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YANG Data Models for requesting Path Computation in Optical Networks
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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 some 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 (OTN, WSON or Flexi-grid) or multi-layer Optical network.

This document define 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 requires 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 the following table.

| Prefix | YANG module | Reference |
|--------------|----------------------------------|-----------|
| 10-types | ietf-layer0-types | [RFC9093] |
| 10-types-ext | ietf-layer0-types-ext | [RFCYYYY] |
| 10-types | ietf-layer0-types | [RFC8776] |
| 11-types | ietf-layer1-types | [RFCZZZZ] |
| te | ietf-te | [RFCXXXX] |
| tep | ietf-te-path-computation | [RFCJJJJ] |
| flexg-pc | ietf-flexi-grid-path-computation | RFCXXXX |
| wson-pc | ietf-wson-path-computation | RFCXXXX |
| otn-pc | ietf-otn-path-computation | RFCXXXX |

Table 1: Prefixes and corresponding YANG modules

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-layer0-types-ext]. Please replace ZZZZ with the RFC number assigned to [I-D.ietf-ccamp-layer1-types]. Please replace KKKK with the RFC number assigned to [I-D.ietf-teas-yang-te]. Please replace JJJJ with the RFC number assigned to [I-D.ietf-teas-yang-path-computation]. Please remove this note.

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.

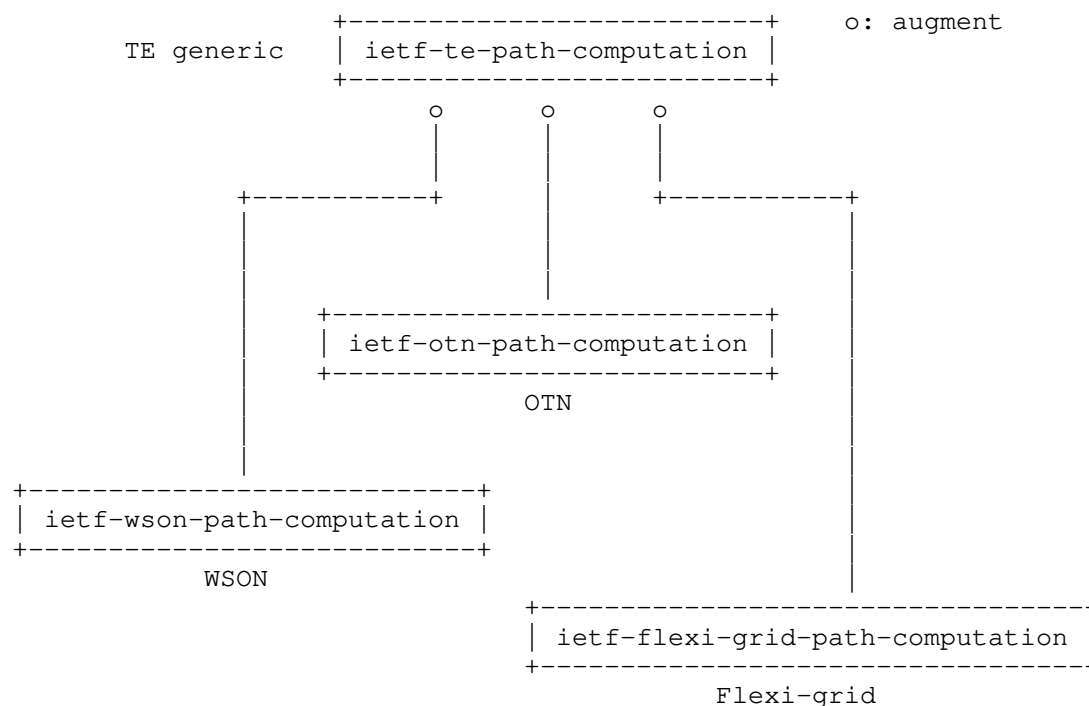


Figure 1: Relationship between WSON, Flexi-grid, OTN and TE path computation models

The entities and 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 l0-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
  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)?
+---: (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: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)?
+---: (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:explicit-route-objects-always
        /tepc:route-object-exclude-always/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: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)
    +--- (l0-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:
    +--: (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-out-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-out-segment
      /tepc:label-restrictions/tepc:label-restriction
      /tepc:label-step/tepc:technology:
    +--: (wson)
      +-- (l0-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:synchronization/tepc:exclude-objects/tepc:excludes
      /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: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:
+--:(wson)
  +--ro (grid-type)?
    +--:(dwdm)
      +--ro (single-or-super-channel)?
        +--:(single)
          | +--ro dwdm-n? 10-types:dwdm-n
        +--:(super)
          | +--ro subcarrier-dwdm-n* 10-types:dwdm-n
    +--:(cwdm)
      +--ro cwdm-n? 10-types:cwdm-n

```

Figure 2: WSON path computation tree diagram

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
  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
+-- flexi-m?    10-types:flexi-m
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
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:
+--:(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:path-in-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-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-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-out-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: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
        /tepc:path-route-objects/tepc:path-route-object/tepc:type
        /tepc:label/tepc:label-hop/tepc:te-label/tepc:technology:
+---:(flexi-grid)
+---ro (single-or-super-channel)?
+---:(single)
|   +---ro flexi-n?           10-types:flexi-n
|   +---ro flexi-m?           10-types:flexi-m
+---:(super)
+---ro subcarrier-flexi-n* [flexi-n]
+---ro flexi-n           10-types:flexi-n
+---ro flexi-m?          10-types:flexi-m

