabilities. Hence, no additional entity is required for describing 3R regenerators in the TE-topology YANG model. The optical transponder capabilities regarding the 3R regenerator function are described by the following two YANG model attributes:

* supported-termination-type
* supported-3r-mode

The supported-termination-type attribute describes whether the optical transponder can be used as tunnel terminating transponder only, as 3R regenerator only, or whether it can support both functions. The supported-3r-mode attribute describes the configuration of the transponder pair forming the 3R regenerator as described above.
2.7. 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.

2.8. 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, pmf, 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.

2.9. WDM-Node Architectures

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

* Integrated WDM-node architecture with local optical transponders
* Integrated WDM-node architecture with local optical transponders and single channel add/drop ports for remote optical transponders
* Disaggregated WDM-node architecture where the WDM-TE-node is composed of degree, add/drop, and optical transponder subsystems handled as separate WDM-nodes

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

The different WDM-node 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 WDM-TE-node requires further investigations and will be addressed in a future revision of this document.]

2.9.1. Integrated WDM-node Architecture with Local Optical Transponders

Figure 2 and Figure 8 below show the typical architecture of an integrated WDM-node, which contains the optical transponders as an integral part of the WDM-node. Such an integrated WDM-node provides DWDM interfaces as external interfaces for interconnecting the device with its neighboring WDM-node (see OMS MCG above). The number of these interfaces denote also the degree of the WDM-node. A degree 3 WDM-node for example has 3 DWDM links that interconnect the WDM-node with 3 neighboring WDM-nodes. Additionally, the WDM-node provides client interfaces for interconnecting the WDM-node with client devices such as IP routers or Ethernet switches. These client interfaces are the client interfaces of the integrated optical transponders.

Figure 8: Integrated WDM-node Architecture with Local Transponders
2.9.2. Integrated WDM-node with Integrated Optical Transponders and Single Channel Add/Drop Interfaces for Remote Optical Transponders

Figure 9 below shows the extreme case where all optical transponders are not integral parts of the WDM-node but are separate devices that are connected to the add/drop ports of the WDM-node. If the optical transponders and the WDM-node are collocated and if short single channel fiber links are used to interconnect the optical transponders with an add/drop port of the WDM-node, the optical domain controller may present these optical transponders in the same way as local optical transponders. If, however, the optical impairments of the single channel fiber link between the optical transponder and the add/drop port of the WDM-node 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].

\[Figure 9: Integrated WDM-node Architecture with Remote Transponders\]
2.9.3. Disaggregated WDM-TE-node Subdivided into Degree, Add/Drop, and Optical Transponder Subsystems

Recently, some DWDM network operators started demanding WDM 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 WDM-TE-node are:

* Single degree subsystems
* Add/drop subsystems
* Optical transponder subsystems

These subsystems are 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 WDM-TE-node. This disaggregated WDM-TE-node architecture is depicted in Figure 10 below.

As this document defines TE topology YANG model augmentations [RFC8795] 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 WDM-TE-node and presents the disaggregated WDM-TE-node in the same way as an integrated WDM-node hiding all the interconnects that are not relevant from an external TE topology view.
Figure 10: Disaggregated WDM-TE-node Architecture with Remote Transponders

2.9.4. Optical Impairments Imposed by WDM-TE-Nodes

[Editor’s note: the following text still needs to be updated based on the agreed terminology]

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:
* Chromatic dispersion (CD)
* Polarization mode dispersion (PMD)
* Polarization dependent loss (PDL)
* Optical amplifier noise due to amplified spontaneous emission (ASE)
* In-band cross-talk
* 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:

* Express path: MC path between two line ports of the ROADM (unidirectional)
* Add Path: MC path from an Add port to a line port of the ROADM
* 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 [RFC8795]. 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).

[RFC8795] 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]

2.10. Protection Architectures

The YANG model defined in this document supports the following protection architectures:

* Individual OTSi protection

* OMS MCG protection = TE-link protection between adjacent WDM-TE-nodes

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

2.10.1. Individual OTSi Protection

Individual OTSi protection is a protection architecture where an individual OTSi signal is protected as defined in Appendix III of ITU-T Recommendation G.873.1 [G.873.1]. This protection architecture requires dedicated photonic protection functions that are typically provided by dedicated protection hardware. These photonic protection functions are a photonic splitter function splitting the OTSi signal in transmit direction and a photonic selector function selecting the OTSi signal in receive direction from one of the two protection legs between the protection functions terminating the individual OTSi protection. This individual OTSi protection scheme can be considered as a photonic 1+1 protection scheme (1+1 sub-network connection protection (SNCP) in ITU-T terminology).

In case of individual OTSi protection, there are two network media channel paths associated with the OTSi signal. In the YANG model, this is modeled as a leaf list of the otsi providing the nmc-path-id for the two network media channel paths associated with the individually protected otsi.
2.10.2. OMS MCG protection

OMS MCG protection is a protection architecture where a TE-link between two adjacent WDM-TE-nodes is protected. This is a local protection scheme, which can be modeled as a TE-link property.

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:
  +--ro otsi-group* [otsi-group-id]
    +--ro otsi-group-id    string
    +--ro otsi* [otsi-carrier-id]
      +--ro otsi-carrier-id    uint16
      +--ro otsi-carrier-frequency?    union
      +--ro nmc-path-id*    uint16

augment /nw:networks/nw:network/nw:node:
  +--ro transponder* [transponder-id]
    +--ro transponder-id    uint32
    +--ro termination-type-capabilities?    enumeration
    +--ro supported-3r-mode?    enumeration
    +--ro transceiver* [transceiver-id]
      +--ro transceiver-id    uint32
      +--ro supported-modes
        +--ro supported-mode* [mode-id]
          +--ro mode-id    string
          +--:(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 transceiver-tunability?
  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 bitrate?
      uint16
    ++ro max-polarization-mode-dispersion?
      decimal164
    ++ro max-chromatic-dispersion?
      decimal164
    ++ro chromatic-dispersion-penalty* []
      ++ro chromatic-dispersion union
      ++ro penalty-value union
    ++ro polarization-dispersion-penalty* []
      ++ro polarization-mode-dispersion union
      ++ro penalty-value union
    ++ro max-diff-group-delay?
      int32
    ++ro max-polarization-dependent-loss-penalty* []
      ++ro max-polarization-dependent-loss
        power-in-db-or-null
      ++ro penalty-value union
    ++ro available-modulation-type?
      identityref
    ++ro min-OSNR?
      snr
    ++ro min-Q-factor?
      int32
    ++ro available-baud-rate?
      uint32
    ++ro roll-off?
      decimal164
---ro min-carrier-spacing?
  |     |              +--ro frequency-ghz
---ro available-fec-type?
  |     |              +--ro identityref
---ro fec-code-rate?
  |     |              +--ro decimal64
---ro fec-threshold?
  |     |              +--ro decimal64
---ro min-central-frequency?
  |     |              +--ro frequency-thz
---ro max-central-frequency?
  |     |              +--ro frequency-thz
---ro transceiver-tunability?
  |     |              +--ro frequency-ghz
---ro tx-channel-power-min?
  |     |              +--ro dbm-t
---ro tx-channel-power-max?
  |     |              +--ro dbm-t
---ro rx-channel-power-min?
  |     |              +--ro dbm-t
---ro rx-channel-power-max?
  |     |              +--ro dbm-t
---ro rx-total-power-max?
  |     |              +--ro dbm-t
---ro configured-mode?
  |     |              +--ro union
  |     |              +--ro union
  |     |              +--ro union
  |     |              +--ro outgoing-otsi
  |     |              +--ro otsi-group-ref?
  |     |              +--ro leafref
  |     |              +--ro incoming-otsi
  |     |              +--ro otsi-group-ref?
  |     |              +--ro leafref
  |     |              +--ro configured-termination-type? enumeration
---ro regen-group* [group-id]
  |     |              +--ro group-id uint32
  |     |              +--ro regen-metric? uint32
  |     |              +--ro transponder-ref* -> ../transponder/transponder-id
augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes:
  |     |              +--ro OMS-attributes
  |     |              +--ro generalized-snr? 10-types:snr
  |     |              +--ro identityref
  |     |              +--ro (power-param)?
++--ro (power-param)?
++--:(channel-power)
  ++--ro nominal-carrier-power?
    10-types:power-in-db-or-null
++--:(power-spectral-density)
  ++--ro nominal-power-spectral-density?
    union
++--ro raman-direction?
  enumeration
++--ro raman-pump* []
  ++--ro frequency?  10-types:frequency-thz
  ++--ro power?
    10-types:decimal-2-digits-or-null
++--:(fiber)
  ++--ro fiber
    ++--ro type-variety  string
    ++--ro length
      10-types:decimal-2-digits-or-null
    ++--ro loss-coef
      10-types:decimal-2-digits-or-null
    ++--ro total-loss  10-types:power-in-db-or-null
    ++--ro pmd?
      10-types:decimal-2-digits-or-null
    ++--ro conn-in?  10-types:power-in-db-or-null
    ++--ro conn-out?  10-types:power-in-db-or-null
++--:(concentratedloss)
  ++--ro concentratedloss
    ++--ro loss  10-types:power-in-db-or-null
 augment /nw:networks/nw:network/nw:node/tet:te
/tet:tunnel-termination-point:
  ++--ro ttp-transceiver* [transponder-ref transceiver-ref]
  ++--ro transponder-ref
    |  --> ..../..../..../transponder/transponder-id
  ++--ro transceiver-ref  leafref
 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 frequency-range
        ++--ro lower-frequency  frequency-thz
        ++--ro upper-frequency  frequency-thz
<snip>

++-ro roadm-pmd?                union
++-ro roadm-cd?                 union
++-ro roadm-pdl?
  |       l0-types:power-in-db-or-null
++-ro roadm-inband-crosstalk?
  |       l0-types:power-in-db-or-null
++-ro roadm-maxloss?
  10-types:power-in-db-or-null
+-:(roadm-add-path)
  ++-ro roadm-add-path* []
    ++-ro frequency-range
      |   ++-ro lower-frequency    frequency-thz
      |   ++-ro upper-frequency    frequency-thz
    ++-ro roadm-pmd?                union
    ++-ro roadm-cd?                 union
    ++-ro roadm-pdl?
      |       l0-types:power-in-db-or-null
    ++-ro roadm-inband-crosstalk?
      |       l0-types:power-in-db-or-null
    ++-ro roadm-maxloss?
      |       l0-types:power-in-db-or-null
    ++-ro roadm-pmax?
      |       l0-types:power-in-dbm-or-null
    ++-ro roadm-osnr?               l0-types:snr-or-null
    ++-ro roadm-noise-figure?       union
+-:(roadm-drop-path)
  ++-ro roadm-drop-path* []
    ++-ro frequency-range
      |   ++-ro lower-frequency    frequency-thz
      |   ++-ro upper-frequency    frequency-thz
    ++-ro roadm-pmd?                union
    ++-ro roadm-cd?                 union
    ++-ro roadm-pdl?
      |       l0-types:power-in-db-or-null
    ++-ro roadm-inband-crosstalk?
      |       l0-types:power-in-db-or-null
    ++-ro roadm-maxloss?
      |       l0-types:power-in-db-or-null
    ++-ro roadm-minloss?
      |       l0-types:power-in-db-or-null
    ++-ro roadm-typloss?
      |       l0-types:power-in-db-or-null
    ++-ro roadm-pmin?
      |       l0-types:power-in-dbm-or-null
    ++-ro roadm-pmax?
      |       l0-types:power-in-dbm-or-null
    ++-ro roadm-ptyp?
      |       l0-types:power-in-dbm-or-null
<snip>
4. Optical Impairment Topology YANG Model

[Editor’s note: YANG code below always has to be updated before submitting a new revision!]
module ietf-optical-impairment-topology {
  yang-version 1.1;

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

  prefix "optical-imp-topo";

  import ietf-optical-imp-topo {
    prefix "nw";
  }

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

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

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

  organization
    "IETF CCAMP Working Group";

  contact
    "WG Web: <https://datatracker.ietf.org/wg/ccamp/>
    WG List: <mailto:ccamp@ietf.org>
    Editor:   Young Lee <younglee.tx@gmail.com>
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    Editor:   Sergio Belotti <Sergio.belotti@nokia.com>
    Editor:   Grisleri Enrico <enrico.grisleri@nokia.com>
    Editor:   Gert Grammel <ggrammel@juniper.net>";

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

Within this module, if the value of a mandatory attribute is unknown, it MUST be reported using the empty type.
If an optional attribute is applicable but its value is unknown, it MUST be reported using the empty type.
If an optional attribute is not applicable to an entity, it MUST be omitted (not be present in the datastore).

The key words 'MUST', 'MUST NOT', 'REQUIRED', 'SHALL', 'SHALL NOT', 'SHOULD', 'SHOULD NOT', 'RECOMMENDED', 'NOT RECOMMENDED', 'MAY', and 'OPTIONAL' in this document are to be interpreted as described in BCP 14 (RFC 2119) (RFC 8174) when, and only when, they appear in all capitals, as shown here.

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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 2022-07-06 {
  description
    "Initial Version";
  reference
    "RFC XXXX: A Yang Data Model for Impairment-aware Optical Networks";
}

// grouping

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";
}

/*
 * 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 operational parameters";
      list amplifier-element {
        description "The list of parallel amplifier elements within an amplifier used to amplify different frequency ranges.";
        leaf name {
          type string;
          description "The name of the amplifier element as specified in the vendor's specification associated with the type-variety.";
        }
        container frequency-range {
          description "The frequency range amplified by the amplifier element.";
          uses l0-types:frequency-range;
        }
        leaf actual-gain {
          type l0-types:power-in-db-or-null;
          mandatory true;
        }
      }
    }
  }
}
description "..";
}
leaf tilt-target {
  type 10-types:decimal-2-digits-or-null;
  mandatory true;
  description
    "The tilt target defined between lower and upper
     frequency of the amplifier frequency range.";
}
leaf out-voa {
  type 10-types:power-in-db-or-null;
  units dB;
  mandatory true;
  description "..";
}
leaf in-voa {
  type 10-types:power-in-db-or-null;
  mandatory true;
  description "..";
}
leaf total-output-power {
  type 10-types:power-in-db-or-null;
  mandatory true;
  description
    "It represent total output power measured in the range
     specified by the frequency-range.
    
    Optical power is especially needed to re-compute/check
    consistency of span (fiber+ concentrated loss) loss
    value, with respect to loss/gain information on
    elements.";
}
uses power-param;
leaf raman-direction {
  type enumeration {
    enum co-propagating {
      description
        "Co-propagating indicates that optical pump light
         is injected in the same direction to the optical
         signal that is amplified (forward pump).";
    }
    enum counter-propagating {
      description
        "Counter-propagating indicates that optical pump
         light is injected in opposite direction to the
         optical signal that is amplified (backward pump).";
    }
  }
}
description
   "The direction of injection of the raman pump.";
}
list raman-pump {
    description
    "The list of pumps for the Raman amplifier.";
    leaf frequency {
        type 10-types:frequency-thz;
        description
        "The raman pump central frequency.";
    }
    leaf power {
        type 10-types:decimal-2-digits-or-null;
        units "Watts";
        description
        "The total pump power considering a depolarized pump
         at the raman pump central frequency.";
    }
}
} // list amplifier-element
} // container operational
} // container amplifier
} // grouping amplifier-params