```

Figure 3: Flexi-grid path computation tree diagram

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)
+--- otn
+--- 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)
  +--- otn
    +--- 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
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:
+--:(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-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-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-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:synchronization/tepc:exclude-objects/tepc:excludes
      /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: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:
+--:(otn)
  +--ro otn-tpn?    otn-tpn
  +--ro tsg?        identityref
  +--ro ts-list?    string

```

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@2021-10-15.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 "l0-types";
}

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

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
  WSON Path Computation.

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

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  identified as authors of the code.  All rights reserved.

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```

Relating to IETF Documents
(<https://trustee.ietf.org/license-info>).

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

```
revision "2021-10-15" {
  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-ext:l0-tunnel-attributes;
  uses l0-types-ext:l0-path-constraints;
}

/*
 * 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 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 l0-types:l0-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 l0-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 l0-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 l0-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: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 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 l0-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@2021-10-15.yang"
module ietf-flexi-grid-path-computation {
  yang-version 1.1;
  namespace
    "urn:ietf:params:xml:ns:yang:ietf-flexi-grid-path-computation";
  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
      Engineering Tunnels and Interfaces. ";
  }

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

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

```

```
}

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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  identified as authors of the code.  All rights reserved.

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  (https://trustee.ietf.org/license-info).

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

revision "2021-10-15" {
  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 flexi-grid
    media channel.";
  uses l0-types-ext:l0-tunnel-attributes;
  uses l0-types-ext:l0-path-constraints;
}

/*
 * 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 l0-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 l0-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 l0-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 l0-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 l0-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-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 flexi-grid {
    uses l0-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 l0-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 l0-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 l0-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 l0-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 l0-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 l0-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 l0-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 l0-types:flexi-grid-label-hop;
    }
}
}
}
<CODE ENDS>
```

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 ll-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 ll-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 ll-types:otn-path-bandwidth;
    }
  }
}

/*
 * 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 ll-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 ll-types:otn-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 otn {
  uses ll-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 ll-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 ll-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 ll-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 ll-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 ll-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 ll-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 ll-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 ll-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-step/tepc:technology" {
  description
    "Augment TE label range end for the egress segment
    of the requested path.";
  case otn {
    uses ll-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 ll-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 ll-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

<Add any IANA considerations>

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This document was prepared using kramdown.

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A YANG Data Model for Flexi-Grid Media Channels
draft-ietf-ccamp-flexigrid-media-channel-yang-04

Abstract

This document defines a YANG model for managing flexi-grid optical media channels, complementing the information provided by the flexi-grid topology model.

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

Transport networks are evolving from current DWDM systems towards elastic optical networks, based on flexi-grid transmission and switching technologies [RFC7698]. Such technology aims at increasing both transport network scalability and flexibility, allowing the optimization of bandwidth usage.

While [I-D.ietf-ccamp-flexigrid-yang] focuses on flexi-grid objects such as nodes, transponders and links, this document presents a YANG [RFC7950] model for the flexi-grid media-channel. This YANG module defines the whole path from a source transponder or node to the destination through a number of intermediate nodes in the flexi-grid network.

This document identifies the flexi-grid media-channel components, parameters and their values, characterizes the features and the performances of the flexi-grid elements. An application example is provided towards the end of the document to better understand their utility.

2. Terminology

Refer to [RFC7446] and [RFC7699] for the key terms used in this document.

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

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

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

- o configuration data
- o state data

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

3. Flexi-Grid Media-Channel Overview

The present model defines a flexi-grid media-channel mainly composed of:

- o source address
- o source flexi-grid port
- o source flexi-grid transponder
- o destination address
- o destination flexi-grid port

- o destination flexi-grid transponder
- o list of links that defines the path
- o other optical attributes

Each path can be a media-channel (only defined by source and destination node) or a network media-channel (additionally needs source and destination transponders). Therefore, all the attributes are optional to support both situations.

This is achieved by a combination of the traffic engineering tunnel attributes explained in [I-D.ietf-teas-yang-te] and augments when necessary. For instance, source address, source flexi-grid transponder, destination address and destination flexi-grid transponder attributes are directly taken from tunnel, whereas other attributes such as source flexi-grid port, destination flexi-grid port are defined, as they are specific for flexi-grid.

4. Example of Use

In order to explain how this model is used, we provide the following example. An optical network usually has multiple transponders, switches (nodes) and links. Figure 1 shows a simple topology, where two physical paths interconnect two optical transponders.

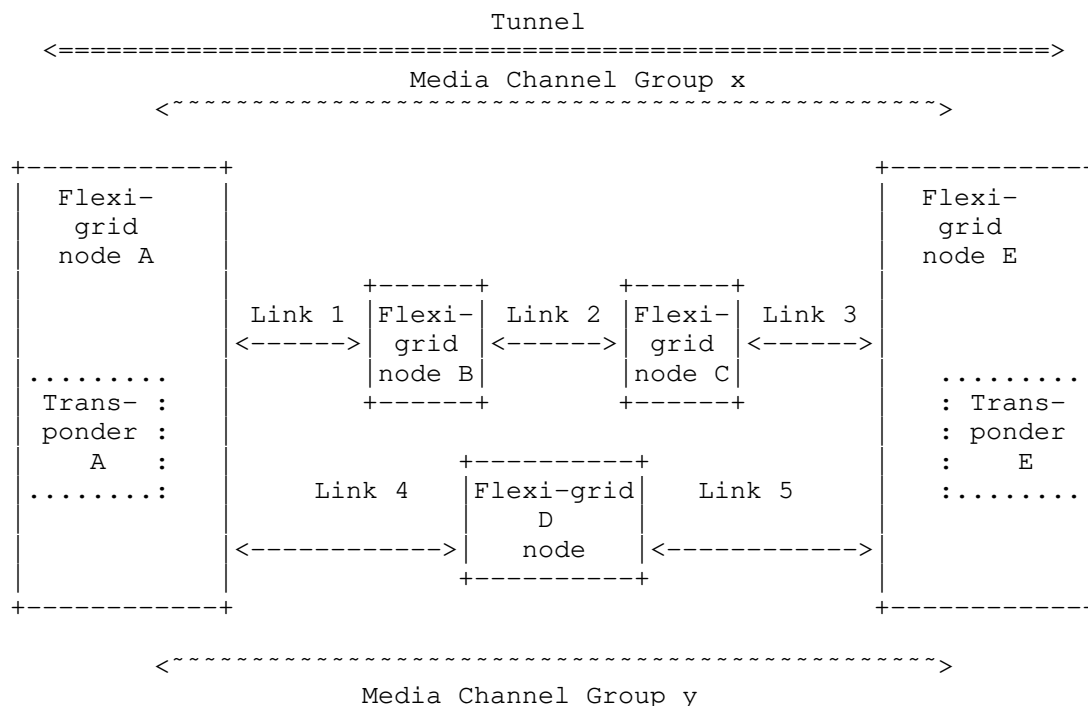


Figure 1: Topology Example

In order to configure a network media channel to interconnect transponders A and E, first of all we have to populate the flexi-grid topology YANG model with all elements in the network:

- o We define the transponders within nodes A and E as tunnel termination points (TTPs) and provide their internal local link connectivity towards the node interfaces. We also provide nodes A and B identifiers, addresses and interfaces.
- o We do the same for the nodes B, C and D, providing their identifiers, addresses and interfaces, as well as the internal connectivity matrix between interfaces.
- o Then, we also define the links 1 to 5 that interconnect nodes, indicating which flexi-grid labels are available.
- o Other information, such as the slot frequency and granularity are also provided.

After the nodes, links and transponders have been defined using [I-D.ietf-ccamp-flexigrid-yang] we can configure the media-channel from the information we have stored in the flexi-grid topology, by querying which elements are available, and planning the resources that have to be provided on each situation. Note that every element in the flexi-grid topology has a reference, and this is the way in which they are called in the media-channel.

- o Depending on the case, it is possible to define either the source and destination node ports, or the source and destination node and transponder. In our case, we would define a network media channel, with source transponder A and source node B, and destination transponder E and destination node C. Thus, we are going to follow path x.
- o Then, for each link in the path x, we indicate which channel we are going to use, providing information about the slots, and what nodes are connected.
- o Finally, the flexi-grid topology has to be updated with each element usage status each time a media channel is created or torn down.

5. YANG Model for Flexi-Grid Media Channel

5.1. YANG Tree

```

module: ietf-te
  +--rw te!
    +--rw globals
      +--rw named-admin-groups
        +--rw named-admin-group* [name]
          {te-types:extended-admin-groups,te-types:named-extended-admin-
groups}?
          +--rw name string
          +--rw bit-position? uint32
      +--rw named-srlgs
        +--rw named-srlg* [name] {te-types:named-srlg-groups}?
          +--rw name string
          +--rw group? te-types:srlg
          +--rw cost? uint32
      +--rw named-path-constraints
        +--rw named-path-constraint* [name]
          {te-types:named-path-constraints}?
          +--rw name string
          +--rw te-bandwidth
            +--rw (technology)?
              +--:(generic)

```

```

|         +---rw generic?    te-bandwidth
+---rw link-protection?      identityref
+---rw setup-priority?       uint8
+---rw hold-priority?        uint8
+---rw signaling-type?       identityref
+---rw path-metric-bounds
|   +---rw path-metric-bound* [metric-type]
|   +---rw metric-type       identityref
|   +---rw upper-bound?      uint64
+---rw path-affinities-values
|   +---rw path-affinities-value* [usage]
|   +---rw usage             identityref
|   +---rw value?            admin-groups
+---rw path-affinity-names
|   +---rw path-affinity-name* [usage]
|   +---rw usage             identityref
|   +---rw affinity-name*    [name]
|   +---rw name              string
+---rw path-srlgs-lists
|   +---rw path-srlgs-list*  [usage]
|   +---rw usage             identityref
|   +---rw values*          srlg
+---rw path-srlgs-names
|   +---rw path-srlgs-name*  [usage]
|   +---rw usage             identityref
|   +---rw names*           string
+---rw disjointness?
|   te-path-disjointness
+---rw explicit-route-objects-always
|   +---rw route-object-exclude-always* [index]
|   +---rw index              uint32
|   +---rw (type)?
|   +---:(numbered-node-hop)
|   |   +---rw numbered-node-hop
|   |   |   +---rw node-id      te-node-id
|   |   |   +---rw hop-type?    te-hop-type
|   |   +---:(numbered-link-hop)
|   |   |   +---rw numbered-link-hop
|   |   |   |   +---rw link-tp-id  te-tp-id
|   |   |   |   +---rw hop-type?    te-hop-type
|   |   |   |   +---rw direction?  te-link-direction
|   |   +---:(unnumbered-link-hop)
|   |   |   +---rw unnumbered-link-hop
|   |   |   |   +---rw link-tp-id  te-tp-id
|   |   |   |   +---rw node-id      te-node-id
|   |   |   |   +---rw hop-type?    te-hop-type
|   |   |   |   +---rw direction?  te-link-direction
|   +---:(as-number)

```