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 10-types:decimal-2-digits-or-null;
            units km;
            mandatory true;
            description "length of fiber";
        }
        leaf loss-coef {
            type 10-types:decimal-2-digits-or-null;
            units dB/km;
            mandatory true;
            description "loss coefficient of the fiber";
        }
        leaf total-loss {
type l0-types:power-in-db-or-null;
mandatory true;
description
  "includes all losses: fiber loss and conn-in and
  conn-out losses";
}
leaf pmd{
  type l0-types:decimal-2-digits-or-null;
  units sqrt(ps);
  description "pmd of the fiber";
}
leaf conn-in{
  type l0-types:power-in-db-or-null;
  description "connector-in";
}
leaf conn-out{
  type l0-types:power-in-db-or-null;
  description "connector-out";
}
}
}

grouping roadm-express-path {
  description
    "The optical impairments of a ROADM express path.";
  leaf roadm-pmd {
    type union {
      type decimal64 {
        fraction-digits 8;
        range "0..max";
      }
      type empty;
    }
    units "ps/(km)^0.5";
    description
      "Polarization Mode Dispersion";
  }
  leaf roadm-cd {
    type union {
      type decimal64 {
        fraction-digits 5;
      }
      type empty;
    }
    units "ps/nm";
    description "Chromatic Dispersion";
  }
  leaf roadm-pdl {
leaf roadm-inband-crosstalk {
  type 10-types:power-in-db-or-null;
  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 10-types:power-in-db-or-null;
  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 "The optical impairments of a ROADM add path.";
  leaf roadm-pmd {
    type union {
      type decimal64 {
        fraction-digits 8;
        range "0..max";
      }
      type empty;
    }
    units "ps";
    description "Polarization Mode Dispersion";
  }
  leaf roadm-cd {
    type union {
      type decimal64 {
        fraction-digits 5;
      }
      type empty;
    }
    units "ps/nm";
    description "Cromatic Dispersion";
  }
  leaf roadm-pdl {
    type 10-types:power-in-db-or-null;
    description "Polarization dependent loss";
  }
}
leaf roadm-inband-crosstalk {
    type 10-types:power-in-db-or-null;
    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 10-types:power-in-db-or-null;
    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 10-types:power-in-dbm-or-null;
    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:snr-or-null;
    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 union {
    type decimal64 {
      fraction-digits 5;
    }
    type empty;
  }
  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";
  leaf roadm-pmd {
    type union {
      type decimal64 {
        fraction-digits 8;
        range "0..max";
      }
      type empty;
    }
    units "ps/(km)^0.5";
    description "Polarization Mode Dispersion";
  }
  leaf roadm-cd {
    type union {
      type decimal64 {
        fraction-digits 5;
      }
      type empty;
    }
    units "ps/nm";
    description "Chromatic Dispersion";
  }
}
leaf roadm-pdl {
    type 10-types:power-in-db-or-null;
    description "Polarization dependent loss";
}
leaf roadm-inband-crosstalk {
    type 10-types:power-in-db-or-null;
    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 10-types:power-in-db-or-null;
    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 contraints. 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 10-types:power-in-db-or-null;
    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 contraints. The min value correspond to best case expected loss, including amplifier gain ripple or uncertainty."
}
leaf roadm-typloss {
    type 10-types:power-in-db-or-null;
    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 contraints. 
The typ value correspond to typical case 
expected loss.
}

leaf roadm-pmin {
    type 10-types:power-in-db-or-null;
    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 10-types:power-in-db-or-null;
    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 10-types:power-in-db-or-null;
    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:snr-or-null;
  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 union {
    type decimal64 {
      fraction-digits 5;
    }
    type empty;
  }
  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 nodes 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 10-types:power-in-db-or-null;
      mandatory true;
      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 {
      leaf nominal-carrier-power{
        type 10-types:power-in-dbm-or-null;
        description "Reference channel power. Same grouping is used for the OMS power after the ROADM (input of the OMS) or after the out-voa of each amplifier.";
      }
    }
    case power-spectral-density{
      leaf nominal-power-spectral-density{
        type union {
          type decimal64 {
            fraction-digits 16;
          }
          type empty;
        }
        units W/Hz;
        description "Reference power spectral density after
the ROADM or after the out-voa.
Typical value: 3.9E-14, resolution 0.1nW/MHz

```yml
grouping oms-general-optical-params {
  description "OMS link optical parameters";
  leaf generalized-snr {
    type l0-types:snr;
    description "generalized snr";
  }
  leaf equalization-mode{
    type identityref {
      base l0-types:type-power-mode;
    }
    mandatory true;
    description "equalization mode";
  }
  uses power-param;
}

grouping otsi-group {
  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 uint16;
      description "OTSi carrier-id";
    }
    leaf otsi-carrier-frequency {
      type union {
        type l0-types:frequency-thz;
        type empty;
      }
      description "OTSi carrier frequency, equivalent to the actual configured transmitter frequency";
    }
    leaf-list nmc-path-id {
      type uint16;
    }
  }
```
description
  "The list of the possible Network Media Channel (NMC) paths associated with the OTSi which have different optical impairments. This list is meaningful in case the OTSi can be associated with multiple NMC paths (e.g., when OPS protection is configured). The list can be empty when the OTSi has only one NMC path."
}
} // 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 l0-types:flexi-grid-frequency-slot;
    leaf otsi-group-ref {
      type leafref {
        path "/nw:networks/nw:network/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"
    }
    list otsi-ref {
      description "The list of references to the OTSis and their NMC paths within the OTSiG carried by this media channel.";
    }
  }
} // media-channel-groups grouping
leaf otsi-carrier-ref {
    type leafref {
        path "/nw:networks/nw:network/
            + "otsi-group[otsi-group-id=current()"
            + "/../otsi-group-ref]"/
        + "otsi/otsi-carrier-id" ;
    }
    description
        "Reference to the OTSi within the OTSiG carried
        by this media channel.";
}
leaf-list nmc-path-ref {
    type leafref {
        path "/nw:networks/nw:network/
            + "otsi-group[otsi-group-id=current()"
            + "/../otsi-group-ref]"/
        + "otsi[otsi-carrier-id=current()"
            + " ../../../otsi-carrier-ref]/nmc-path-id" ;
    }
    description
        "References to the NMC paths of this OTSi which are
        routed through this media channel.";
}
leaf delta-power {
    type l0-types:power-in-dbm-or-null;
    description
        " Deviation from the reference carrier power defined for
        the OMS.";
}
} // 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 oms-element-uid {
  type union {
    type string;
    type empty;
  }
  description
    "unique id of the element if it exists";
}
container reverse-element-ref {
  description
    "It contains references to the elements which are
    associated with this element in the reverse
direction.";
  leaf link-ref {
    type leafref {
      path "../../../nt:link/nt:link-id";
    }
    description
      "The reference to the OMS link which the OMS elements
      belongs to.";
  }
  leaf-list oms-element-ref {
    type leafref {
      path "../../../nt:link[nt:link-id=" + "current()//link-ref]/tet:te/
        + "tet:te-link-attributes/OMS-attributes/
        + "OMS-elements/elt-index";
    }
    description
      "The references to the OMS elements.";
  }
}
choice element {
  mandatory true;
  description "OMS element type";
  case amplifier {
    uses tet:geolocation-container;
    uses amplifier-params;
  }
  case fiber {
    uses fiber-params;
  }
  case concentratedloss {
    uses concentratedloss-params;
  }
}
grouping otsi-ref {
  description
  "References to an OTSi.
  This grouping is intended to be reused within the
  transceiver’s list only."
  leaf otsi-group-ref {
    type leafref {
      path "../../../../../otsi-group/otsi-group-id";
    }
    description
    "The OTSi generated by the transceiver’s transmitter.";
  }
  leaf otsi-ref {
    type leafref {
      path "../../../../../otsi-group[otsi-group-id=" +
        "current()//otsi-group-ref]//otsi/otsi-carrier-id";
    }
    description
    "The OTSi generated by the transceiver’s transmitter.";
  }
}

  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" {
  when "nw:network-types/tet:te-topology" +
    "/optical-imp-topo:optical-impairment-topology" {
    description
    "This augment is only valid for Optical Impairment.";
  }
  description
  "Network augmentation for optical impairments data.";
  list otsi-group {
    key "otsi-group-id";
    config false;
    description
    "the list of possible OTSiG representing client digital
    stream";
  }
leaf otsi-group-id {
    type string;
    description
        "A network-wide unique identifier of otsi-group element.
         It could be structured e.g., as an URI or as an UUID."
}
uses otsi-group;
} // list of OTSiG

augment "/nw:networks/nw:network/nw:node" {
    when "./nw:network-types/tet:te-topology" +
        "/optical-imp-topo:optical-impairment-topology" {
        description
            "This augment is only valid for Optical Impairment.";
    }
    description
        "Node augmentation for optical impairments data.";
    list transponder {
        key "transponder-id";
        config false;
        description "list of transponder";
        leaf transponder-id {
            type uint32;
            description "transponder identifier";
        }
        leaf termination-type-capabilities {
            type enumeration {
                enum tunnel-only {
                    description
                        "The transponder can only be used in an Optical
                        Tunnel termination configuration.";
                }
                enum 3r-only {
                    description
                        "The transponder can only be used in a 3R
                        configuration.";
                }
                enum 3r-or-tunnel {
                    description
                        "The transponder can be configure to be used either
                        in an Optical Tunnel termination configuration or in
                        a 3R configuration.";
                }
            }
            description
                "Describes whether the transponder can be used in an
                Optical Tunnel termination configuration or in a 3R
configuration (or both).";
}
leaf supported-3r-mode {
  when '(.../termination-type-capabilities = "3r-only") or
    (.../termination-type-capabilities = "3r-or-tunnel")',
    description
      "Applies only when the transponder supports 3R
 configuration.";
}
type enumeration {
  enum unidir {
    description
      "Unidirectional 3R configuration.";
  }
  enum bidir {
    description
      "Bidirectional 3R configuration.";
  }
}
description
  "Describes the supported 3R configuration type.";
}
list transceiver {
  key "transceiver-id";
  config false;
  description "list of transceiver related to a transponder";
  leaf transceiver-id {
    type uint32;
    description "transceiver identifier";
  }
  uses l0-types:transceiver-capabilities;
  leaf configured-mode {
    type leafref {
      path "../supported-modes/supported-mode/mode-id";
    }
    description
      "Reference to the configured mode for transceiver
 compatibility approach.";
  }
  uses l0-types:common-transceiver-configured-param;
  container outgoing-otsi {
    description
      "The OTSi generated by the transceiver’s transmitter.";
    uses otsi-ref;
  }
  container incoming-otsi {
    description
      "Describes the supported 3R configuration type.";
  }
}
"The OTSi received by the transceiver’s received."
uses otsi-ref;
}
leaf configured-termination-type {
  type enumeration {
    enum tunnel-termination {
      description
      "The transceiver is currently used in an Optical Tunnel termination configuration.";
    }
    enum 3r-regeneration {
      description
      "The transceiver is currently used in a 3R configuration.";
    }
  }
  description
  "Describes whether the current configuration of the transceiver is used in an Optical Tunnel termination configuration or in a 3R configuration.
  If empty, it means that the transceiver is not used.";
}
} // end of list of transceiver
} // end list of transponder
list regen-group {
  key "group-id";
  config false;
  description
  "List of 3R groups.
  Any 3R group represent a group of transponder in which an an electrical connectivity is either in place or could be dynamically provided, to associated transponders used for 3R regeneration.";
  leaf group-id {
    type uint32;
    description
    "Group identifier used an index to access elements in the list of 3R groups.";
  }
  leaf regen-metric {
    type uint32;
    description
    "The cost permits choice among different group of transponders during path computation";
  }
  leaf-list transponder-ref {
    type leafref {

path ".//transponder/transponder-id";
}
description
"The list of transponder belonging to this 3R group."
}
} // end 3R-group

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 ttp-transceiver {
  key "transponder-ref transceiver-ref";
  config false;
  description
  "The list of the transceivers used by the TTP.";
  leaf transponder-ref {
    type leafref {
      path ".//..//..//transponder/transponder-id"
    }
  }
}
description
"The reference to the transponder hosting the transceiver
of the TTP.";

leaf transceiver-ref {
  type leafref {
    path "../../transponder[transponder-id=current()] + 
          "../transponder-ref]/transceiver/transceiver-id";
  }
  description
  "The reference to the transceiver of the TTP.";
}
} // list of transceivers
} // 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 augmentation for optical-impairment ROADM
   node";
}

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

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 {
        list roadm-express-path {
            description "The list of optical impairments on a ROADM express path for different frequency ranges.

            Two elements in the list must not have the same range or overlapping ranges.";
        }
    }
    case roadm-add-path {
        list roadm-add-path {
            description "The list of optical impairments on a ROADM add path for different frequency ranges.

            Two elements in the list must not have the same range or overlapping ranges.";
        }
    }
    case roadm-drop-path {
        list roadm-drop-path {
            description "The list of optical impairments on a ROADM add path for different frequency ranges.";
        }
    }
}
Two elements in the list must not have the same range or overlapping ranges.

container frequency-range {
  description
    "The frequency range for which these optical impairments apply.";
  uses 10-types:frequency-range;
}
uses roadm-drop-path;
}

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

  + "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

  + "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 ";
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";
}

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";

augment "// augmentation local-link-connectivities

augment "// augmentation local-link-connectivities

augment "+ "tet:tunnel-termination-point/"
+ "tet:local-link-connectivities/"
+ "tet:local-link-connectivity" {

when "+ "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";
}
list llc-transceiver {
  key "ttp-transponder-ref ttp-transceiver-ref";
  config false;
  description
    "The list of transceivers having a LLC different from the
     default LLC.";
  leaf ttp-transponder-ref {
    type leafref {
      path "+ ../..../..//ttp-transceiver/transponder-ref";
    }
    description
      "The reference to the transponder hosting the transceiver

of this LLCL entry."
}
leaf ttp-transceiver-ref {
  type leafref {
    path "../../../../ttp-transceiver/transceiver-ref";
  }
  description
  "The reference to the transceiver of this LLCL entry.";
}
leaf is-allowed {
  type boolean;
  description
  "'true' - connectivity from this transceiver is allowed;
  'false' - connectivity from this transceiver is disallowed.";
}
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