```

    +--rw as-number-hop
      +--rw as-number      inet:as-number
      +--rw hop-type?     te-hop-type
+--:(label)
  +--rw label-hop
    +--rw te-label
      +--rw (technology)?
        +--:(generic)
          +--rw generic?
            rt-types:generalized-label
      +--rw direction?
        te-label-direction
+--rw route-object-include-exclude* [index]
+--rw explicit-route-usage?      identityref
+--rw index                      uint32
+--rw (type)?
+--:(numbered-node-hop)
  +--rw numbered-node-hop
    +--rw node-id      te-node-id
    +--rw hop-type?    te-hop-type
+--:(numbered-link-hop)
  +--rw numbered-link-hop
    +--rw link-tp-id    te-tp-id
    +--rw hop-type?     te-hop-type
    +--rw direction?    te-link-direction
+--:(unnumbered-link-hop)
  +--rw unnumbered-link-hop
    +--rw link-tp-id    te-tp-id
    +--rw node-id      te-node-id
    +--rw hop-type?     te-hop-type
    +--rw direction?    te-link-direction
+--:(as-number)
  +--rw as-number-hop
    +--rw as-number      inet:as-number
    +--rw hop-type?     te-hop-type
+--:(label)
  +--rw label-hop
    +--rw te-label
      +--rw (technology)?
        +--:(generic)
          +--rw generic?
            rt-types:generalized-label
      +--rw direction?
        te-label-direction
+--:(srlg)
  +--rw srlg
    +--rw srlg?    uint32
+--rw shared-resources-tunnels

```

```

|   +---rw lsp-shared-resources-tunnel*   tunnel-ref
+---rw path-in-segment!
|   +---rw label-restrictions
|       +---rw label-restriction* [index]
|           +---rw restriction?   enumeration
|           +---rw index          uint32
|       +---rw label-start
|           +---rw te-label
|               +---rw (technology)?
|                   +---:(generic)
|                       +---rw generic?
|                           rt-types:generalized-label
|               +---rw direction?
|                   te-label-direction
|       +---rw label-end
|           +---rw te-label
|               +---rw (technology)?
|                   +---:(generic)
|                       +---rw generic?
|                           rt-types:generalized-label
|               +---rw direction?
|                   te-label-direction
|       +---rw label-step
|           +---rw (technology)?
|               +---:(generic)
|                   +---rw generic?   int32
|       +---rw range-bitmap?   yang:hex-string
+---rw path-out-segment!
|   +---rw label-restrictions
|       +---rw label-restriction* [index]
|           +---rw restriction?   enumeration
|           +---rw index          uint32
|       +---rw label-start
|           +---rw te-label
|               +---rw (technology)?
|                   +---:(generic)
|                       +---rw generic?
|                           rt-types:generalized-label
|               +---rw direction?
|                   te-label-direction
|       +---rw label-end
|           +---rw te-label
|               +---rw (technology)?
|                   +---:(generic)
|                       +---rw generic?
|                           rt-types:generalized-label
|               +---rw direction?
|                   te-label-direction

```

```

    |         +---rw label-step
    |         |   +---rw (technology)?
    |         |   +---:(generic)
    |         |   +---rw generic?    int32
    |         +---rw range-bitmap?   yang:hex-string
+---rw tunnels
  +---rw tunnel* [name]
    +---ro operational-state?          identityref
    +---rw name                        string
    +---rw identifier?                 uint16
    +---rw description?                string
    +---rw encoding?                   identityref
    +---rw switching-type?              identityref
    +---rw provisioning-state?          identityref
    +---rw preference?                 uint8
    +---rw reoptimize-timer?            uint16
    +---rw source?                     te-types:te-node-id
    +---rw destination?                te-types:te-node-id
    +---rw src-tp-id?                  yang:hex-string
    +---rw dst-tp-id?                  yang:hex-string
    +---rw bidirectional?               boolean
    +---rw association-objects
      +---rw association-object*
        [type ID source global-source]
        +---rw type                    identityref
        +---rw ID                      uint16
        +---rw source                  te-types:te-node-id
        +---rw global-source            te-types:te-node-id
      +---rw association-object-extended*
        [type ID source global-source extended-ID]
        +---rw type                    identityref
        +---rw ID                      uint16
        +---rw source                  te-types:te-node-id
        +---rw global-source            te-types:te-node-id
        +---rw extended-ID              yang:hex-string
    +---rw protection
      +---rw enable?                   boolean
      +---rw protection-type?           identityref
      +---rw protection-reversion-disable? boolean
      +---rw hold-off-time?             uint32
      +---rw wait-to-revert?            uint16
      +---rw aps-signal-id?             uint8
    +---rw restoration
      +---rw enable?                   boolean
      +---rw restoration-type?           identityref
      +---rw restoration-scheme?         identityref
      +---rw restoration-reversion-disable? boolean
      +---rw hold-off-time?             uint32

```