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]:

```
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
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.

8. References

8.1. Normative References


8.2. Informative References


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A YANG Data Model for Layer 0 Types
draft-ietf-ccamp-rfc9093-bis-01

Abstract

This document defines a collection of common data types and groupings in the YANG data modeling language. These derived common types and groupings are intended to be imported by modules that model Layer 0 optical Traffic Engineering (TE) configuration and state capabilities such as Wavelength Switched Optical Networks (WSONs) and flexi-grid Dense Wavelength Division Multiplexing (DWDM) networks.

This document obsoletes RFC 9093.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."
1. Introduction

YANG [RFC7950] is a data modeling language used to model configuration data, state data, Remote Procedure Calls, and notifications for network management protocols such as the Network Configuration Protocol (NETCONF) [RFC6241]. The YANG language supports a small set of built-in data types and provides mechanisms to derive other types from the built-in types.

This document introduces a collection of common data types derived from the built-in YANG data types. The derived types and groupings are designed to be the common types applicable for modeling Traffic Engineering (TE) features as well as non-TE features (e.g., physical network configuration aspects) for Layer 0 optical networks in model(s) defined outside of this document. The applicability of
Layer 0 types specified in this document includes Wavelength Switched Optical Networks (WSONs) [RFC6163] [ITU-T_G.698.2] and flexi-grid Dense Wavelength Division Multiplexing (DWDM) networks [RFC7698] [ITU-T_G.694.1].

[Editors’ Note]: This is the introduction from draft-ietf-ccamp-layer0-types-ext-01, to be reconciled with the introduction from RFC9093 above

YANG [RFC7950] is a data modeling language used to model configuration data, state data, Remote Procedure Calls, and notifications for network management protocols such as NETCONF [RFC6241]. The YANG language supports a small set of built-in data types and provides mechanisms to derive other types from the built-in types.

This document introduces a collection of common data types derived from the built-in YANG data types. The derived types and groupings are designed to be the common types applicable for modeling Traffic Engineering (TE) features as well as non-TE features (e.g., physical network configuration aspect) for Layer 0 optical networks in model(s) defined outside of this document.

This document adds new type definitions to the YANG modules and obsoletes [RFC9093]. For further details, see the revision statements of the YANG module in Section 3 or the summary in Appendix A.

1.1. Terminology and Notations

Refer to [RFC7446] and [RFC7581] for the key terms used in this document, and the terminology for describing YANG data models can be found in [RFC7950].

The YANG data model in this document conforms to the Network Management Datastore Architecture defined in [RFC8342].

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

1.2. 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.
<table>
<thead>
<tr>
<th>Prefix</th>
<th>YANG module</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-types</td>
<td>ietf-layer0-types</td>
<td>RFC XXXX</td>
</tr>
</tbody>
</table>

Table 1: Prefixes and corresponding YANG modules

RFC Editor Note: Please replace XXXX with the RFC number assigned to this document.

The YANG module "ietf-layer0-types" (defined in Section 3) references [RFC4203], [RFC6163], [RFC6205], [RFC7698], [RFC7699], [RFC8363], [ITU-T_G.694.1], and [ITU-T_G.694.2].

2. Layer 0 Types Module Contents

This document defines a YANG module for common Layer 0 types, ietf-layer0-types. This module is used for WSON and flexi-grid DWDM networks. The "ietf-layer0-types" module contains the following YANG reusable types and groupings:

l0-grid-type:

A base YANG identity for the grid type as defined in [RFC6163] and [RFC7698].

dwdm-ch-spc-type:

A base YANG identity for the DWDM channel-spacing type as defined in [RFC6205].

cwdm-ch-spc-type:

A base YANG identity for the Coarse Wavelength Division Multiplexing (CWDM) channel-spacing type as defined in [RFC6205].

wson-label-start-end:

The WSON label range was defined in [RFC6205], and the generic topology model defines the label-start/label-end in [RFC8795]. This grouping shows the WSON-specific label-start and label-end information.

wson-label-hop:
The WSON label range was defined in [RFC6205], and the generic topology model defines the label-hop in [RFC8795]. This grouping shows the WSON-specific label-hop information.

l0-label-range-info:

A YANG grouping that defines the Layer 0 label range information applicable for WSON as defined in [RFC6205]. This grouping is used in the flexi-grid DWDM by adding more flexi-grid-specific parameters.

wson-label-step:

A YANG grouping that defines label steps for WSON as defined in [RFC8776].

flexi-grid-label-start-end:

The flexi-grid label range was defined in [RFC7698], and the generic topology model defines the label-start/label-end in [RFC8795]. This grouping shows the flexi-grid-specific label-start and label-end information.

flexi-grid-label-hop:

The flexi-grid label range was defined in [RFC7698], and the generic topology model defines the label-hop in [RFC8795]. This grouping shows the WSON-specific label-hop information.

flexi-grid-label-range-info:

A YANG grouping that defines flexi-grid label range information as defined in [RFC7698] and [RFC8363].

flexi-grid-label-step:

A YANG grouping that defines flexi-grid label steps as defined in [RFC8776].

transceiver-capabilities:

a YANG grouping to define the transceiver capabilities (also called "modes") needed to determine optical signal compatibility.

standard-mode:

a YANG grouping for ITU-T G.698.2 standard mode that guarantees interoperability.
organizational-mode:

   a YANG grouping to define transponder operational mode supported
   by organizations or vendors.

common-explicit-mode:

   a YANG grouping to define the list of attributes related to
   optical impairments limits in case of transceiver explicit mode.
   This grouping should be the same used in
   [I-D.ietf-ccamp-dwdm-if-param-yang].

common-organizational-explicit-mode:

   a YANG grouping to define the common capabilities attributes limit
   range in case of operational mode and explicit mode. Also this
   grouping should be used in [I-D.ietf-ccamp-dwdm-if-param-yang].

cd-pmd-penalty:

   a YANG grouping to define the triplet used as entries in the list
   optional penalty associated with a given accumulated CD and PMD.
   This list of triplet cd, pmd, penalty can be used to sample the
   function penalty = f(CD, PMD).

3. YANG Module for Layer 0 Types

<CODE BEGINS> file "ietf-layer0-types@2022-07-11.yang"
module ietf-layer0-types {  
yang-version 1.1;
namespace "urn:ietf:params:xml:ns:yang:ietf-layer0-types";
prefix l0-types;
organization
   "IETF CCAMP Working Group";
contact
   "WG Web: <https://datatracker.ietf.org/wg/ccamp/>  
   WG List: <mailto:ccamp@ietf.org>
   Editor: Haomian Zheng  
   <mailto:zhenghaomian@huawei.com>
   Editor: Young Lee  
   <mailto:younglee.tx@gmail.com>
   Editor: Aihua Guo  
   <mailto:aihuaguo.ietf@gmail.com>
description
"This module defines Optical Layer 0 types. This module provides groupings that can be applicable to Layer 0 Fixed Optical Networks (e.g., CWDM (Coarse Wavelength Division Multiplexing) and DWDM (Dense Wavelength Division Multiplexing)) and flexi-grid 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.

The key words 'MUST', 'MUST NOT', 'REQUIRED', 'SHALL', 'SHALL NOT', 'SHOULD', 'SHOULD NOT', 'RECOMMENDED', 'NOT RECOMMENDED', 'MAY', and 'OPTIONAL' in this document are to be interpreted as described in BCP 14 (RFC 2119) (RFC 8174) when, and only when, they appear in all capitals, as shown here."

// 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 2022-07-11 {
  description
    "To be updated";
  reference
    "RFC XXXX: A YANG Data Model for Layer 0 Types";
}
revision 2021-08-13 {
  description
    "Initial version";
  reference
    "RFC 9093: A YANG Data Model for Layer 0 Types";
identity l0-grid-type {
    description "Layer 0 grid type";
    reference
        "RFC 6163: Framework for GMPLS and Path Computation Element (PCE) Control of Wavelength Switched Optical Networks (WSONs), ITU-T G.694.1 (10/2020): Spectral grids for WDM applications: DWDM frequency grid,
}

identity flexi-grid-dwdm {
    base l0-grid-type;
    description "Flexi-grid";
    reference
        "RFC 7698: Framework and Requirements for GMPLS-Based Control of Flexi-Grid Dense Wavelength Division Multiplexing (DWDM) Networks,
}

identity wson-grid-dwdm {
    base l0-grid-type;
    description "DWDM grid";
    reference
        "RFC 6163: Framework for GMPLS and Path Computation Element (PCE) Control of Wavelength Switched Optical Networks (WSONs),
}

identity wson-grid-cwdm {
    base l0-grid-type;
    description "CWDM grid";
    reference
        "RFC 6205: Generalized Labels for Lambda-Switch-Capable (LSC) Label Switching Routers,

}

identity dwdm-ch-spc-type {
  description
    "DWDM channel-spacing type";
  reference
    "RFC 6205: Generalized Labels for Lambda-Switch-Capable (LSC) Label Switching Routers, 
}

identity dwdm-100ghz {
  base dwdm-ch-spc-type;
  description
    "100 GHz channel spacing";
}

identity dwdm-50ghz {
  base dwdm-ch-spc-type;
  description
    "50 GHz channel spacing";
}

identity dwdm-25ghz {
  base dwdm-ch-spc-type;
  description
    "25 GHz channel spacing";
}

identity dwdm-12p5ghz {
  base dwdm-ch-spc-type;
  description
    "12.5 GHz channel spacing";
}

identity flexi-ch-spc-type {
  description
    "Flexi-grid channel-spacing type";
  reference
    "RFC 7698: Framework and Requirements for GMPLS-Based Control of Flexi-Grid Dense Wavelength Division Multiplexing (DWDM) Networks, 
}
identity flexi-ch-spc-6p25ghz {
    base flexi-ch-spc-type;
    description
        "6.25 GHz channel spacing";
}

identity flexi-slot-width-granularity {
    description
        "Flexi-grid slot width granularity";
}

identity flexi-swg-12p5ghz {
    base flexi-slot-width-granularity;
    description
        "12.5 GHz slot width granularity";
}

identity cwdm-ch-spc-type {
    description
        "CWDM channel-spacing type";
    reference
        "RFC 6205: Generalized Labels for Lambda-Switch-Capable (LSC) Label Switching Routers,
}

identity cwdm-20nm {
    base cwdm-ch-spc-type;
    description
        "20nm channel spacing";
}

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

identity DPSK {
    base modulation;
    description
        "DPSK (Differential Phase Shift Keying) modulation";
}

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 symbols Quadrature Amplitude Modulation)";
}

identity DP-QAM8 {
    base modulation;
    description
        "DP-QAM8 (8 symbols Dual Polarization Quadrature Amplitude Modulation)";
}

identity DC-DP-QAM8 {
    base modulation;
    description
        "DC DP-QAM8 (8 symbols Dual Carrier Dual Polarization Quadrature Amplitude Modulation)";
}

identity QAM16 {
    base modulation;
    description
        "QAM16 (16 symbols Quadrature Amplitude Modulation)";
}

identity DP-QAM16 {
    base modulation;
    description
        "DP-QAM16 (16 symbols Dual Polarization Quadrature Amplitude Modulation)";
}

identity DC-DP-QAM16 {
    base modulation;
    description
        "DC DP-QAM16 (16 symbols Dual Carrier Dual Polarization Quadrature Amplitude Modulation)";
}

identity QAM32 {
base modulation;
  description  
    "QAM32 (32 symbols Quadrature Amplitude Modulation)";
}

identity DP-QAM32 {
  base modulation;
  description  
    "DP-QAM32 (32 symbols Dual Polarization Quadrature Amplitude Modulation)";
}

identity QAM64 {
  base modulation;
  description  
    "QAM64 (64 symbols Quadrature Amplitude Modulation)";
}

identity DP-QAM64 {
  base modulation;
  description  
    "DP-QAM64 (64 symbols Dual Polarization Quadrature Amplitude Modulation)";
}

identity fec-type {
  description  
    "Base identity from which specific FEC (Forward Error Correction) type identities are derived.";
}

identity g-fec {
  base fec-type;
  description  
    "G-FEC (Generic-FEC)";
}

identity e-fec {
  base fec-type;
  description  
    "E-FEC (Enhanced-FEC)";
}

identity no-fec {
  base fec-type;
  description  
    "No FEC";
}

identity reed-solomon {
base fec-type;
  description
    "Reed-Solomon error correction";
}

identity hamming-code {
  base fec-type;
  description
    "Hamming Code error correction";
}

identity golay {
  base fec-type;
  description "Golay error correction";
}

identity line-coding {
  description
    "base line-coding class";
  reference
    "ITU-T G.698.2-201811 section 7";
}

identity line-coding-NRZ-2p5G {
  base line-coding;
  description
    "ITU-T G.698.2-201811 section 7 table 8-1";
}

identity line-coding-NRZ-OTU1 {
  base line-coding;
  description
    "ITU-T G.698.2-201811 section 7 table 8-2";
}

identity line-coding-NRZ-10G {
  base line-coding;
  description
    "ITU-T G.698.2-201811 section 7 table 8-3/8-5";
}

identity line-coding-NRZ-OTU2 {
  base line-coding;
  description
    "ITU-T G.698.2-201811 section 7 table 8-4/8-6";
}

identity wavelength-assignment {
description
"Wavelength selection base";
reference
"RFC6163:Framework for GMPLS and Path Computation Element
(PCE) Control of Wavelength Switched Optical Networks (WSONs)";
}

identity first-fit-wavelength-assignment {
  base wavelength-assignment;
  description
    "All the available wavelengths are numbered,
     and this WA (Wavelength Assignment) method chooses
     the available wavelength with the lowest index";
}

identity random-wavelength-assignment {
  base wavelength-assignment;
  description
    "This WA method chooses an available
     wavelength randomly";
}

identity least-loaded-wavelength-assignment {
  base wavelength-assignment;
  description
    "This WA method selects the wavelength that
     has the largest residual capacity on the most loaded
     link along the route (in multi-fiber networks)";
}

identity term-type {
  description
    "Termination type";
  reference
    "ITU-T G.709: Interfaces for the Optical Transport Network";
}

identity term-phys {
  base term-type;
  description
    "Physical layer termination";
}

identity term-otu {
  base term-type;
  description
    "OTU (Optical Transport Unit) termination";
}
identity term-odu {
  base term-type;
  description
    "ODU (Optical Data Unit) termination";
}

identity term-opu {
  base term-type;
  description
    "OPU (Optical Payload Unit) termination";
}

identity otu-type {
  description
    "Base identity from which specific OTU identities are derived";
  reference
    "ITU-T G.709: Interfaces for the Optical Transport Network";
}

identity OTU1 {
  base otu-type;
  description
    "OTU1 (2.66 Gb/s)";
}

identity OTU1e {
  base otu-type;
  description
    "OTU1e (11.04 Gb/s)";
}

identity OTU1f {
  base otu-type;
  description
    "OTU1f (11.27 Gb/s)";
}

identity OTU2 {
  base otu-type;
  description
    "OTU2 (10.70 Gb/s)";
}

identity OTU2e {
  base otu-type;
  description
    "OTU2e (11.09 Gb/s)";
}
identity OTU2f {
    base otu-type;
    description
        "OTU2f (11.31G)";
}

identity OTU3 {
    base otu-type;
    description
        "OTU3 (43.01 Gb/s)";
}

identity OTU3e1 {
    base otu-type;
    description
        "OTU3e1 (44.57 Gb/s)";
}

identity OTU3e2 {
    base otu-type;
    description
        "OTU3e2 (44.58 Gb/s)";
}

identity OTU4 {
    base otu-type;
    description
        "OTU4 (111.80 Gb/s)";
}

identity OTUCn {
    base otu-type;
    description
        "OTUCn (n x 105.25 Gb/s)";
}

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

/*
 * Typedefs
 */
typedef dwdm-n {
    type int16;
    description
        "The given value 'N' is used to determine the nominal central
        frequency.

        The nominal central frequency, 'f', is defined by:
        f = 193100.000 GHz + N x channel spacing (measured in GHz),

        where 193100.000 GHz (193.100000 THz) is the ITU-T 'anchor
        frequency' for transmission over the DWDM grid, and where
        'channel spacing' is defined by the dwdm-ch-spctype.");
    reference
        "RFC6205: Generalized Labels for Lambda-Switch-Capable (LSC)
        Label Switching Routers,
        ITU-T G.694.1 (10/2020): Spectral grids for WDM applications:
        DWDM frequency grid";
}

typedef cwdm-n {
    type int16;
    description
        "The given value 'N' is used to determine the nominal central
        wavelength.

        The nominal central wavelength is defined by:
        Wavelength = 1471 nm + N x channel spacing (measured in nm)

        where 1471 nm is the conventional 'anchor wavelength' for
        transmission over the CWDM grid, and where 'channel spacing'
        is defined by the cwdm-ch-spctype.");
    reference
        "RFC 6205: Generalized Labels for Lambda-Switch-Capable (LSC)
        Label Switching Routers,
        ITU-T G.694.2 (12/2003): Spectral grids for WDM applications:
        CWDM wavelength grid";
}
typedef flexi-n {
  type int16;
  description
    "The given value 'N' is used to determine the nominal central frequency.
    The nominal central frequency, 'f', is defined by:
    \[ f = 193100.000 \text{ GHz} + N \times \text{channel spacing (measured in GHz)}, \]
    where 193100.000 GHz (193.100000 THz) is the ITU-T 'anchor frequency' for transmission over the DWDM grid, and where 'channel spacing' is defined by the flexi-ch-spc-type.
    Note that the term 'channel spacing' can be substituted by the term 'nominal central frequency granularity' defined in clause 8 of ITU-T G.694.1.";
  reference
    "RFC 7698: Framework and Requirements for GMPLS-Based Control of Flexi-Grid Dense Wavelength Division Multiplexing (DWDM) Networks,
}

typedef flexi-m {
  type uint16;
  description
    "The given value 'M' is used to determine the slot width.
    A slot width is defined by:
    \[ \text{slot width} = M \times \text{SWG (measured in GHz)}, \]
    where SWG is defined by the flexi-slot-width-granularity.";
  reference
    "RFC 7698: Framework and Requirements for GMPLS-Based Control of Flexi-Grid Dense Wavelength Division Multiplexing (DWDM) Networks.
}

typedef operational-mode {
  type string;
  description
    "Organization/vendor specific mode that guarantees interoperability.";
    // RFC Ed.: replace YYYY with actual RFC number and remove
    // this note after draft-ietf-ccamp-optical-impairment-topology-yang
}
typedef standard-mode {
  type string;
  description
    "ITU-T G.698.2 standard mode that guarantees interoperability. 
    It must be a string with the following format: B-DScW-ytz(v) where all these attributes 
    are conformant to the ITU-T recommendation";
  reference "ITU-T G.698.2 (11/2018)";
}

typedef organization-identifier {
  type string;
  description
    "vendor/organization identifier that uses a private mode out of already defined in G.698.2 ITU-T application-code";
  reference "RFC7581: Routing and Wavelength Assignment Information Encoding for Wavelength Switched Optical Networks";
}

typedef frequency-thz {
  type decimal64 {
    fraction-digits 6;
  }
  units THz;
  description 
    "The DWDM frequency in THz, e.g., 193.112500";
}

typedef frequency-ghz {
  type decimal64 {
    fraction-digits 3;
  }
  units GHz;
  description 
    "The DWDM frequency in GHz, e.g., 193112.500";
}

typedef dbm-t {
  type int32;
  units ".01dbm";
description
"Amplifiers and Transceivers Power in dBm."
}

typedef snr {
type decimal64 {
   fraction-digits 2;
}
units "dB@0.1nm";
description
   "(Optical) Signal to Noise Ratio measured over 0.1 nm resolution bandwidth";
}

typedef snr-or-null {
type union {
   type snr;
   type empty;
}
description
   "(Optical) Signal to Noise Ratio measured over 0.1 nm resolution bandwidth, when known, or an empty value when unknown.";
}

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
typedef decimal-2-digits {
    type decimal64 {
        fraction-digits 2;
    }
    description
    "A decimal64 value with two digits.";
}

typedef decimal-2-digits-or-null {
    type union {
        type decimal-2-digits;
        type empty;
    }
    description
    "A decimal64 value with two digits, when the value is known or an empty value when the value is not known.";
}

typedef power-in-db {
    type decimal-2-digits;
    units dB;
    description
    "The power in dB.";
}

typedef power-in-db-or-null {
    type union {
        type power-in-db;
        type empty;
    }
    description
    "The power in dB, when it is known or an empty value when the power is not known.";
}

typedef power-in-dbm {
    type decimal-2-digits;
    units dBm;
    description
    "The power in dBm.";
}

typedef power-in-dbm-or-null {
    type union {
        type power-in-dbm;
        type empty;
    }
    description
    "The power in dBm, when it is known or an empty value when the power is not known.";
}
type empty;
}
description
 "The power in dBm, when it is known or an empty value when the
 power is not known.";
}

/*
 * Groupings
 */

grouping wson-label-start-end {

description
 "The WSON label-start or label-end used to specify WSON label
 range.";

choice grid-type {

description
 "Label for DWDM or CWDM grid";

case dwdm {

leaf dwdm-n {

when "derived-from-or-self(../../../grid-type,
 \"wson-grid-dwdm\")" {

description
 "Valid only when grid type is DWDM.";
}

type l0-types:dwdm-n;

description
 "The central frequency of DWDM.";

reference
 "RFC 6205: Generalized Labels for Lambda-Switch-Capable
 (LSC) Label Switching Routers";
}
}

case cwdm {

leaf cwdm-n {

when "derived-from-or-self(../../../grid-type,
 \"wson-grid-cwdm\")" {

description
 "Valid only when grid type is CWDM.";
}

type l0-types:cwdm-n;

description
 "Channel wavelength computing input.";

reference
 "RFC 6205: Generalized Labels for Lambda-Switch-Capable
 (LSC) Label Switching Routers";
}
}
grouping wson-label-hop {
  description "Generic label-hop information for WSON";
  choice grid-type {
    description "Label for DWDM or CWDM grid";
    case dwdm {
      choice single-or-super-channel {
        description "single or super channel";
        case single {
          leaf dwdm-n {
            type 10-types:dwdm-n;
            description "The given value 'N' is used to determine the nominal central frequency.";
          }
        }
        case super {
          leaf-list subcarrier-dwdm-n {
            type 10-types:dwdm-n;
            description "The given values 'N' are used to determine the nominal central frequency for each subcarrier channel.";
            reference "ITU-T Recommendation G.694.1: Spectral grids for WDM applications: DWDM frequency grid";
          }
        }
      }
      case cwdm {
        leaf cwdm-n {
          type 10-types:cwdm-n;
          description "The given value 'N' is used to determine the nominal central wavelength.";
            reference "RFC 6205: Generalized Labels for Lambda-Switch-Capable (LSC) Label Switching Routers";
        }
      }
    }
  }
}

reference
"RFC 6205: Generalized Labels for Lambda-Switch-Capable (LSC) Label Switching Routers";
grouping l0-label-range-info {
  description "Information about Layer 0 label range."
  leaf grid-type {
    type identityref {
      base 10-grid-type;
    }
    description "Grid type";
  }
  leaf priority {
    type uint8;
    description "Priority in Interface Switching Capability Descriptor (ISCD).";
    reference "RFC 4203: OSPF Extensions in Support of Generalized Multi-Protocol Label Switching (GMPLS)";
  }
  reference "RFC 6205: Generalized Labels for Lambda-Switch-Capable (LSC) Label Switching Routers";
}

grouping wson-label-step {
  description "Label step information for WSON";
  choice 10-grid-type {
    description "Grid type: DWDM, CWDM, etc.";
    case dwdm {
      leaf wson-dwdm-channel-spacing {
        when "derived-from-or-self(../../grid-type, "wson-grid-dwdm")" {
          description "Valid only when grid type is DWDM.";
        }
        type identityref {
          base dwdm-ch-spc-type;
        }
        description
      }
    }
  }
  reference "RFC 6205: Generalized Labels for Lambda-Switch-Capable (LSC) Label Switching Routers";
}
"Label-step is the channel spacing (GHz), e.g., 100.000, 50.000, 25.000, or 12.500 GHz for DWDM."
reference
"RFC 6205: Generalized Labels for Lambda-Switch-Capable (LSC) Label Switching Routers";
}
}

reference
"RFC 6205: Generalized Labels for Lambda-Switch-Capable (LSC) Label Switching Routers,


grouping flexi-grid-label-start-end {
    description
    "The flexi-grid label-start or label-end used to specify flexi-grid label range.";
    leaf flexi-n {
        type l0-types:flexi-n;
        description
        "The given value 'N' is used to determine the nominal central frequency.";
    }
    reference
    "RFC 7698: Framework and Requirements for GMPLS-Based Control of Flexi-Grid Dense Wavelength Division Multiplexing (DWDM) Networks";
}

grouping flexi-grid-frequency-slot {
  description "Flexi-grid frequency slot grouping.";
  uses flexi-grid-label-start-end;
  leaf flexi-m {
    type l0-types:flexi-m;
    description "The given value 'M' is used to determine the slot width.";
  }
  reference "RFC 7698: Framework and Requirements for GMPLS-Based Control of Flexi-Grid Dense Wavelength Division Multiplexing (DWDM) Networks";
}

grouping flexi-grid-label-hop {
  description "Generic label-hop information for flexi-grid";
  choice single-or-super-channel {
    description "single or super channel";
    case single {
      uses flexi-grid-frequency-slot;
    }
    case super {
      list subcarrier-flexi-n {
        key "flexi-n";
        uses flexi-grid-frequency-slot;
        description "List of subcarrier channels for flexi-grid super channel.";
      }
    }
  }
  reference "RFC 7698: Framework and Requirements for GMPLS-Based Control of Flexi-Grid Dense Wavelength Division Multiplexing (DWDM) Networks";
}

grouping flexi-grid-label-range-info {
  description "Flexi-grid-specific label range related information";
  uses l0-label-range-info;
  container flexi-grid {
    description "flexi-grid definition";
    leaf slot-width-granularity {
type identityref {
    base flexi-slot-width-granularity;
}
default "flexi-swg-12p5ghz";
description
    "Minimum space between slot widths. Default is 12.500
    GHz.";
reference
    "RFC 7698: Framework and Requirements for GMPLS-Based
    Control of Flexi-Grid Dense Wavelength Division
    Multiplexing (DWDM) Networks";
}
leaf min-slot-width-factor {
    type uint16 {
        range "1..max";
    }
default "1";
description
    "A multiplier of the slot width granularity, indicating
    the minimum slot width supported by an optical port.

    Minimum slot width is calculated by:
    Minimum slot width (GHz) =
    min-slot-width-factor * slot-width-granularity.";
reference
    "RFC 8363: GMPLS OSPF-TE Extensions in Support of Flexi-
    Grid Dense Wavelength Division Multiplexing (DWDM)
    Networks";
}
leaf max-slot-width-factor {
    type uint16 {
        range "1..max";
    }
    must '. >= ../min-slot-width-factor' {
        error-message
            "Maximum slot width must be greater than or equal to
            minimum slot width.";
    }
description
    "A multiplier of the slot width granularity, indicating
    the maximum slot width supported by an optical port.

    Maximum slot width is calculated by:
    Maximum slot width (GHz) =
    max-slot-width-factor * slot-width-granularity

    If specified, maximum slot width must be greater than or
equal to minimum slot width. If not specified, maximum slot width is equal to minimum slot width.

reference
"RFC 8363: GMPLS OSPF-TE Extensions in Support of Flexi-Grid Dense Wavelength Division Multiplexing (DWDM) Networks";

}
}

grouping flexi-grid-label-step {
  description
    "Label step information for flexi-grid";
  leaf flexi-grid-channel-spacing {
    type identityref {
      base flexi-ch-spc-type;
    }
    default "flexi-ch-spc-6p25ghz";
    description
      "Label-step is the nominal central frequency granularity (GHz), e.g., 6.25 GHz.";
    reference
      "RFC 7699: Generalized Labels for the Flexi-Grid in Lambda Switch Capable (LSC) Label Switching Routers";
  }
  leaf flexi-n-step {
    type uint8;
    description
      "This attribute defines the multiplier for the supported values of 'N'.

For example, given a grid with a nominal central frequency granularity of 6.25 GHz, the granularity of the supported values of the nominal central frequency could be 12.5 GHz. In this case, the values of flexi-n should be even and this constraint is reported by setting the flexi-n-step to 2.

This attribute is also known as central frequency granularity in RFC 8363."
    reference
      "RFC 8363: GMPLS OSPF-TE Extensions in Support of Flexi-Grid Dense Wavelength Division Multiplexing (DWDM) Networks";
  }
  }
/* supported inverse multiplexing capabilities such as max. OTSiG:OTSi cardinality
It is a transponder attribute not transceiver

leaf multiplexing-cap {
  type uint32;
  config false;
  description "supported inverse multiplexing capabilities
  such as max. OTSiG:OTSi cardinality";
}
*/

grouping transceiver-mode {
  description "This grouping is intended to be used for reporting the
  information of a transceiver’s mode.";
  choice mode {
    mandatory true;
    description "Indicates whether the transceiver’s mode is a standard
    mode, an organizational mode or an explicit mode.";
    case G.698.2 {
      uses standard-mode;
    }
    case organizational-mode {
      container organizational-mode {
        description "The set of attributes for an organizational mode";
        uses organizational-mode;
        uses common-organizational-explicit-mode;
      } // container organizational-mode
    }
    case explicit-mode {
      container explicit-mode {
        description "The set of attributes for an explicit mode";
        container supported-modes {
          description "Container for all the standard and organizational
          modes supported by the transceiver's explicit
          mode.";
          leaf-list supported-application-codes {
            type leafref {
              path "../../../mode-id";
            }
            must "../../../../../../"
            + "supported-mode[mode-id=current()]"/
            + "standard-mode" {
              description "The pointer is only for application codes

supported by transceiver."
}
description
"List of pointers to the application codes
supported by the transceiver’s explicit mode."
}
leaf-list supported-organizational-modes {  
type leafref {  
  path "../../../mode-id";
}
must "../../../"  
  + "supported-mode[mode-id=current()]/"  
  + "organizational-mode" {  
description
"The pointer is only for organizational modes
supported by transceiver."
}
description
"List of pointers to the organizational modes
supported by the transceiver’s explicit mode."
}
}  // container supported-modes
uses common-explicit-mode;
uses common-organizational-explicit-mode;
}  // container explicit-mode
}  // end of case explicit-mode
}  // end of choice

grouping transceiver-capabilities {  
description
"This grouping is intended to be used for reporting the
capabilities of a transceiver."

container supported-modes {  
description
"Transceiver’s supported modes.";
list supported-mode {  
  key "mode-id";
  config false;
  description "list of supported transceiver’s modes.";
  leaf mode-id {  
    type string {  
      length "1..255";
    }
    description "ID for the supported transceiver’s mode.";
  }
  uses transceiver-mode;
}  // list supported-modes
grouping standard-mode {
    description
    "ITU-T G.698.2 standard mode that guarantees interoperability.
    It must be an string with the following format:
    B-DScW-ytz(v) where all these attributes are conformant
to the ITU-T recomendation";

    leaf standard-mode {
        type standard-mode;
        config false;
        description
        "G.698.2 standard mode";
    }
}

grouping organizational-mode {
    description
    "Transponder operational mode supported by organizations or
    vendor";

    leaf operational-mode {
        type operational-mode;
        config false;
        description
        "configured organization- or vendor-specific
        application identifiers (AI) supported by the transponder";
    }

    leaf organization-identifier {
        type organization-identifier;
        config false;
        description
        "organization identifier that uses organizational
        mode";
    }
}

grouping penalty-value {
    description
    "A common definition of the penalty value used for describing
    multiple penalty types (.e.g, CD, PMD, PDL).";

    leaf penalty-value {
        type union {
            type decimal64 {
                fraction-digits 2;
            }
        }
    }
}
range "0..max";
    }
    type empty;
    }
  units "dB";
  config false;
  mandatory true;
  description
    "OSNR penalty associated with the related optical
     impairment at the receiver.";
  }
}

/*
 * This grouping represent the list of attributes related to
 * optical impairment limits for explicit mode
 * (min OSNR, max PMD, max CD, max PDL, Q-factor limit, etc.)
 * In case of standard and operational mode the attributes are
 * implicit
 */

grouping common-explicit-mode {
  description "Attributes capabilities related to
               explicit mode of an optical transceiver";

  leaf line-coding-bitrate {
    type identityref {
      base line-coding;
    }
    config false;
    description
      "Bit rate/line coding of the optical tributary signal.";
    reference
      "ITU-T G.698.2 section 7.1.2";
  }
  leaf bitrate {
    type uint16;
    units "Gbit/sec";
    config false;
    description
      "The gross bitrate (e.g., 100, 200) of the optical tributary
       signal.";
  }
  leaf max-polarization-mode-dispersion {
    type decimal64 {
      fraction-digits 2;
      range "0..max";
    }
  }
  // Other leaves...
}
units "ps";
config false;
description
  "Maximum acceptable accumulated polarization mode
dispersion on the receiver";
}
leaf max-chromatic-dispersion {
  type decimal64 {
    fraction-digits 2;
    range "0..max";
  }
  units "ps/nm";
  config false;
description
  "Maximum acceptable accumulated chromatic dispersion
  on the receiver";
}
list chromatic-dispersion-penalty {
  config false;
description
  "Optional penalty associated with a given accumulated
  chromatic dispersion (CD) value.
  This list of pair cd and penalty can be used to
  sample the function penalty = f(CD).";
  leaf chromatic-dispersion {
    type union {
      type decimal64 {
        fraction-digits 2;
        range "0..max";
      }
      type empty;
    }
  units "ps/nm";
  config false;
  mandatory true;
description "Chromatic dispersion";
}
uses penalty-value;
}
list polarization-dispersion-penalty {
  config false;
description
  "Optional penalty associated with a given accumulated
  polarization mode dispersion (PMD) value.
  This list of pair pmd and penalty can be used to
  sample the function penalty = f(PMD).";
  leaf polarization-mode-dispersion {
    type union {

type decimal64 {
  fraction-digits 2;
  range "0..max";
}

leaf max-diff-group-delay {
  type int32;
  config false;
  description "Maximum Differential group delay of this mode
  for this lane";
}

list max-polarization-dependent-loss-penalty {
  config false;
  description
    "Optional penalty associated with the maximum acceptable
    accumulated polarization dependent loss.
    This list of pair pdl and penalty can be used to
    sample the function pdl = f(penalty).";
  leaf max-polarization-dependent-loss {
    type power-in-db-or-null;
    config false;
    mandatory true;
    description
      "Maximum acceptable accumulated polarization dependent
      loss.";
  }
  uses penalty-value;
}

leaf available-modulation-type {
  type identityref {
    base modulation;
  }
  config false;
  description
    "Modulation type the specific transceiver in the list
    can support";
}

leaf min-OSNR {
  type snr;
  config false;
}
description "min OSNR measured over 0.1 nm resolution bandwidth:
if received OSNR at minimum Rx-power is lower than MIN-OSNR,
an increased level of bit-errors post-FEC needs to be expected."
// change resolution BW from 12.5 GHz to 0.1 nm
}
leaf min-Q-factor {
  type int32;
  units "dB";
  config false;
  description "min Qfactor at FEC threshold";
}
leaf available-baud-rate {
  type uint32;
  units Bd;
  config false;
  description
  "Baud-rate the specific transceiver in the list can support.
  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 roll-off {
  type decimal64 {
    fraction-digits 4;
    range "0..1";
  }
  config false;
  description
  "the roll-off factor (beta with values from 0 to 1) identifies how the real signal shape exceed the baud rate. If=0 it is exactly matching the baud rate. If=1 the signal exceeds the 50% of the baud rate at each side.";
}
leaf min-carrier-spacing {
  type frequency-ghz;
  config false;
  description
  "This attribute specifies the minimum nominal difference
between the carrier frequencies of two homogeneous OTSIs (which have the same optical characteristics but the central frequencies) such that if they are placed next to each other the interference due to spectrum overlap between them can be considered negligible.

In case of heterogeneous OTSi it is up to path computation engine to determine the minimum distance between the carrier frequency of the two adjacent OTSi.

leaf available-fec-type {
  type identityref {
    base fec-type;
  }
  config false;
  description "Available FEC";
}
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 common-explicit-mode

/* transmitter tuning range (f_tx-min, f_tx-max) */

leaf min-central-frequency {
  type frequency-thz;
  config false;
description
   "This parameter indicates the minimum frequency for the
   transmitter tuning range.";
}
leaf max-central-frequency {
    type frequency-thz;
    config false;
    description
    "This parameter indicates the maximum frequency for the
    transmitter tuning range.";
}

leaf transceiver-tunability {
    type frequency-ghz;
    config false;
    description
    "This parameter indicates the transmitter frequency fine
    tuning steps e.g 3.125GHz or 0.001GHz.";
}

/* supported transmitter power range [p_tx-min, p_tx_max] */
leaf tx-channel-power-min {
    type dbm-t;
    config false;
    description "The minimum output power of this interface";
}
leaf tx-channel-power-max {
    type dbm-t;
    config false;
    description "The maximum output power of this interface";
}

/* supported receiver power range [p_rx-min, p_rx_max] */
leaf rx-channel-power-min {
    type dbm-t;
    config false;
    description "The minimum input power of this interface";
}
leaf rx-channel-power-max {
    type dbm-t;
    config false;
    description "The maximum input power of this interface";
}
leaf rx-total-power-max {
    type dbm-t;
}
config false;
description "Maximum rx optical power for all the channels";
}
} // grouping common-organizational-explicit-mode

/* This grouping represent the list of configured parameters */
/* values independent of operational mode */

grouping common-transceiver-configured-param {
  description "Capability of an optical transceiver";

  leaf tx-channel-power {
    type union {
      type dbm-t;
      type empty;
    }
    description "The current channel transmit power";
  }

  leaf rx-channel-power {
    type union {
      type dbm-t;
      type empty;
    }
    config false;
    description "The current channel received power ";
  }

  leaf rx-total-power {
    type union {
      type dbm-t;
      type empty;
    }
    config false;
    description "Current total received power";
  }
}
} // grouping for configured attributes out of mode

grouping l0-tunnel-attributes {
  description
    "Parameters for Layer0 (WSON or Flexi-Grid) Tunnels.";

  leaf bit-stuffing {
    type boolean;
    description
      "Bit stuffing enabled/disabled.";
  }

  leaf wavelength-assignment {
    type identityref {
      base wavelength-assignment;
    }
}

grouping frequency-range {
  description "This grouping defines the lower and upper bounds of a frequency range (e.g., a band).

  This grouping SHOULD NOT be used to define a frequency slot, which SHOULD be defined using the n and m values instead."

  leaf lower-frequency {
    type frequency-thz;
    mandatory true;
    description "The lower frequency boundary of the frequency range.";
  }

  leaf upper-frequency {
    type frequency-thz;
    must '. > ../lower-frequency' {
      error-message "The upper frequency must be greater than the lower frequency.";
    }
    mandatory true;
    description "The upper frequency boundary of the frequency range.";
  }
}

grouping l0-path-constraints {
  description "Common attribute for Layer 0 path constraints to be used by Layer 0 computation."

  leaf gsnr-margin {
    type snr {
      range 0..max;
    }
    default 0;
    description "An additional margin to be added to the OSNR-min of the transceiver when checking the estimated received Generalized SNR (GSNR)."
  }
}
grouping l0-path-properties {
  description
    "Common attribute for reporting the Layer 0 computed path properties.";
  leaf estimated-gsnr {
    type snr;
    config false;
    description
      "The estimate received GSNR for the computed path.";
  }
}

4. 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 Network Configuration Access Control Model (NACM) [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 NETCONF protocol over Secure Shell (SSH) specification [RFC6242] describes a method for invoking and running NETCONF within a Secure Shell (SSH) session as an SSH subsystem.

The objects in this YANG module are common data types and groupings. No object in this module can be read or written to. These definitions can be imported and used by other Layer 0 specific modules. It is critical to consider how imported definitions will be utilized and accessible via RPC operations, as the resultant schema will have data nodes that can be writable, or readable, and will have a significant effect on the network operations if used incorrectly or maliciously. All of these considerations belong in the document that defines the modules that import from this YANG module. Therefore, it is important to manage access to resultant data nodes that are considered sensitive or vulnerable in some network environments.

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

IANA has assigned new URIs from the "IETF XML Registry" [RFC3688] as follows:

Registrant Contact: The IESG
XML: N/A; the requested URI is an XML namespace.

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

Name: ietf-layer0-types
Prefix: 10-types
Reference: RFC 9093

[Editors’ Note] Check the IANA considerations in other bis documents

6. References

6.1. Normative References


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6.2. Informative References


Appendix A. Changes from RFC 9093

To be added in a future revision of this draft.

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Framework and Data Model for OTN Network Slicing
draft-ietf-ccamp-yang-otn-slicing-02

Abstract

The requirement of slicing network resources with desired quality of service is emerging at every network technology, including the Optical Transport Networks (OTN). As a part of the transport network, OTN can 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 and a YANG data model augmentation of the OTN topology model. Additional YANG data model augmentations will be defined in a future version of this draft.

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1. Introduction

The requirement of slicing network resources with desired quality of service is emerging at every network technology, including the Optical Transport Networks (OTN). As a part of the transport network, OTN can 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 and a YANG data model augmentation of the OTN topology model. Additional YANG data model augmentations will be defined in a future version of this draft.

1.1. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

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

1.2. 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.
### Table 1: Prefixes and Corresponding YANG Modules

<table>
<thead>
<tr>
<th>Prefix</th>
<th>YANG Module</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>yang</td>
<td>ietf-yang-types</td>
<td>[RFC6991]</td>
</tr>
<tr>
<td>inet</td>
<td>ietf-inet-types</td>
<td>[RFC6991]</td>
</tr>
<tr>
<td>nt</td>
<td>ietf-network-topology</td>
<td>[RFC8345]</td>
</tr>
<tr>
<td>nw</td>
<td>ietf-network-topology</td>
<td>[RFC8345]</td>
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<td>RFCXXXX</td>
</tr>
<tr>
<td>otns-mpi</td>
<td>ietf-otn-slice-mpi</td>
<td>RFCXXXX</td>
</tr>
</tbody>
</table>

RFC Editor Note: Please replace XXXX with the RFC number assigned to this document. Please replace YYYY with the RFC number assigned to [I-D.ietf-ccamp-otn-topo-yang]. Please replace ZZZZ with the RFC number assigned to [I-D.ietf-ccamp-layer1-types]. Please remove this note.

### 1.3. Definition of OTN Slice

An OTN slice is an OTN virtual network topology connecting a number of OTN endpoints using a set of shared or dedicated OTN network resources to satisfy specific service level objectives (SLOs).

An OTN slice is a technology-specific realization of an IETF network slice [I-D.ietf-teas-ietf-network-slices] in the OTN domain, with the capability of configuring slice resources in the term of OTN technologies. Therefore, all the terms and definitions concerning network slicing as defined in [I-D.ietf-teas-ietf-network-slices] apply to OTN slicing.
An OTN slice can span multiple OTN administrative domains, encompassing access links, intra-domain paths, and inter-domain links. An OTN slice may include multiple endpoints, each associated with a set of physical or logical resources, e.g., optical port or time slots, at the termination point (TP) of an access link or inter-domain link at an OTN provider edge (PE) equipment.

An end-to-end OTN slice may be composed of multiple OTN segment slices in a hierarchical or sequential (or stitched) combination.

Figure 1 illustrates the scope of OTN slices in multi-domain environment.

<------------------End-to-end OTN Slice----------------->

<- OTN Segment Slice 1 -->  <-- OTN Segment Slice 2 -->

Figure 1: OTN Slice

OTN slices may be pre-configured by the management plane and presented to the customer via the northbound interface (NBI), or be dynamically provisioned by a higher layer slice controller, e.g., an IETF network slice controller (IETF NSC) through the NBI. The OTN slice is provided by a service provider to a customer to be used as though it was part of the customer’s own networks.

2. Use Cases for OTN Network Slicing
2.1. Leased Line Services with OTN

For end business customers (like OTT or 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 in 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 been allocated to them and which could be used to support their leased lines, when needed. Users may formulate policies based on the demand for services and time to schedule the resources from the entire network's perspective flexibly. 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 a specific time interval to maximize network resource utilization efficiency.

2.2. Co-construction and Sharing

Co-construction and sharing of a network are becoming a popular means among service providers to reduce 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 occupies a certain percentage of the usage rights of the network resources. In this scenario, the network O&M is performed by a certain founder in each region, where the same founder usually deploys an independent management and control system. The other founders of the network use each other’s management and control system to provision services remotely. In this scenario, different founders’ network resources need to be automatically (associated) divided, isolated, and visualized. All founders may share or 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 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 use the leased network resources flexibly, 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, flexibly and independently, 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 for 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, the 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.

2.5. End-to-end network slicing

In an end-to-end network slicing scenario such as 5G network slicing [TS.28.530-3GPP], an IETF network slice [I-D.ietf-teas-ietf-network-slices] provides the required connectivity between other different segments of an end-to-end network slice, such as the Radio Access Network (RAN) and the Core Network (CN) segments, with a specific performance commitment. An IETF network slice could be composed of network slices from multiple technological and administrative domains. An IETF network slice can be realized by using or combining multiple underlying OTN slices with OTN resources, e.g., ODU time slots or ODU containers, to achieve end-to-end slicing across the transport domain.
3. Framework for OTN slicing

OTN slices may be abstracted differently depending on the requirement contained in the configuration provided by the slice customer. Whereas the customer requests an OTN slice to provide connectivity between specified endpoints, an OTN slice can be abstracted as a set of endpoint-to-endpoint links, with each link formed by an end-to-end tunnel across the underlying OTN networks. The resources associated with each link of the slice is reserved and commissioned in the underlying physical network upon the completion of configuring the OTN slice and all the links are active.

An OTN slice can also be abstracted as an abstract topology when the customer requests the slice to share resources between multiple endpoints and to use the resources on demand. The abstract topology may consist of virtual nodes and virtual links, and their associated resources are reserved but not commissioned across the underlying OTN networks. The customer can later commission resources within the slice dynamically using the NBI provided by the service provider. An OTN slice could use abstract topology to connect endpoints with shared resources to optimize the resource utilization, and connections can be activated within the slice as needed.

It is worth noting that those means to abstract an OTN slice are similar to the Virtual Network (VN) abstraction defined for higher-level interfaces in [RFC8453], in which context a connectivity-based slice corresponds to Type 1 VN and a resource-based slice corresponds to Type 2 VN, respectively.

A particular resource in an OTN network, such as a port or link, may be sliced with one of the two granularity levels:

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

Furthermore, an OTN switch is typically fully non-blocking switching at the lowest ODU container granularity, it is desirable to specify just the total number of ODU containers in the lowest granularity (e.g. ODU0), when configuring tributary-slot based slicing on links and ports internal to an OTN network. In multi-domain OTN network scenarios where separate OTN slices are created on each of the OTN networks and are stitched at inter-domain OTN links, it is necessary to specify matching tributary slots at the endpoints of the inter-
domain links. In some real network scenarios, OTN network resources including tributary slots are managed explicitly by network operators for network maintenance considerations. Therefore, an OTN slice controller shall support configuring an OTN slice with both options.

An OTN slice controller (OTN-SC) is a logical function responsible for the life-cycle management of OTN slices instantiated within the corresponding OTN network domains. The OTN-SC provides technology-specific interfaces at its northbound (OTN-SC NBI) to allow a higher-layer slice controller, such as an IETF network slice controller (NSC) or an orchestrator, to request OTN slices with OTN-specific requirements. The OTN-SC interfaces at the southbound using the MDSC-to-PNC interface (MPI) with a Physical Network Controller (PNC) or Multi-Domain Service Orchestrator (MDSC), as defined in the ACTN control framework [RFC8453]. The logical function within the OTN-SC is responsible for translating the OTN slice requests into concrete slice realization which can be understood and provisioned at the southbound by the PNC or MDSC.

The presence of OTN-SC provides multiple options for a high-level slice controller or an orchestrator to configure and realize slicing in OTN networks, depending on whether a customer’s slice request is technology agnostic or technology specific:

Option 1[opt.1]: An IETF NSC receives a technology-agnostic slice request from the IETF NSC NBI and realizes full or part of the slice in OTN networks directly through MPI provided by the PNC or MDSC. The IETF NSC is responsible for mapping a technology-agnostic slicing request into an OTN technology-specific realization. In this option, the OTN-SC is not used.

Option 2[opt.2]: An IETF NSC receives a technology-agnostic slice request from the IETF NSC NBI and delegates the request to the OTN-SC through the OTN-SC NBI, which is OTN technology specific. The OTN-SC in turn realizes the slice in single or multi domain OTN networks by working with the underlying PNC or MDSC. In this option, the OTN-SC is considered as a realization of IETF NSC, i.e., an NS realizer as per [I-D.draft-contreras-teas-slice-controller-models], when the underlying network is OTN. The OTN-SC is also a subordinate slice controller of the IETF NSC, which is consistent with the hierarchical control of slices defined by the IETF network slice framework.

Option 3[opt.3]: An OTN-aware orchestrator may request an OTN technology-specific slice with OTN-specific SLOs through the OTN-SC NBI to the OTN-SC. The OTN-SC in turn realizes the slice in single or multi domain OTN networks by working with the underlying PNC or MDSC.
An OTN slice may be realized by using standard MPI interfaces, control plane, network management system (NMS) or any other proprietary interfaces as needed. Examples of such interfaces include the abstract TE topology [RFC8795], TE tunnel [I-D.ietf-teas-yang-te], L1VPN[RFC4847], or Netconf/YANG based interfaces such as OpenConfig. Some of these interfaces, such as the TE tunnel model, are suitable for creating connectivity-based OTN slices which represent a slice as a set of TE tunnels, while other interfaces such as the TE topology model are more suitable for creating resource-based OTN slices which represent a slice as a topology.

The OTN-SC NBI is a technology-specific interface that augments the IETF NSC NBI, which is technology-agnostic.

Figure 2 illustrates the OTN slicing control hierarchy, the positioning of the OTN slicing interfaces as well as the options for OTN slice configuration.