```

+--rw wait-to-restore?                uint16
+--rw wait-to-revert?                 uint16
+--rw te-topology-identifier
+--rw provider-id?    te-global-id
+--rw client-id?      te-global-id
+--rw topology-id?    te-topology-id
+--rw te-bandwidth
+--rw (technology)?
+--:(generic)
+--rw generic?    te-bandwidth
+--rw link-protection?    identityref
+--rw setup-priority?     uint8
+--rw hold-priority?      uint8
+--rw signaling-type?     identityref
+--rw dependency-tunnels
+--rw dependency-tunnel* [name]
+--rw name
+--rw -> ../../../../tunnels/tunnel/name
+--rw encoding?           identityref
+--rw switching-type?     identityref
+--rw hierarchical-link
+--rw local-te-node-id?    te-types:te-node-id
+--rw local-te-link-tp-id? te-types:te-tp-id
+--rw remote-te-node-id?   te-types:te-node-id
+--rw te-topology-identifier
+--rw provider-id?    te-global-id
+--rw client-id?      te-global-id
+--rw topology-id?    te-topology-id
+--rw p2p-primary-paths
+--rw p2p-primary-path* [name]
+--rw name                string
+--rw path-setup-protocol? identityref
+--rw path-computation-method? identityref
+--rw path-computation-server?
+--rw inet:ip-address
+--rw compute-only?       empty
+--rw use-path-computation? boolean
+--rw lockdown?           empty
+--rw path-scope?         identityref
+--rw optimizations
+--rw (algorithm)?
+--:(metric) {path-optimization-metric}?
+--rw optimization-metric* [metric-type]
+--rw metric-type
+--rw identityref
+--rw weight?
+--rw uint8
+--rw explicit-route-exclude-objects

```

```

+---rw route-object-exclude-object*
|   [index]
+---rw index
|   uint32
+---rw (type)?
|   +---:(numbered-node-hop)
|   |   +---rw numbered-node-hop
|   |   |   +---rw node-id
|   |   |   |   te-node-id
|   |   |   +---rw hop-type?
|   |   |   |   te-hop-type
|   |   +---:(numbered-link-hop)
|   |   |   +---rw numbered-link-hop
|   |   |   |   +---rw link-tp-id
|   |   |   |   |   te-tp-id
|   |   |   |   +---rw hop-type?
|   |   |   |   |   te-hop-type
|   |   |   |   +---rw direction?
|   |   |   |   |   te-link-direction
|   |   +---:(unnumbered-link-hop)
|   |   |   +---rw unnumbered-link-hop
|   |   |   |   +---rw link-tp-id
|   |   |   |   |   te-tp-id
|   |   |   |   +---rw node-id
|   |   |   |   |   te-node-id
|   |   |   |   +---rw hop-type?
|   |   |   |   |   te-hop-type
|   |   |   |   +---rw direction?
|   |   |   |   |   te-link-direction
|   |   +---:(as-number)
|   |   |   +---rw as-number-hop
|   |   |   |   +---rw as-number
|   |   |   |   |   inet:as-number
|   |   |   |   +---rw hop-type?
|   |   |   |   |   te-hop-type
|   |   +---:(label)
|   |   |   +---rw label-hop
|   |   |   |   +---rw te-label
|   |   |   |   |   +---rw (technology)?
|   |   |   |   |   |   +---:(generic)
|   |   |   |   |   |   |   +---rw generic?
|   |   |   |   |   |   |   rt-types:generalized
|   |   |   |   |   |   +---rw direction?
|   |   |   |   |   |   |   te-label-direction
|   |   +---:(srlg)
|   |   |   +---rw srlg
|   |   |   |   +---rw srlg?   uint32
+---rw explicit-route-include-objects

```

```

+---rw route-object-include-object*
|   [index]
+---rw index
|   uint32
+---rw (type)?
+---:(numbered-node-hop)
|   +---rw numbered-node-hop
|   |   +---rw node-id
|   |   |   te-node-id
|   |   +---rw hop-type?
|   |   |   te-hop-type
+---:(numbered-link-hop)
|   +---rw numbered-link-hop
|   |   +---rw link-tp-id
|   |   |   te-tp-id
|   |   +---rw hop-type?
|   |   |   te-hop-type
|   |   +---rw direction?
|   |   |   te-link-direction
+---:(unnumbered-link-hop)
|   +---rw unnumbered-link-hop
|   |   +---rw link-tp-id
|   |   |   te-tp-id
|   |   +---rw node-id
|   |   |   te-node-id
|   |   +---rw hop-type?
|   |   |   te-hop-type
|   |   +---rw direction?
|   |   |   te-link-direction
+---:(as-number)
|   +---rw as-number-hop
|   |   +---rw as-number
|   |   |   inet:as-number
|   |   +---rw hop-type?
|   |   |   te-hop-type
+---:(label)
|   +---rw label-hop
|   |   +---rw te-label
|   |   |   +---rw (technology)?
|   |   |   |   +---:(generic)
|   |   |   |   |   +---rw generic?
|   |   |   |   |   |   rt-types:generalized
+---rw direction?
|   te-label-direction
+---rw tiebreakers
|   +---rw tiebreaker* [tiebreaker-type]
|   |   +---rw tiebreaker-type
|   |   |   identityref
+---:(objective-function)

```

```

        {path-optimization-objective-function}?
        +--rw objective-function
            +--rw objective-function-type?
                identityref
        +--rw preference?                               uint8
        +--rw k-requested-paths?                         uint8
        +--rw named-path-constraint?                     leafref
            {te-types:named-path-constraints}?
        +--rw te-bandwidth
            +--rw (technology)?
                +--:(generic)
                    +--rw generic?    te-bandwidth
        +--rw link-protection?                           identityref
        +--rw setup-priority?                             uint8
        +--rw hold-priority?                             uint8
        +--rw signaling-type?                           identityref
        +--rw path-metric-bounds
            +--rw path-metric-bound* [metric-type]
                +--rw metric-type    identityref
                +--rw upper-bound?   uint64
        +--rw path-affinities-values
            +--rw path-affinities-value* [usage]
                +--rw usage          identityref
                +--rw value?        admin-groups
        +--rw path-affinity-names
            +--rw path-affinity-name* [usage]
                +--rw usage          identityref
                +--rw affinity-name* [name]
                    +--rw name       string
        +--rw path-srlgs-lists
            +--rw path-srlgs-list* [usage]
                +--rw usage          identityref
                +--rw values*        srlg
        +--rw path-srlgs-names
            +--rw path-srlgs-name* [usage]
                +--rw usage          identityref
                +--rw names*         string
        +--rw disjointness?
            te-path-disjointness
        +--rw explicit-route-objects-always
            +--rw route-object-exclude-always* [index]
                +--rw index          uint32
                +--rw (type)?
                    +--:(numbered-node-hop)
                        +--rw numbered-node-hop
                            +--rw node-id    te-node-id
                            +--rw hop-type?   te-hop-type
                    +--:(numbered-link-hop)

```

```

+---rw numbered-link-hop
+---rw link-tp-id      te-tp-id
+---rw hop-type?      te-hop-type
+---rw direction?     te-link-direction
+---:(unnumbered-link-hop)
+---rw unnumbered-link-hop
+---rw link-tp-id      te-tp-id
+---rw node-id         te-node-id
+---rw hop-type?      te-hop-type
+---rw direction?     te-link-direction
+---:(as-number)
+---rw as-number-hop
+---rw as-number       inet:as-number
+---rw hop-type?      te-hop-type
+---:(label)
+---rw label-hop
+---rw te-label
+---rw (technology)?
+---:(generic)
+---rw generic?
+---rw direction?
+---rw direction?     te-label-direction
+---rw route-object-include-exclude* [index]
+---rw explicit-route-usage?          identityref
+---rw index                          uint32
+---rw (type)?
+---:(numbered-node-hop)
+---rw numbered-node-hop
+---rw node-id      te-node-id
+---rw hop-type?    te-hop-type
+---:(numbered-link-hop)
+---rw numbered-link-hop
+---rw link-tp-id      te-tp-id
+---rw hop-type?      te-hop-type
+---rw direction?     te-link-direction
+---:(unnumbered-link-hop)
+---rw unnumbered-link-hop
+---rw link-tp-id      te-tp-id
+---rw node-id         te-node-id
+---rw hop-type?      te-hop-type
+---rw direction?     te-link-direction
+---:(as-number)
+---rw as-number-hop
+---rw as-number       inet:as-number
+---rw hop-type?      te-hop-type
+---:(label)
+---rw label-hop

```

```

        +---rw te-label
            +---rw (technology)?
                +---:(generic)
                    +---rw generic?
                        rt-types:generalized-label
            +---rw direction?
                te-label-direction
        +---:(srlg)
            +---rw srlg
                +---rw srlg?    uint32
+---rw shared-resources-tunnels
|   +---rw lsp-shared-resources-tunnel*    tunnel-ref
+---rw path-in-segment!
    +---rw label-restrictions
        +---rw label-restriction* [index]
            +---rw restriction?    enumeration
            +---rw index          uint32
            +---rw label-start
                +---rw te-label
                    +---rw (technology)?
                        +---:(generic)
                            +---rw generic?
                                rt-types:generalized-label
                +---rw direction?
                    te-label-direction
            +---rw label-end
                +---rw te-label
                    +---rw (technology)?
                        +---:(generic)
                            +---rw generic?
                                rt-types:generalized-label
                +---rw direction?
                    te-label-direction
            +---rw label-step
                +---rw (technology)?
                    +---:(generic)
                        +---rw generic?    int32
            +---rw range-bitmap?    yang:hex-string
+---rw path-out-segment!
    +---rw label-restrictions
        +---rw label-restriction* [index]
            +---rw restriction?    enumeration
            +---rw index          uint32
            +---rw label-start
                +---rw te-label
                    +---rw (technology)?
                        +---:(generic)
                            +---rw generic?

```