```
+---------------------+        +---------------------+
| Provider's User     |        | Orchestrator / E2E Slice Controller |
|                     |        +-------------------------------+
| CMI                 |        | NSC-NBI                         |
|                     |        +-----------------------------+
| opt.3               |        | IETF Network Slice Controller   |
| OTN-SC NBI          |        |                               |
| opt.2               |        | opt.1                          |
| OTN-SC NBI          |        |                               |
| OTN-SC              |        |                               |
| MPI                 |        |                               |
| PNC                 |        |                               |
| SBI                 |        +-------------------------------+
| OTN Physical Network|
```

Figure 2: Positioning of OTN Slicing Interfaces
OTN-SC functionalities may be recursive such that a higher-level OTN-SC may designate the creation of OTN slices to a lower-level OTN-SC in a recursive manner. This scenario may apply to the creation of OTN slices in multi-domain OTN networks, where multiple domain-wide OTN slices provisioned by lower-layer OTN-SCs are stitched to support a multi-domain OTN slice provisioned by the higher-level OTN-SC. Alternatively, the OTN-SC may interface with an MDSC, which in turn interfaces with multiple PNCs through the MPI to realize OTN slices in multi-domain OTN networks without OTN-SC recursion. Figure 3 illustrates both options for OTN slicing in multi-domain.

![Diagram](image-url)

**Figure 3: OTN-SC for multi-domain**

OTN-SC functionalities are logically independent and may be deployed in different combinations to cater to the realization needs. In reference to the ACTN control framework [RFC8453], an OTN-SC may be deployed

* as an independent network function;
* together with a Physical Network Controller (PNC) for single-domain or with a Multi-Domain Service Orchestrator (MDSC) for multi-domain;
* together with a higher-level network slice controller to support end-to-end network slicing;

4. Realizing OTN Slices

[I-D.ietf-teas-ietf-network-slices] introduces a mechanism for an IETF network slice controller to realize network slices by constructing Network Resource Partitions (NRP). A NRP is a collection of resources identified in the underlay network to facilitate the mapping of network slices onto available network resources. An NRP is a scope view of a topology and may be
considered as a topology in its own right. Thus, in traffic-engineered (TE) networks including OTN, an NRP may be simply represented as an abstract TE topology defined by [RFC8795]. For OTN networks, an NRP may be represented as an abstract OTN topology defined by [I-D.ietf-ccamp-otn-topo-yang].

The NRP may be used to address the scalability issues where there may be considerable numbers of control and data plane states required to be stored and programmed if network slices are mapped directly to the underlay topology. NRP is internal to a network slice controller, and use of NRPs is optional yet could benefit a network slice realization in large-scale networks, including OTN networks.

For connectivity-based OTN slices, a connection within an OTN slice is typically realized by an OTN tunnel in the underlay topology and resources are reserved by the tunnel, thus use of NRP is optional in this case.

For resource-based OTN slices, the OTN-SC may map an OTN slice directly onto the underlay TE topology presented by the subtended network controller (MDSC or PNC) without creating NRP topologies. Due to the need for reserving resources, the OTN-SC needs to color corresponding link resources of the underlay topology with a slice identifier and maintain the coloring to keep track of the mapping of OTN slices. The OTN-SC may push the colored topology to the subtended MDSC or PNC using the MPI model defined in this draft.

Alternatively, an OTN slice may be mapped to a NRP as an overlay abstract OTN TE topology on top of the underlay topology. The corresponding link resources allocated to the slice is encapsulated in and tracked by the abstract topology, and a given link or port in the NRP topology represents resources that are reserved in the underlay topology. One slice topology for a resource-based OTN slice is typically realized by one dedicated NRP topology, and all the resources within that NRP topology are reserved for the OTN slice. In this case, the use of NRP eliminates the need for coloring links in the underlay topology, and the NRP topology may be pushed directly to the subtended MDSC or PNC by the OTN-SC.

Multiple OTN slices may be mapped to the same NRP, and a single connectivity construct of the slice may be mapped to only one NRP, as per [I-D.ietf-teas-ietf-network-slices].

Figure 4 illustrates the relationship between OTN slices and NRP.
5. YANG Data Model for OTN Slicing Configuration

5.1. OTN Slicing YANG Model for MPI
5.1.1. MPI YANG Model Overview

For the configuration of connectivity-based OTN slices, existing models such as the TE tunnel interface [I-D.ietf-teas-yang-te] may be used and no addition is needed. This model is addressing the case for configuring resource-based OTN slices, where the model permits to reserve resources exploiting the common knowledge of an underlying virtual topology between the OTN-SC and the subtended network controller (MDSC or PNC). The slice is configured by marking corresponding link resources on the TE topology received from the underlying MDSC or PNC with a slice identifier and OTN-specific resource requirements, e.g. the number of ODU time slots or the type/number of ODU containers. The MDSC or PNC, based on the marked resources by the OTN-SC, will update the underlying TE topology with new TE link for each of the colored links to keep booked the reserved OTN resources e.g. time slots or ODU containers.

5.1.2. MPI YANG Model Tree

module: ietf-otn-slice-mpi

augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes:
  +--rw (otn-slice-granularity)?
  | +--rw slice-id? uint32
  +--rw (link-resource)
     +--rw slices* [slice-id]
        +--rw slice-id uint32
        +--rw (technology)?
           +--rw (slice-bandwidth)?
              +--rw (containers)
                 +--rw odulist* [odu-type]
                    +--rw odu-type identityref
                    +--rw number? uint16
                 +--rw (time-slots)
                    +--rw otn-ts-num? uint32
     +--ro sliced-link-ref?
        -> ../../../../../nt:link/link-id

Figure 5: OTN slicing MPI tree diagram

5.1.3. MPI YANG Code
<CODE BEGINS> file "ietf-otn-slice-mpi@2022-07-09.yang"
module ietf-otn-slice-mpi {
    yang-version 1.1;
    prefix "otns-mpi";

    import ietf-network {
        prefix "nw";
        reference
            "RFC 8345: A YANG Data Model for Network Topologies";
    }

    import ietf-network-topology {
        prefix "nt";
        reference
            "RFC 8345: A YANG Data Model for Network Topologies";
    }

    import ietf-te-topology {
        prefix "tet";
        reference
            "RFC8795: YANG Data Model for Traffic Engineering (TE) Topologies";
    }

    import ietf-otn-topology {
        prefix "otnt";
        reference
            "I-D.ietf-ccamp-otn-topo-yang: A YANG Data Model for Optical Transport Network Topology";
    }

    import ietf-layer1-types {
        prefix "l1-types";
        reference
            "I-D.ietf-ccamp-layer1-types: A YANG Data Model for Layer 1 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>
The model fully conforms to the Network Management Datastore Architecture (NMDA).

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revision "2022-07-09" {
    description
        "Latest revision of MPI YANG model for OTN slicing.";
    reference
        "draft-ietf-ccamp-yang-otn-slicing-02: Framework and Data Model for OTN Network Slicing";
}

/* Groupings */

grouping otn-link-slice-profile {
    description
        "Profile of an OTN link slice.";
    choice otn-slice-granularity {
        default "link";
        description
            "Link slice granularity.";
    }
}
case link {
  leaf slice-id {
    type uint32;
    description
    "Slice identifier";
  }
}

case link-resource {
  list slices {
    key slice-id;
    description
    "List of slices.";
    leaf slice-id {
      type uint32;
      description
      "Slice identifier";
    }
  choice technology {
    description
    "Data plane technology types.";
    case otn {
      choice slice-bandwidth {
        description
        "Bandwidth specification for OTN slices.";
        case containers {
          uses l1-types:otn-link-bandwidth;
        }
        case time-slots {
          leaf otn-ts-num {
            type uint32;
            description
            "Number of OTN tributary slots allocated
            for the slice.";
          }
        }
      }
    }
  }
}

leaf sliced-link-ref {
  type leafref {
    path "./././././nt:link/nt:link-id";
  }
  config false;
  description
  "Relative reference to virtual links generated from
  this TE link.";
}
augment "/nw:networks/nw:network/nt:link/tet:te/"
+ "tet:te-link-attributes" {
  when "/.//nw:network-types/tet:te-topology/
+ "otnt:otn-topology" {
      description
      "Augmentation parameters apply only for networks with
          OTN topology type."
    }
  description
  "Augment OTN TE link attributes with slicing profile.";
  uses otnt-link-slice-profile;
}
<CODE ENDS>

Figure 6: OTN slicing MPI YANG model

5.2. OTN Slicing YANG Model for OTN-SC NBI

5.2.1. NBI YANG Model Overview

The YANG model for OTN-SC NBI is OTN-technology specific, but shares many common constructs and attributes with generic network slicing YANG models. Furthermore, the OTN-SC NBI YANG is expected to support both connectivity-based and resource-based slice configuration, which is likely a common requirement for supporting slicing at other transport network layers, e.g. WDM or MPLS(-TP). Therefore, the OTN-SC NBI YANG model is designed into two models, a common base model for transport network slicing, and an OTN slicing model which augments the base model with OTN technology-specific constructs.

The base model defines a transport network slice (TNS) with the following constructs and attributes:

* Common attributes, which include a set of common attributes like slice identifier, name, description, and names of customers who use the slice.

* Endpoints, which represent conceptual points of connection from a customer device to the TNS. An endpoint is mapped to specific physical or virtual resources of the customer and provider, and
such mapping is pre-negotiated and known to both the customer and provider prior to the slice configuration. The mechanism for endpoint negotiation is outside the scope of this draft.

* **Network topology**, which represent set of shared, reserved resources organized as a virtual topology between all of the endpoints. A customer could use such network topology to define detailed connectivity path traversing the topology, and allow sharing of resources between its multiple endpoint pairs.

* **Connectivity matrix**, which represent the intended virtual connections between the endpoints within a TNS. A connectivity matrix entry could be associated with an explicit path over the above network topology.

* **Service-level objectives (SLOs)** associated with different objects, including the TNS, node, link, termination point, and explicit path, within a TNS.

### 5.2.2. NBI YANG Model Tree for Transport Network Slice
module: ietf-transport-network-slice

augment /ietf-nss:network-slice-services/ietf-nss:slice-service:
  ++-rw network-topologies
    ++-rw network-topology* [topology-id]
      ++-rw topology-id       string
      ++-rw slo-sle-policy
        ++-rw optimization-criterion?   identityref
        ++-rw delay-tolerance?          boolean
        ++-rw periodicity*              uint64
        ++-rw isolation-level?          identityref
      ++-rw node* [node-id]
        ++-rw node-id              inet:uri
        ++-rw slo-sle-policy
          ++-rw optimization-criterion?   identityref
          ++-rw delay-tolerance?          boolean
          ++-rw periodicity*              uint64
          ++-rw isolation-level?          identityref
        ++-rw termination-point* [tp-id]
          ++-rw tp-id     inet:uri
          ++-rw sdp-id?   leafref
      ++-rw link* [link-id]
        ++-rw link-id           inet:uri
        ++-rw slo-sle-policy
          ++-rw optimization-criterion?   identityref
          ++-rw delay-tolerance?          boolean
          ++-rw periodicity*              uint64
          ++-rw isolation-level?          identityref
        ++-rw source
          ++-rw source-node?   -> ../../../node/node-id
          ++-rw source-tp?     leafref
        ++-rw destination
          ++-rw dest-node?   -> ../../../node/node-id
          ++-rw dest-tp?     leafref

augment /ietf-nss:network-slice-services/ietf-nss:slice-service
  /ietf-nss:connection-groups/ietf-nss:connection-group
  /ietf-nss:connectivity-construct:
    ++-rw topology-id?     leafref
    ++-rw explicit-path* [tp-id]
    ++-rw tp-id      leafref

Figure 7: Tree diagram for transport network slice

5.2.3.  NBI YANG Code for Transport Network Slice
<CODE BEGINS> file "ietf-transport-network-slice@2022-07-09.yang"
module ietf-transport-network-slice {
  yang-version 1.1;
  namespace
  prefix "tns";

  import ietf-inet-types {
    prefix inet;
    reference
      "RFC 6991: Common YANG Data Types";
  }

  import ietf-te-types {
    prefix "te-types";
    reference
      "RFC 8776: Traffic Engineering Common YANG Types";
  }

  import ietf-network-slice-service {
    prefix "ietf-nss";
    reference
      "draft-ietf-teas-ietf-network-slice-nbi-yang-00:
        IETF Network Slice Service YANG Model";
  }

  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>
    Editor: Aihua Guo
      <mailto:aihuaguo.ietf@gmail.com>
    Editor: Sergio Belotti
      <mailto:sergio.belotti@nokia.com>";

  description
    "This module defines a base YANG data model for configuring
generic network slices in optical transport networks, e.g.,
Optical Transport Network (OTN)."
The model fully conforms to the Network Management Datastore Architecture (NMDA).

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revision "2022-07-09" {
  description
    "Latest revision of NBI YANG model for OTN slicing.";
  reference
    "draft-ietf-ccamp-yang-otn-slicing-02: Framework and Data Model for OTN Network Slicing";
}

/* Identities */
identity isolation-level {
  description
    "Base identity for the isolation-level.";
  reference
    "GSMA-NS-Template: Generic Network Slice Template, Version 3.0.";
}
identity no-isolation {
  base isolation-level;
  description
    "Network slices are not separated.";
}
identity physical-isolation {
  base isolation-level;
  description
    "Network slices are physically separated (e.g. different rack, different hardware, different location, etc.).";
}
identity logical-isolation {
  base isolation-level;
  description
"Network slices are logically separated."

identity process-isolation {
    base physical-isolation;
    description
        "Process and threads isolation."
}

identity physical-memory-isolation {
    base physical-isolation;
    description
        "Process and threads isolation."
}

identity physical-network-isolation {
    base physical-isolation;
    description
        "Process and threads isolation."
}

identity virtual-resource-isolation {
    base logical-isolation;
    description
        "A network slice has access to specific range of resources
        that do not overlap with other network slices
        (e.g. VM isolation)."
}

identity network-functions-isolation {
    base logical-isolation;
    description
        "NF (Network Function) is dedicated to the network slice,
        but virtual resources are shared."
}

identity service-isolation {
    base logical-isolation;
    description
        "NSC data are isolated from other NSCs, but virtual
        resources and NFs are shared."
}

/*
 * Groupings
 */

grouping slo-sle-policy {
    description
        "Policy grouping for Transport Network Slices."
}

container slo-sle-policy {
    description
        "SLO/SLE policy container";
leaf optimization-criterion {
    type identityref {
        base te-types:objective-function-type;
    }
    description
    "Optimization criterion applied to this topology."
}
leaf delay-tolerance {
    type boolean;
    description
    "true’ if is not too critical how long it takes to
deliver the amount of data.”;
    reference
    "GSMA-NS-Template: Generic Network Slice Template,
    Version 3.0.”;
}
leaf-list periodicity {
    type uint64;
    units seconds;
    description
    "A list of periodicities supported by the network
    slice.”;
    reference
    "GSMA-NS-Template: Generic Network Slice Template,
    Version 3.0.”;
}
leaf isolation-level {
    type identityref {
        base isolation-level;
    }
    description
    "A network slice instance may be fully or partly,
    logically and/or physically, isolated from another
    network slice instance. This attribute describes
different types of isolation:’’;
}
}
}
grouping network-topology-def {
    description
    "Network topology definition”;
    uses slo-sle-policy;
    list node {
        key "node-id";
        description
        "The inventory of nodes of this topology.”;
        leaf node-id {

list termination-point {
  key "tp-id";
  description "TP identifier";
  leaf tp-id {
    type inet:uri;
    description "Termination point identifier.";
  }
  uses slo-sle-policy;
  leaf sdp-id {
    type leafref {
      path "/ietf-nss:network-slice-services="/ +
      "/ietf-nss:slice-service="/ +
      "[ietf-nss:slice-service-id=current()="/ +
      "/..//..//..//ietf-nss:slice-service-id"]="/ +
    }
    description "Relative reference to SDP id.";
  }
}

list link {
  key "link-id";
  description "Link identifier.";
  leaf link-id {
    type inet:uri;
    description "Link identifier.";
  }
  uses slo-sle-policy;
  container source {
    description "Link source node";
    leaf source-node {
      type leafref {
        path "/..//..//node/node-id";
      }
      description "Source node identifier, must be in same topology.";
    }
    leaf source-tp {
      type
type leafref {
    path "../../../node[node-id=current()]/source-node/termination-point/tp-id";
} 

description
  "Termination point within source node that terminates the link."
}
}

container destination {

description
  "Link destination node";
leaf dest-node {
    type leafref {
        path ".../../node/node-id";
    }

description
  "Destination node identifier, must be in same topology."
}

leaf dest-tp {
    type leafref {
        path ".../../node[node-id=current()]/dest-node/termination-point/tp-id";
    }

description
  "Termination point within destination node that terminates the link."
}
}

grouping topology-ref {

description
  "Grouping for network topology reference.";
leaf topology-id {
    type leafref {
        path ".../../network-topologies/network-topology"+
            "/network-topology";
    }

description
  "Relative reference to network topology id.";
}
uses explicit-path;
}

grouping explicit-path {

}
description
"Explicit path for a connectivity matrix entry";

list explicit-path {
key "tp-id";
description
"List of TPs within a network topology that form a path.";
leaf tp-id {
type leafref {
path "/ietf-nss:network-slice-services"+
"/ietf-nss:slice-service"+
"[ietf-nss:service-id=current()]+"+
"/.../.../.../ietf-nss:service-id]+"+
"/network-topologies"+
"/network-topology[topology-id=current()]+"+
"/.../.../topology-id]/node/termination-point"+
"/tp-id";
}
description
"Relative reference to TP id.";
}}

/*
* Augmented data nodes
*/
augment "/ietf-nss:network-slice-services" +
"/ietf-nss:slice-service" {
description
"Augment IETF network slice services to include network topologies.";
container network-topologies {
description
"Set of network topologies referenced by network slices";
list network-topology {
key "topology-id";
description
"List of network topologies";
leaf topology-id {
type string;
description
"Topology identifier";
}
uses network-topology-def;
}
augment "/ietf-nss:network-slice-services" + 
"/ietf-nss:slice-service" + 
"/ietf-nss:connection-groups" + 
"/ietf-nss:connection-group" + 
"/ietf-nss:connectivity-construct"{
    description 
    "Add topology id and explicit path to a connectivity 
    construct";
    uses topology-ref;
}
"<CODE ENDS>

Figure 8: YANG model for transport network slice

5.2.4. NBI YANG Model Tree for OTN slice

TBD.

5.2.5. NBI YANG Code for OTN Slice

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

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.

There are a number of data nodes defined in this YANG module that are writable/creatable/deletable (i.e., config true, which is the default). These 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. Considerations in Section 8 of [RFC8795] are also applicable to their subtrees in the module defined in this document.

Some of the readable data nodes in this YANG module may be considered sensitive or vulnerable in some network environments. It is thus important to control read access (e.g., via get, get-config, or notification) to these data nodes. Considerations in Section 8 of [RFC8795] are also applicable to their subtrees in the module defined in this document.

8. IANA Considerations

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

Registrant Contact: The IESG
XML: N/A; the requested URI is an XML namespace.

Registrant Contact: The IESG
XML: N/A; the requested URI is an XML namespace.

This document registers a YANG module in the YANG Module Names registry [RFC6020].
name: ietf-transport-network-slice
prefix: tns
reference: RFC XXXX

name: ietf-otn-slice
prefix: otns
reference: RFC XXXX

name: ietf-otn-slice-mpi
prefix: otns-mpi
reference: RFC XXXX

9. Normative References

[GSMA-NS-Template]

[I-D.draft-contreras-teas-slice-controller-models]

[I-D.ietf-ccamp-layer1-types]

[I-D.ietf-ccamp-otn-topo-yang]


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Problem Statement and Gap Analysis for Connecting to Cloud DCs via Optical Networks
draft-liu-ccamp-optical2cloud-problem-statement-02

Abstract

Many applications, including optical leased line, cloud VR and computing cloud, benefit from the network scenario where the data traffic to cloud data centers (DCs) is carried end-to-end over an optical network. This document describes the problem statement and requirements for connecting to cloud DCs over optical networks, and presents a gap analysis for existing control plane protocols for supporting this network scenario.

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1. Introduction

Cloud applications are becoming more popular and widely deployed in enterprises and vertical industries. Organizations with multiple campuses are interconnected together with the remote cloud for storage and computing. Such cloud services demand that the underlying network provides high quality of experience, such as high availability, low latency, on-demand bandwidth adjustments, and so on.

Cloud services have been carried over IP/Ethernet-based aggregated networks for years. MPLS-based VPNs with traffic engineering (TE) are usually used to achieve desired service quality. Provisioning and management of MPLS VPNs is known to be complicated and typically involves manual TE configuration across the network.

To improve the performance and flexibility of aggregated networks, Optical Transport Network (OTN) technology is introduced to complement the IP/Ethernet-based aggregation networks to enable full-fiber connections. This scenario is described in the Fifth
Generation Fixed Network Architecture by the ETSI F5G ISG [ETSI.GR.F5G.001]. OTN can be used to provide high quality carrier services in addition to the traditional MPLS VPN services. OTN provides Time Division Multiplexing (TDM) based connections with no queueing or scheduling needed, with an access bandwidth granularity of 1.25Gbps, i.e., ODU0 (Optical Data Unit 0) and above. This bandwidth granularity is typically more than what a single application would demand; therefore, user traffic usually needs to be aggregated before being carried forward through the network. However, advanced OTN technologies developed in ITU-T work items have aimed to enhance OTN to support services of much finer granularity. These enhancements, when implemented, will make OTN an even more suitable solution for bearing cloud traffic with high quality and bandwidth granularity close to what an IP/Ethernet-based network could offer.

Many cloud-based services that require high bandwidth, deterministic service quality, and flexible access could potentially benefit from the network scenario of using OTN-based aggregation networks to interconnect cloud data centers (DCs). For example, intra-city Data Center Interconnects (DCIs), which communicate with each other to support public and/or private cloud services, can use OTN for intra-city DCI networks to ensure ultra-low latency and on-demand provisioning of large bandwidth connections for their Virtual Machine (VM) migration services. Another example is the high quality private line, which can be provided over OTN dedicated connections with high security and reliability for large enterprises such as financial, medical centers, and education customers. Yet another example is the Cloud Virtual Reality (VR) services, which typically require high bandwidth (e.g., over 10Gbps for 4K or 8K VR) links with low latency (e.g., 10ms or less) and low jitter (e.g., 5ms or less) for rendering with satisfactory user experience. These network properties required for cloud VR services can typically be offered by OTNs with higher quality comparing to IP/Ethernet based networks.

[I-D.ietf-rtgwg-net2cloud-problem-statement] and [I-D.ietf-rtgwg-net2cloud-gap-analysis] present a detailed analysis of the coordination requirements between IP-based networks and cloud DCs. This document complements that analysis by further examining the requirements and gaps from the control plane perspective when accessing cloud DCs through OTNs. Data plane requirements are out of the scope of this document.

2. Requirements and Gap Analysis
2.1. Multi-cloud Access

Cloud services are deployed in geographically distributed locations for scalability and resiliency, and they are usually hosted by multiple interconnected DCs. DCs have usually been interconnected through Layer 2/3 switches or routers with full mesh connectivity. To improve interaction efficiency as well as service experience, OTN is also considered as an option for DC interconnection. This network scenario is illustrated in Figure 1.

![Figure 1: Multi-cloud access through an OTN](image)

A customer application is connected to the cloud via one of the Customer Premises Equipment (CPE), and access cloud services are hosted in multiple clouds that are attached to different cloud gateways. Layer 2 or Layer 3 Virtual Private Networks (L2VPN or L3VPN) are used as overlay services on top of the OTN to support multi-cloud access. Serving as an overlay, the OTNs should provide the capability to create different types of connections, including point-to-point (P2P), point-to-multipoint (P2MP) and multipoint-to-multipoint (MP2MP) connections to support diverse L2VPN or L3VPN services.

In the data plane, OTN connections are P2P by nature. To support P2MP and MP2MP services, multiple P2P OTN connections can be established between each source and destination pair. The routing and signaling protocols for OTN need to coordinate these OTN connections to ensure they are routed with proper diverse paths to meet resiliency and path quality constraints.
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[RFC4461] defines the requirements for establishing P2MP MPLS traffic engineering label switched paths (LSPs). [RFC6388] describes extensions to the Label Distribution Protocol (LDP) for the setup of P2MP and MP2MP LSPs in MPLS Networks. The generic rules introduced by those documents work also apply to OTNs, however, the protocol extensions are missing and are required for establishing P2MP and MP2MP connections with OTN resources, i.e., time slots.

2.2. Service Awareness

Cloud-oriented services are dynamic in nature with frequent changes in bandwidth and quality of service (QoS) requirements. However, in typical OTN scenarios, OTN connections are preconfigured between provider edge (PE) nodes, and client traffic like IP or Ethernet is fixed-mapped onto the payload of OTN frames at the ingress PE node. This makes the OTN connections rather static and they cannot accommodate the dynamicity of the traffic unless they are permanently over-provisioned, resulting in slow and inefficient use of the OTN bandwidth resources. To address this issue and to make the OTN more suitable for carrying cloud-oriented services, it needs to be able to understand the type of traffic and its QoS requirements, so that OTN connections can be dynamically built and selected with the best feasible paths. The mapping of client services to OTN connections should also be dynamically configured or modified to better adapt to the traffic changes.

New service-aware capabilities are needed for both the control plane and data plane to address this challenge for OTNs. In the data plane, new hardware that can examine cloud traffic packet header fields (such as the IP header source and destination IP address and/or the type of service (TOS) field, virtual routing and forwarding (VRF) identifiers, layer 2 Media Access Control (MAC) address or virtual local area network (VLAN) identifiers) are introduced to make the PE node able to sense the type of traffic. This work for the data plane is out of the scope of this document.

Being service aware allows the OTN network to accurately identify the characteristics of carried client service flows and the real-time traffic of each flow, making it possible to achieve automated and real-time operations such as dynamic connection establishment and dynamic bandwidth adjustment according to preset policies. Those capabilities help to optimize the resource utilization and significantly reduce the operational cost of the network.

Upon examining the client traffic header fields and obtaining client information such as the cloud destination and QoS requirements, the OTN PE node needs to forward such information to the control entity of the OTN to make decisions on connection configurations, and map...
the client packets of different destination/QoS to different ODU connections. The client information could include, but is not limited to, the destination IP addresses, type of cloud service, and QoS information such as bandwidth, latency bounds, and resiliency factors. The control entity may be an SDN controller or a control plane instance: in the former case communications are established between each of the PE nodes and the controller, and the controller serves as a central authority for OTN connection configurations; whereas in the latter case, all of the PE nodes need to disseminate client information to each other using control plane protocols or possibly through some intermediate reflectors. It is desirable that the protocols used for both cases are consistent, and ideally, the same. A candidate protocol is the PCE communication Protocol (PCEP) [RFC5440], but there are currently no extensions defined for describing such client traffic information. Extensions to PCEP could be defined outside this document to support the use case. It is also possible to use the BGP Link State (BGP-LS) protocol [RFC7752] to perform the distribution of client information. However, an OTN PE node does not typically run BGP protocols due to that BGP lacks protocol extensions to support optical networks. Therefore, PCEP seems to be a better protocol choice in this case.

3. Framework

3.1. Service Identification and Mapping

The OTN PE node should support the learning and identification of the packet header carried by client services. The identification content may include but not limited to the following content:

* Source and destination MAC addresses
* Source and destination IP addresses
* VRF identifier
* VLAN (S-VLAN and/or C-VLAN) identifier
* MPLS label

The OTN PE node should support reporting the above identified client services to the management and control system, which can obtain the client-side addresses reported by each node in the entire network to build up a global topology. Some of the learnt content, such as the VLAN identifier, are not required to be reported since VLAN is of only local significance.
Internet-Draft       Cloud Optical Problem Statement           July 2022

The management and control system should be able to calculate the corresponding ODU connection route based on the source and destination addresses of the service, and create the mapping between service address and the ODU connection according to preset policies. The mapping table can be generated through management plane configuration or control plane protocol.

3.2. Reporting Service Identification

The control plane protocol extension should report to the controller service identification contents, which should include at least the following content:

* A private network or network slice identifier, which is a globally unique identifier to identify different tenants or applications supported by the private network

* OTN node identifier, which identify the OTN PE node that reported this packet

* The IP/MAC address of the client side learned by the OTN PE node

When the PCEP protocol is used, this extension may be defined as a PCEP Report message.

3.3. Configuring Service Mapping

The control plane protocol extension may be defined to push the mapping table between service address to ODU connections from the controller to the OTN PE nodes. The message should include at least the following content:

* A private network or network slice identifier, which is a globally unique identifier to identify different tenants or applications supported by the private network

* A mapping table of \{service address, ODU connection identifier\}, with each entry of the table contains at least the information of \{remote OTN node, remote service address\}, where the concept of "remote" is based on the perspective of the OTN device that receives this packet

When the PCEP protocol is used, this extension may be defined as a PCEP Update message.
4. Manageability Considerations

TBD

5. Security Considerations

This document analyzes the requirements and gaps in connecting to cloud DCs over optical networks without defining new protocols or interfaces. Therefore, this document introduces no new security considerations to the control or management plane of OTN. Risks presented by existing OTN control plane are described in [RFC4203] and [RFC4328], and risks presented by existing northbound and southbound control interfaces in general are described in [RFC8453]. Moreover, the data communication network (DCN) for OTN control plane protocols are encapsulated in fibers, which provides a much better security environment for running the protocols.

6. IANA Considerations

This document requires no IANA actions.

7. References

7.1. Normative References

[ETSI.GR.F5G.001]
European Telecommunications Standards Institute (ETSI), "Fifth Generation Fixed Network (F5G); F5G Generation Definition Release 1", ETSI GR F5G 001, December 2020, <https://www.etsi.org/deliver/etsi_gr/F5G/001_099/001/01.01.01_60/gr_F5G001v010101p.pdf>.


7.2. Informative References


Acknowledgments

TBD

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Abstract

This document defines a YANG data model for network hardware inventory data information.

The YANG data model presented in this document is intended to be used as the basis toward a generic YANG data model for network hardware inventory data information which can be augmented, when required, with technology-specific (e.g., optical) inventory data, to be defined either in a future version of this document or in another document.

The YANG data model defined in this document conforms to the Network Management Datastore Architecture (NMDA).

Status of This Memo

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1. Introduction

Network hardware inventory management is a key component in operators’ OSS architectures.

Network inventory is a fundamental functionality in network management and was specified many years ago. Given the emerging of data models and their deployment in operator’s management and control systems, the traditional function of inventory management is also requested to be defined as a data model.

Network inventory management and monitoring is a critical part of ensuring the network stays healthy, well-planned, and functioning in the operator’s network. Network inventory management allows the operator to keep track of what physical network devices are staying in the network including relevant software and hardware.

The network inventory management also helps the operator to know when to acquire new assets and what is needed, or to decommission old or faulty ones, which can help to improve network performance and capacity planning.

In [I-D.ietf-teas-actn-poi-applicability] a gap was identified regarding the lack of a YANG data model that could be used at ACTN MPI interface level to report whole/partial hardware inventory information available at PNC level towards north-bound systems (e.g., MDSC or OSS layer).

[RFC8345] initial goal was to make possible the augmentation of the YANG data model with network inventory data model but this was never developed and the scope was kept limited to network topology data only.

It is key for operators to drive the industry towards the use of a standard YANG data model for network inventory data instead of using vendors proprietary APIs (e.g., REST API).

In the ACTN architecture, this would bring also clear benefits at MDSC level for packet over optical integration scenarios since this would enable the correlation of the inventory information with the links information reported in the network topology model.

The intention is to define a generic YANG data model that would be as much as possible technology agnostic (valid for IP, optical and microwave networks) and that could be augmented, when required, to include some technology-specific inventory details.
[RFC8348] defines a YANG data model for the management of the hardware on a single server and therefore it is more applicable to the PNC South Bound Interface (SBI) towards the network elements rather than at the PNC MPI. However, the YANG data model defined in [RFC8348] has been used as a reference for defining the YANG network hardware inventory data model.

For optical network hardware inventory, the network inventory YANG data model should support the use cases (4a and 4b) and requirements defined in [ONF_TR-547], in order to guarantee a seamless integration at MDSC/OSS/orchestration layers.

The proposed YANG data model has been analyzed to cover the requirements and use cases for Optical Network Hardware Inventory.

Being based on [RFC8348], this data model should be a good starting point toward a generic data model and applicable to any technology. However, further analysis of requirements and use cases is needed to extend the applicability of this YANG data model to other types of networks (IP and microwave) and to identify which aspects are generic and which aspects are technology-specific for optical networks.

This document defines one YANG module: ietf-network-inventory.yang (Section 4).

Note: review in future versions of this document the related modules, depending on the augmentation relationship.

The YANG data model defined in this document conforms to the Network Management Datastore Architecture [RFC8342].

1.1. Terminology and Notations

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

* client
* server
* augment
* data model
* data node

The following terms are defined in [RFC6241] and are not redefined here:
* configuration data
* state data

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

TBD: Recap the concept of chassis/slot/component/board/... in [TMF-MTOSI].

Following terms are used for the representation of the hierarchies in the network hardware inventory.

Network Element:

a device installed on one or several chassis and can afford some specific transmission function independently.

Rack:

a holder of the device and provides power supply for the device in it.

Chassis:

a holder of the device installation.

Slot:

a holder of the board.

Component:

holders and equipment of the network element, including chassis, slot, sub-slot, board and port.

Board/Card:

a pluggable equipment can be inserted into one or several slots/sub-slots and can afford a specific transmission function independently.

Port:

an interface on board
1.2. Requirements Notation

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

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. 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, as shown in the following table.

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Yang Module</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>ianahw</td>
<td>iana-hardware</td>
<td>[RFC8348]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ni</td>
<td>ietf-network-inventory</td>
<td>RFC XXXX</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>yang</td>
<td>ietf-yang-types</td>
<td>[RFC6991]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Prefixes and corresponding YANG modules

RFC Editor Note: Please replace XXXX with the RFC number assigned to this document. Please remove this note.

2. YANG Data Model for Network Hardware Inventory

2.1. YANG Model Overview

Based on TMF classification in [TMF-MTOSI], inventory objects can be divided into two groups, holder group and equipment group. The holder group contains rack, chassis, slot, sub-slot while the equipment group contains network-element, board and port. With the requirement of GIS and on-demand domain controller selection raised, the equipment room becomes a new inventory object to be managed besides TMF classification.
Logically, the relationship between these inventory objects can be described by Figure 1 below:

```
+-------------+     +-----------------+
|  inventory  |     | network element |
+-------------+     +-----------------+
   // \       // \ 1:M
  1:N //   \ 1:M
   // \       // \
+-----------------+     +-----------------+
| equipment room |     | network element |
+-----------------+     +-----------------+
   // \       // \ 1:M
  1:N //   \ 1:M
   // \       // \
+------------+               ||1:M
|    rack    |               ||
+------------+               ||
   \         \               ||
    \     \                 ||
     \   \                  ||
      \ \                  ||
       \                    ||
        \                   ||
         \                  ||
          \                 ||
           \               ||
            \             ||
             \           ||
              \         ||
               \     ||
                \   ||
                 \||
                  \____1:N______\____1:M_______
                    \________________________
                        \________________________
```

Figure 1: Relationship between inventory objects

In [RFC8348], rack, chassis, slot, sub-slot, board and port are defined as components of network elements with generic attributes.

Considering there are some special scenarios, the relationship between the rack and network elements is not 1 to 1 nor 1 to n. The network element cannot be the direct parent node of the rack. So there should be n to m relationship between racks and network elements. And the chassis in the rack should have some reference information to the component.
While [RFC8348] is used to manage the hardware of a single server (e.g., a Network Element), the Network Inventory YANG data model is used to retrieve the network hardware inventory information that a controller discovers from multiple Network Elements under its control.

However, the YANG data model defined in [RFC8348] has been used as a reference for defining the YANG network inventory data model. This approach can simplify the implementation of this network hardware inventory model when the controller uses the YANG data model defined in [RFC8348] to retrieve the hardware from the network elements under its control.

Note: review in future versions of this document which attributes from [RFC8348] are required also for network hardware inventory and whether there are attributes not defined in [RFC8348] which are required for network hardware inventory

Note: review in future versions of this document whether to re-use definitions from [RFC8348] or use schema-mount.

```
++--ro network-inventory
  +--ro equipment-rooms
    +--ro equipment-room* [uuid]
      +--ro uuid        yang:uuid
      ...................................
    +--ro racks
      +--ro rack* [uuid]
        +--ro uuid           yang:uuid
        ...................................
  +--ro network-elements
    +--ro network-element* [uuid]
      +--ro uuid           yang:uuid
      ...................................
    +--ro components
      +--ro component* [uuid]
        +--ro uuid           yang:uuid
        ...................................
```

2.1.1. Common Design for All Inventory Objects

For all the inventory objects, there are some common attributes existing. Such as:
Identifier: here we suggest to use uuid format which is widely used by development of systems. It could be globally unique easily.

Name: name is a human-readable label information which could be used to present on GUI. This name is suggested to be provided by server.

Alias: alias is also a human-readable label information which could be modified by user. It could also be present on GUI instead of name.

Description: description is a human-readable information which could be also input by user. Description provides more detailed information to prompt users when maintaining.

Location: location is a common management requirement of operators. This location could be absolute position, e.g. address, or relative position, e.g. port index. Different types of inventory objects require different types of position.
module: ietf-network-inventory
  +--ro network-inventory
     +--ro equipment-rooms
        +--ro equipment-room* [uuid]
           +--ro uuid             yang:uuid
           +--ro name?            string
           +--ro description?     string
           +--ro alias?           string
           +--ro location?        string
           ...................................
        +--ro racks
           +--ro rack* [uuid]
              +--ro uuid             yang:uuid
              +--ro name?            string
              +--ro description?     string
              +--ro alias?           string
              +--ro rack-location
                 +--ro equipment-room-name? leafref
                 +--ro row-number?      uint32
                 +--ro column-number?   uint32
        ...................................
     +--ro network-elements
        +--ro network-element* [uuid]
           +--ro uuid             yang:uuid
           +--ro name?            string
           +--ro description?     string
           +--ro alias?           string
           +--ro ne-location
              +--ro equipment-room-name* leafref
        ...................................
     +--ro components
        +--ro component* [uuid]
           +--ro uuid             yang:uuid
           +--ro name?            string
           +--ro description?     string
           +--ro alias?           string
           +--ro location         string
        ...................................

2.1.2. Reference from RFC8348

The YANG data model for network hardware inventory mainly follows the same approach of [RFC8348] and reports the network hardware inventory as a list of components with different types (e.g., chassis, module, port).
But we refined some attributes in [RFC8348], based on some integration experience we had.

2.1.3. Refinement of RFC8348

2.1.3.1. New Parent Identifiers’ Reference

[RFC8348] provided an "parent-ref" attribute, which was an identifier reference to its parent component. When the MDSC or OSS systems want to find this component’s grandparent or higher hierarchal level component, they need to retrieve this parent-ref step by step. To reduce this duplicated work, we tend to provide a list of hierarchical parent components’ identifier reference.