```

|           rt-types:generalized-label
|           +---rw direction?
|               te-label-direction
+---rw label-end
|   +---rw te-label
|       +---rw (technology)?
|           +---:(generic)
|               +---rw generic?
|                   rt-types:generalized-label
|           +---rw direction?
|               te-label-direction
+---rw label-step
|   +---rw (technology)?
|       +---:(generic)
|           +---rw generic?   int32
+---rw range-bitmap?   yang:hex-string
+---ro computed-paths-properties
|   +---ro computed-path-properties* [k-index]
|       +---ro k-index             uint8
|   +---ro path-properties
|       +---ro path-metric* [metric-type]
|           +---ro metric-type         identityref
|           +---ro accumulative-value? uint64
|   +---ro path-affinities-values
|       +---ro path-affinities-value* [usage]
|           +---ro usage         identityref
|           +---ro value?       admin-groups
|   +---ro path-affinity-names
|       +---ro path-affinity-name* [usage]
|           +---ro usage         identityref
|           +---ro affinity-name* [name]
|               +---ro name      string
|   +---ro path-srlgs-lists
|       +---ro path-srlgs-list* [usage]
|           +---ro usage         identityref
|           +---ro values*       srlg
|   +---ro path-srlgs-names
|       +---ro path-srlgs-name* [usage]
|           +---ro usage         identityref
|           +---ro names*        string
+---ro path-route-objects
|   +---ro path-computed-route-object*
|       [index]
|       +---ro index
|           |
|           |   uint32
|       +---ro (type)?
|           +---:(numbered-node-hop)
|               +---ro numbered-node-hop

```

| | | | | | | |
|-----|--|--|--|---|-------------------------|------------|
| | | | | | +--ro node-id | te-node-id |
| | | | | | +--ro hop-type? | |
| | | | | | te-hop-type | |
| | | | | +---:(numbered-link-hop) | | |
| | | | | +--ro numbered-link-hop | | |
| | | | | +--ro link-tp-id | te-tp-id | |
| | | | | +--ro hop-type? | | |
| | | | | | te-hop-type | |
| | | | | +--ro direction? | | |
| | | | | te-link-direction | | |
| | | | | +---:(unnumbered-link-hop) | | |
| | | | | +--ro unnumbered-link-hop | | |
| | | | | +--ro link-tp-id | te-tp-id | |
| | | | | +--ro node-id | | |
| | | | | | te-node-id | |
| | | | | +--ro hop-type? | | |
| | | | | | te-hop-type | |
| | | | | +--ro direction? | | |
| | | | | te-link-direction | | |
| | | | | +---:(as-number) | | |
| | | | | +--ro as-number-hop | | |
| | | | | +--ro as-number | | |
| | | | | | inet:as-number | |
| | | | | +--ro hop-type? | | |
| | | | | te-hop-type | | |
| | | | | +---:(label) | | |
| | | | | +--ro label-hop | | |
| | | | | +--ro te-label | | |
| | | | | +--ro (technology)? | | |
| | | | | | +---:(generic) | |
| | | | | | +--ro generic? | |
| | | | | | rt-types:generalized-la | |
| bel | | | | | +--ro direction? | |
| | | | | | te-label-direction | |
| | | | | +---ro shared-resources-tunnels | | |
| | | | | +---ro lsp-shared-resources-tunnel* | | |
| | | | | tunnel-ref | | |
| | | | | +--ro lsps | | |
| | | | | +--ro lsp* | | |
| | | | | [source destination tunnel-id lsp-id extended-tunnel- | | |
| id] | | | | | | |
| | | | | +--ro source | | |
| | | | | | te-types:te-node-id | |
| | | | | +--ro destination | | |
| | | | | | te-types:te-node-id | |
| | | | | +--ro tunnel-id | | |
| | | | | | uint16 | |
| | | | | +--ro lsp-id | | |
| | | | | | uint16 | |


```

+---ro extended-tunnel-id
|   yang:dotted-quad
+---ro operational-state?
|   identityref
+---ro path-setup-protocol?
|   identityref
+---ro origin-type?
|   enumeration
+---ro lsp-resource-status?
|   enumeration
+---ro lockout-of-normal?
|   boolean
+---ro freeze?
|   boolean
+---ro lsp-protection-role?
|   enumeration
+---ro lsp-protection-state?
|   identityref
+---ro protection-group-ingress-node-id?
|   te-types:te-node-id
+---ro protection-group-egress-node-id?
|   te-types:te-node-id
+---ro lsp-shared-resources-tunnel?
|   tunnel-ref
+---ro lsp-record-route-information
|   +---ro lsp-record-route-information* [index]
|   |   +---ro index
|   |   |   uint32
|   |   +---ro (type)?
|   |   |   +---:(numbered-node-hop)
|   |   |   |   +---ro numbered-node-hop
|   |   |   |   |   +---ro node-id      te-node-id
|   |   |   |   |   +---ro flags*
|   |   |   |   |       path-attribute-flags
|   |   |   |   +---:(numbered-link-hop)
|   |   |   |   |   +---ro numbered-link-hop
|   |   |   |   |   |   +---ro link-tp-id    te-tp-id
|   |   |   |   |   |   +---ro flags*
|   |   |   |   |       path-attribute-flags
|   |   |   |   +---:(unnumbered-link-hop)
|   |   |   |   |   +---ro unnumbered-link-hop
|   |   |   |   |   |   +---ro link-tp-id    te-tp-id
|   |   |   |   |   |   +---ro node-id?      te-node-id
|   |   |   |   |   |   +---ro flags*
|   |   |   |   |       path-attribute-flags
|   |   |   +---:(label)
|   |   |   |   +---ro label-hop
|   |   |   |   |   +---ro te-label

```