```
++--ro components
     ++--ro component* [uuid]
        ++--ro component-reference* [index]
           ++--ro index    uint8
           ++--ro class?   leafref
           ++--ro uuid?    leafref
```
The hierarchical components' identifier could be found by the "component-reference" list. The "index" in this list which starts from 0 is sort by the hierarchical relationship from topmost component to bottom component.

2.1.3.2. Component-Specific Info Design

According to the management requirements from operators, some important attributes are not defined in [RFC8348]. These attributes could be component specific and are not suitable to define under the component list node. So we define a choice-case structure for this component-specific extension, which is:

```
+--ro components
  +--ro component* [uuid]
               -----------------------
    +--ro (component-class)?
    +--:(chassis)
      |  +--ro chassis-specific-info
    +--:(container)
      |  +--ro slot-specific-info
    +--:(module)
      |  +--ro board-specific-info
    +--:(port)
      +--ro port-specific-info
               -----------------------
```

Note: The *-specific-info container is still under discussing, will be enriched in future.

2.1.3.3. Part Number

According to the description in [RFC8348], the attribute named "model-name" under the component, is preferred to have a customer-visible part number value. Model-name is not quite recognized and we suggest to refine it to part number directly.

```
+--ro components
  +--ro component* [uuid]
               -----------------------
    +--ro part-number? string
               -----------------------
```

2.1.4. Equipment Room

Note: add some more attributes about equipment room in the future.
2.1.5. Rack

Besides the common attribute mentioned in above section, rack could have some specific attributes, such as attributes about appearance-related attributes and electricity-related attributes. The height, depth and width are described by the figure below (please imagined that the door of rack face to the user):

![Diagram of rack with height, depth, and width labels](image)

Figure 2: height, width and width of rack

The attributes for rack includes:
Max-voltage: the maximum voltage could be supported by the rack.

2.1.6. Network Element

We consider that some attributes defined in [RFC8348] for components are also applicable for network element. Includes:

```
+-ro network-elements
  +--ro network-element* [uuid]
      ..............................
      +--ro hardware-rev?    string
      +--ro firmware-rev?    string
      +--ro software-rev?    string
      +--ro mfg-name?        string
      +--ro mfg-date?        yang:date-and-time
      +--ro part-number?     string
      +--ro serial-number?   string
      +--ro product-name?    string
      ..............................
```

Note: the attributes of network element are still under discussing.

2.2. Efficiency Issue

During doing the design of integration with OSS, some efficiency issues have been discovered. More discussion is needed to be done in the future to address this issue.

Considering relational database is widely used by traditional OSS systems and part of PNCs, the inventory objects are probably saved in different tables. If the generic model is adopted, when doing a full synchronization, PNC needs to convert all inventory objects of each NE into component objects and combine them together into a single list, and then construct a response and send to OSS or MDSC. The OSS or MDSC needs to classify the component list and divide them into different groups, in order to save them in different tables. The combining-regrouping steps are impacting the PNC & OSS/MDSC processing, which may result in efficiency issue in large scale networks.
We also designed a YANG model which defines the inventory objects directly instead of defining with generic components. There still could be some scalability issues when synchronizing full inventory resource in large scale of networks. This scalability issue is caused by the small transmission capability of HTTP protocol. We think that this scalability should be solved on protocol level instead of some specific data model.

In case there are some other special types of inventory objects could be used in other technologies and have not been recognized by us, we would like to provide a generic model. If we define the inventory objects directly and give them fixed hierarchical relationships in YANG model, once there is a new type of inventory object needs to be introduced into the model, we need to break down our YANG model and insert the new one, this is incompatible change which is unacceptable by the developer to implement. In comparison, we only need to augment a new component class and extend some specific attributes for this new inventory if we adopt generic model, which is more acceptable. We think this compatible issue is prior to the efficiency issue mentioned above, therefore, we continue to work on generic component model.

2.3. Some Other Considerations

Note: review in future versions of this document whether the component list should be under the network-inventory instead of under the network-element container.

Note that in [RFC8345], topology and inventory are two subsets of network information. However, considering the complexity of the existing topology models and to have a better extension capability, we define a separate root for the inventory model. We will consider some other ways to do some associations between the topology model and inventory model in the future.

Note: review in future versions of this document whether network hardware inventory should be defined as an augmentation of the network model defined in [RFC8345] instead of under a new network-inventory root.

The proposed YANG data model has been analyzed to cover the requirements and use cases for Optical Network Inventory.

Further analysis of requirements and use cases is needed to extend the applicability of this YANG data model to other types of networks (IP and microwave) and to identify which aspects are generic and which aspects are technology-specific for optical networks.
3. Network Hardware Inventory Tree Diagram

Figure 3 below shows the tree diagram of the YANG data model defined in module ietf-network-inventory.yang (Section 4).

module: ietf-network-inventory
  +--ro network-inventory
    +--ro equipment-rooms
      +--ro equipment-room* [uuid]
        +--ro uuid           yang:uuid
        +--ro name?          string
        +--ro description?   string
        +--ro alias?         string
        +--ro location?      string
        +--ro racks
          +--ro rack* [uuid]
            +--ro uuid           yang:uuid
            +--ro name?          string
            +--ro description?   string
            +--ro alias?         string
            +--ro rack-location
              +--ro equipment-room-name? leafref
              +--ro row-number?      uint32
              +--ro column-number?   uint32
            +--ro rack-number?     uint32
            +--ro height?         uint16
            +--ro width?          uint16
            +--ro depth?          uint16
            +--ro max-voltage?    uint16
          +--ro contained-chassis* [ne-ref component-ref]
            +--ro ne-ref           leafref
            +--ro component-ref    leafref
    +--ro network-elements
      +--ro network-element* [uuid]
        +--ro uuid           yang:uuid
        +--ro name?          string
        +--ro description?   string
        +--ro alias?         string
        +--ro ne-location
          +--ro equipment-room-name* leafref
        +--ro hardware-rev?   string
        +--ro firmware-rev?   string
        +--ro software-rev?   string
        +--ro mfg-name?       string
        +--ro mfg-date?       yang:date-and-time
        +--ro part-number?    string
        +--ro serial-number?  string
        +--ro product-name?   string
+--ro components
   +--ro component* [uuid]
      +--ro uuid                           yang:uuid
      +--ro name?                          string
      +--ro description?                   string
      +--ro alias?                         string
      +--ro location?                      string
      +--ro class?                         identityref
      +--ro contained-child*               -> ../uuid
      +--ro parent-rel-pos?                int32
      +--ro parent-references
         +--ro equipment-room-uuid?    leafref
         +--ro ne-uuid?                 leafref
         +--ro rack-uuid?                leafref
         +--ro component-references
            +--ro component-reference* [index]
               +--ro index    uint8
               +--ro class?   -> ../../../../class
               +--ro uuid?    -> ../../../../uuid
      +--ro hardware-rev?                  string
      +--ro firmware-rev?                  string
      +--ro software-rev?                  string
      +--ro serial-num?                    string
      +--ro mfg-name?                      string
      +--ro part-number?                   string
      +--ro asset-id?                      string
      +--ro is-fru?                        boolean
      +--ro mfg-date?
         |  yang:date-and-time
      +--ro uri*                           inet:uri
      +--ro (component-class)?
         +--:(chassis)
            +--ro chassis-specific-info
         +--:(container)
            +--ro slot-specific-info
         +--:(module)
            +--ro board-specific-info
         +--:(port)
            +--ro port-specific-info

Figure 3: Network inventory tree diagram

4. YANG Model for Network Hardware Inventory
<CODE BEGINS> file "ietf-network-inventory@2022-07-11.yang"
module ietf-network-inventory {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-network-inventory";
  prefix ni;

  import ietf-yang-types {
    prefix yang;
    reference
      "RFC6991: Common YANG Data Types.";
  }

  import iana-hardware {
    prefix ianahw;
    reference
      "RFC 8348: A YANG Data Model for Hardware Management.";
  }

  import ietf-inet-types {
    prefix inet;
  }

  organization
    "IETF CCAMP Working Group";
  contact
    "WG Web:   <https://datatracker.ietf.org/wg/ccamp/>
    WG List:  <mailto:ccamp@ietf.org>
    Editor:   Chaode Yu
    <yuchaode@huawei.com>
    Editor:   Italo Busi
    <italo.busi@huawei.com>
    Editor:   Aihua Guo
    <aihuaguo.ietf@gmail.com>
    Editor:   Sergio Belotti
    <sergio.belotti@nokia.com>
    Editor:   Jean-Francois Bouquier
    <jeff.bouquier@vodafone.com>
    Editor:   Fabio Peruzzini
    <fabio.peruzzini@telecomitalia.it>";

description
  "This module defines a model for retrieving network inventory."
The model fully conforms to the Network Management Datastore Architecture (NMDA).

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

The key words 'MUST', 'MUST NOT', 'REQUIRED', 'SHALL', 'SHALL NOT', 'SHOULD', 'SHOULD NOT', 'RECOMMENDED', 'NOT RECOMMENDED', 'MAY', and 'OPTIONAL' in this document are to be interpreted as described in BCP 14 (RFC 2119) (RFC 8174) when, and only when, they appear in all capitals, as shown here.

// RFC Ed.: replace XXXX with actual RFC number and remove this note.
// RFC Ed.: update the date below with the date of RFC publication
// and remove this note.

revision 2022-07-11 {
  description
    "version 3.0.0";
  reference
    "draft-yg3bp-ccamp-inventory-yang-01: A YANG Data Model for Network Inventory.";
}

revision 2022-03-04 {
  description
    "version 3.0.0";
  reference
    "draft-yg3bp-ccamp-inventory-yang-00: A YANG Data Model for Network Inventory.";
}

revision 2021-11-09 {
  description
    "version 2.0.0";
  reference
    "draft-yg3bp-ccamp-optical-inventory-yang-00: A YANG Data Model for Network Inventory.";
}
Model for Optical Network Inventory.

revision 2021-10-25 {
  description
    "Initial revision.";
  reference
    "draft-yg3bp-ccamp-optical-inventory-yang-00: A YANG Data
    Model for Optical Network Inventory.";
}

container network-inventory {
  config false;
  description
    "The top-level container for the network inventory
    information.";
  uses equipment-rooms-grouping;
  uses network-elements-grouping;
}

grouping common-entity-attributes {
  description
    "A set of attributes which are common to all the entities
    (e.g., component, equipment room) defined in this module.";
  leaf uuid {
    type yang:uuid;
    description
      "Uniquely identifies an entity (e.g., component).";
  }
  leaf name {
    type string;
    description
      "A name for an entity (e.g., component), as specified by
      a network manager, that provides a non-volatile ‘handle’
      for the entity and that can be modified anytime during the
      entity lifetime.

      If no configured value exists, the server MAY set the value
      of this node to a locally unique value in the operational
      state.";
  }
  leaf description {
    type string;
    description "a textual description of inventory object";
  }
  leaf alias {
    type string;
    description
  }
}
"a alias name of inventory objects. This alias name can be specified by network manager."

}

}

grouping network-elements-grouping {

description
"The attributes of the network elements."

container network-elements {

description
"The container for the list of network elements."

list network-element {

key uuid;

description
"The list of network elements within the network."

uses common-entity-attributes;

container ne-location {

description
"To be added."

leaf-list equipment-room-name {

    type leafref {

    path "/ni:network-inventory/ni:equipment-rooms/" + 
    "ni:equipment-room/ni:name";

    }

description
"Names of equipment rooms where the NE is located. Please note that a NE could be located in several equipment rooms.";

    }

uses ne-specific-info-grouping;

uses components-grouping;

}

}

}

grouping ne-specific-info-grouping {

description
"To be added."

leaf hardware-rev {

type string;

description
"The vendor-specific hardware revision string for the NE.";

}

leaf firmware-rev {

type string;

description
"The vendor-specific firmware revision string for the NE.";

}
leaf software-rev {
  type string;
  description  "The vendor-specific software revision string for the NE.";
}

leaf mfg-name {
  type string;
  description  "The name of the manufacturer of this NE";
}

leaf mfg-date {
  type yang:date-and-time;
  description  "The date of manufacturing of the NE.";
}

leaf part-number {
  type string;
  description  "The vendor-specific model name identifier string associated with this NE. The preferred value is the customer-visible part number, which may be printed on the NE itself.";
}

leaf serial-number {
  type string;
  description  "The vendor-specific serial number string for the NE";
}

leaf product-name {
  type string;
  description  "indicates the vendor-specific device type information.";
}

}

grouping equipment-rooms-grouping {
  description  "The attributes of the equipment rooms.";
  container equipment-rooms {
    description  "The container for the list of equipment rooms.";
    list equipment-room {
      key uuid;
      description  "The list of equipment rooms within the network.";
      uses common-entity-attributes;
      leaf location {
        type string;
        description  "compared with the location information of the other
inventory objects, a GIS address is preferred for equipment room;}
}
container racks {
description "To be added."
list rack {
  key uuid;
description "The list of racks within an equipment room."
uses common-entity-attributes;
uses rack-specific-info-grouping;
list contained-chassis {
  key "ne-ref component-ref";
description "The list of chassis within a rack."
leaf ne-ref {
  type leafref {
  }
description "The reference to the network element containing the chassis component.";
}
leaf component-ref {
  type leafref {
  }
description "The reference to the chassis component within the network element and contained by the rack.";
}
}
}
}
}
}
}
}
grouping rack-specific-info-grouping {
description "To be added."
container rack-location {
description"The list of racks within an equipment room."
uses common-entity-attributes;
uses rack-specific-info-grouping;
list contained-chassis {
  key "ne-ref component-ref";
description "The list of chassis within a rack."
leaf ne-ref {
  type leafref {
  }
description "The reference to the network element containing the chassis component.";
}
leaf component-ref {
  type leafref {
  }
description "The reference to the chassis component within the network element and contained by the rack.";
}
}
}
leaf equipment-room-name {
  type leafref {
    path "/ni:network-inventory/ni:equipment-rooms" + "ni:equipment-room/ni:name";
  }
  description
  "Name of equipment room where this rack is located."
}
leaf row-number {
  type uint32;
  description
  "Identifies the row within the equipment room where
  the rack is located."
}
leaf column-number {
  type uint32;
  description
  "Identifies the physical location of the rack within
  the column."
}
leaf rack-number {
  type uint32;
  description
  "An integer identifier of rack."
}
leaf height {
  type uint16;
  units millimeter;
  description
  "To be added."
}
leaf width {
  type uint16;
  units millimeter;
  description
  "To be added."
}
leaf depth {
  type uint16;
  units millimeter;
  description
  "To be added."
}
leaf max-voltage {
  type uint16;
  units volt;
description
  "The maximum voltage could be supported by the rack.";
}
}
grouping components-grouping {
  description
  "The attributes of the hardware components.";
  container components {
    description
      "The container for the list of components.";
    list component {
      key uuid;
      description
        "The list of components within a network element.";
      uses common-entity-attributes;
      leaf location {
        type string;
        description
          "To be added.

          In optical transport network, the location string is using the following pattern:
          '/ne=<nw-ne-name>[/r=<r_index>][/sh=<sh_index>
            [s_sh=<s_sh_index> ...]][/sl=<sl_index>
            [s_sl=<s_sl_index> ...]][/p=<p_index> ]'
          
          ";
        }
      }
      leaf class {
        type identityref {
          base ianahw:hardware-class;
        }
        description
          "An indication of the general hardware type of the component.";
        reference
          "RFC 8348: A YANG Data Model for Hardware Management.";
      }
      leaf-list contained-child {
        type leafref {
          path "../ni:uuid";
        }
        description
          "The child components’ identifier that are physically contained by this component.";
      }
      leaf parent-rel-pos {
        type int32 {
range "0 .. 2147483647";
}
description
 "To be added.";
reference
 "RFC 6933: Entity MIB (Version 4) - entPhysicalParentRelPos";
}
container parent-references {
 description
 "To be added.";
leaf equipment-room-uuid {
 type leafref {
 path "/ni:network-inventory/ni:equipment-rooms/" + "ni:equipment-room/ni:uuid";
 }
 description
 "To be added.";
}
leaf ne-uuid {
 type leafref {
 path "/ni:network-inventory/ni:network-elements/" + "ni:network-element/ni:uuid";
 }
 description
 "To be added.";
}
leaf rack-uuid {
 type leafref {
 path "/ni:network-inventory/ni:equipment-rooms/" + "ni:equipment-room/ni:racks/ni:rack/ni:uuid";
 }
 description
 "To be added.";
}
container component-references {
 description
 "To be added.";
list component-reference {
 key index;
 description
 "this list object is used to indicate its hierarchial parent components’ identifier. This hierarchial relation can be found by index parameter. The topest parent component should be 0-index.";
leaf index {
 type uint8;
description
"To be added.";
}
leaf class {
  type leafref {
    path "../../ni:class";
  }
  description
  "To be added.";
}
leaf uuid {
  type leafref {
    path "../../ni:uuid";
  }
  description
  "To be added.";
}
leaf hardware-rev {
  type string;
  description
  "The vendor-specific hardware revision string for the
  component. The preferred value is the hardware revision
  identifier actually printed on the component itself (if
  present).";
  reference
  "RFC 6933: Entity MIB (Version 4) -
  entPhysicalHardwareRev";
}
leaf firmware-rev {
  type string;
  description
  "The vendor-specific firmware revision string for the
  component.";
  reference
  "RFC 6933: Entity MIB (Version 4) -
  entPhysicalFirmwareRev";
}
leaf software-rev {
  type string;
  description
  "The vendor-specific software revision string for the
  component.";
  reference
  "RFC 6933: Entity MIB (Version 4) -
  entPhysicalSoftwareRev";
leaf serial-num {
  type string;
  description
    "The vendor-specific serial number string for the component. The preferred value is the serial number string actually printed on the component itself (if present).";
  reference
    "RFC 6933: Entity MIB (Version 4) - entPhysicalSerialNum";
}
leaf mfg-name {
  type string;
  description
    "The name of the manufacturer of this physical component. The preferred value is the manufacturer name string actually printed on the component itself (if present).

    Note that comparisons between instances of the 'model-name', 'firmware-rev', 'software-rev', and 'serial-num' nodes are only meaningful amongst components with the same value of 'mfg-name'.

    If the manufacturer name string associated with the physical component is unknown to the server, then this node is not instantiated.";
  reference
    "RFC 6933: Entity MIB (Version 4) - entPhysicalMfgName";
}
leaf part-number {
  type string;
  description
    "The vendor-specific model name identifier string associated with this physical component. The preferred value is the customer-visible part number, which may be printed on the component itself.

    If the model name string associated with the physical component is unknown to the server, then this node is not instantiated.";
  reference
    "RFC 6933: Entity MIB (Version 4) - entPhysicalModelName";
}
leaf asset-id {
  type string;
  description
"This node is a user-assigned asset tracking identifier for the component.

A server implementation MAY map this leaf to the entPhysicalAssetID MIB object. Such an implementation needs to use some mechanism to handle the differences in size and characters allowed between this leaf and entPhysicalAssetID. The definition of such a mechanism is outside the scope of this document.";

reference
"RFC 6933: Entity MIB (Version 4) - entPhysicalAssetID"
}

leaf is-fru {
  type boolean;
  description
  "This node indicates whether or not this component is considered a 'field-replaceable unit' by the vendor. If this node contains the value 'true', then this component identifies a field-replaceable unit. For all components that are permanently contained within a field-replaceable unit, the value 'false' should be returned for this node.";

  reference
  "RFC 6933: Entity MIB (Version 4) - entPhysicalIsFRU"
}

leaf mfg-date {
  type yang:date-and-time;
  description
  "The date of manufacturing of the managed component.";

  reference
  "RFC 6933: Entity MIB (Version 4) - entPhysicalMfgDate"
}

leaf-list uri {
  type inet:uri;
  description
  "This node contains identification information about the component.";

  reference
  "RFC 6933: Entity MIB (Version 4) - entPhysicalUris"
}

uses component-specific-info-grouping;
}

}

grouping component-specific-info-grouping {
  description
  "In case if there are some missing attributes of component not
defined by RFC8348. These attributes could be
component-specific.
Here we provide a extension structure for all the components
we recognized. We will enrich these component specific
containers in the future.

choice component-class {
  description
    "To be added.";
  case chassis {
    when "./class = 'ianahw:chassis'";
    container chassis-specific-info {
      description
        "This container contains some attributes belong to
        chassis only.";
      uses chassis-specific-info-grouping;
    }
  }
  case container {
    when "./class = 'ianahw:container'";
    container slot-specific-info {
      description
        "This container contains some attributes belong to
        slot or sub-slot only.";
      uses slot-specific-info-grouping;
    }
  }
  case module {
    when "./ni:class = 'ianahw:module'";
    container board-specific-info {
      description
        "This container contains some attributes belong to
        board only.";
      uses board-specific-info-grouping;
    }
  }
  case port {
    when "./ni:class = 'ianahw:port'";
    container port-specific-info {
      description
        "This container contains some attributes belong to
        port only.";
      uses port-specific-info-grouping;
    }
  }
  //TO BE ADDED: transceiver
}

grouping chassis-specific-info-grouping {
    //To be enriched in the future.
    description
        "To be added.";
}

grouping slot-specific-info-grouping {
    //To be enriched in the future.
    description
        "To be added.";
}

grouping board-specific-info-grouping {
    //To be enriched in the future.
    description
        "To be added.";
}

grouping port-specific-info-grouping {
    //To be enriched in the future.
    description
        "To be added.";
}

Figure 4: Network inventory YANG module

5. Manageability Considerations
   <Add any manageability considerations>

6. Security Considerations
   <Add any security considerations>

7. IANA Considerations
   <Add any IANA considerations>

8. References

8.1. Normative References

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