```

+---ro (technology)?
|   +---:(generic)
|       +---ro generic?
|           rt-types:generalized-label
+---ro direction?
|       te-label-direction
+---ro flags*
|       path-attribute-flags
+---ro path-properties
|   +---ro path-metric* [metric-type]
|       +---ro metric-type          identityref
|       +---ro accumulative-value?  uint64
+---ro path-affinities-values
|   +---ro path-affinities-value* [usage]
|       +---ro usage          identityref
|       +---ro value?        admin-groups
+---ro path-affinity-names
|   +---ro path-affinity-name* [usage]
|       +---ro usage          identityref
|       +---ro affinity-name* [name]
|           +---ro name      string
+---ro path-srlgs-lists
|   +---ro path-srlgs-list* [usage]
|       +---ro usage          identityref
|       +---ro values*      srlg
+---ro path-srlgs-names
|   +---ro path-srlgs-name* [usage]
|       +---ro usage          identityref
|       +---ro names*      string
+---ro path-route-objects
|   +---ro path-computed-route-object*
|       [index]
|       +---ro index
|           |          uint32
|       +---ro (type)?
|           +---:(numbered-node-hop)
|               +---ro numbered-node-hop
|                   +---ro node-id      te-node-id
|                   +---ro hop-type?
|                       te-hop-type
|           +---:(numbered-link-hop)
|               +---ro numbered-link-hop
|                   +---ro link-tp-id    te-tp-id
|                   +---ro hop-type?
|                       |          te-hop-type
|                   +---ro direction?
|                       te-link-direction
|           +---:(unnumbered-link-hop)

```

```

+---ro unnumbered-link-hop
+---ro link-tp-id    te-tp-id
+---ro node-id
|   te-node-id
+---ro hop-type?
|   te-hop-type
+---ro direction?
|   te-link-direction
+---:(as-number)
+---ro as-number-hop
+---ro as-number
|   inet:as-number
+---ro hop-type?
|   te-hop-type
+---:(label)
+---ro label-hop
+---ro te-label
+---ro (technology)?
|   +---:(generic)
|       +---ro generic?
|           rt-types:generalized-la
bel
+---ro direction?
|   te-label-direction
+---ro shared-resources-tunnels
+---ro lsp-shared-resources-tunnel*
|   tunnel-ref
+---rw p2p-primary-reverse-path
+---rw name?                                string
+---rw path-setup-protocol?
|   identityref
+---rw path-computation-method?
|   identityref
+---rw path-computation-server?
|   inet:ip-address
+---rw compute-only?                        empty
+---rw use-path-computation?                boolean
+---rw lockdown?                           empty
+---ro path-scope?
|   identityref
+---rw optimizations
|   +---rw (algorithm)?
|       +---:(metric) {path-optimization-metric}?
|           +---rw optimization-metric* [metric-type]
|               +---rw metric-type
|                   identityref
|           +---rw weight?
|               uint8
+---rw explicit-route-exclude-objects

```

```

+--rw route-object-exclude-object*
|   [index]
+--rw index
|   uint32
+--rw (type)?
|   +--:(numbered-node-hop)
|   |   +--rw numbered-node-hop
|   |   |   +--rw node-id
|   |   |   |   te-node-id
|   |   |   +--rw hop-type?
|   |   |   |   te-hop-type
|   |   +--:(numbered-link-hop)
|   |   |   +--rw numbered-link-hop
|   |   |   |   +--rw link-tp-id
|   |   |   |   |   te-tp-id
|   |   |   |   +--rw hop-type?
|   |   |   |   |   te-hop-type
|   |   |   |   +--rw direction?
|   |   |   |   |   te-link-direction
|   |   +--:(unnumbered-link-hop)
|   |   |   +--rw unnumbered-link-hop
|   |   |   |   +--rw link-tp-id
|   |   |   |   |   te-tp-id
|   |   |   |   +--rw node-id
|   |   |   |   |   te-node-id
|   |   |   |   +--rw hop-type?
|   |   |   |   |   te-hop-type
|   |   |   |   +--rw direction?
|   |   |   |   |   te-link-direction
|   |   +--:(as-number)
|   |   |   +--rw as-number-hop
|   |   |   |   +--rw as-number
|   |   |   |   |   inet:as-number
|   |   |   |   +--rw hop-type?
|   |   |   |   |   te-hop-type
|   |   +--:(label)
|   |   |   +--rw label-hop
|   |   |   |   +--rw te-label
|   |   |   |   |   +--rw (technology)?
|   |   |   |   |   |   +--:(generic)
|   |   |   |   |   |   |   +--rw generic?
|   |   |   |   |   |   |   |   rt-types:generalized
|   |   |   |   |   |   |   |   +--rw direction?
|   |   |   |   |   |   |   |   |   te-label-direction
|   |   +--:(srlg)
|   |   |   +--rw srlg
|   |   |   |   +--rw srlg?   uint32
+--rw explicit-route-include-objects

```

```

+--rw route-object-include-object*
+--rw index
+--rw (type)?
+--:(numbered-node-hop)
+--rw numbered-node-hop
+--rw node-id
+--rw hop-type?
+--rw te-hop-type
+--:(numbered-link-hop)
+--rw numbered-link-hop
+--rw link-tp-id
+--rw te-tp-id
+--rw hop-type?
+--rw te-hop-type
+--rw direction?
+--rw te-link-direction
+--:(unnumbered-link-hop)
+--rw unnumbered-link-hop
+--rw link-tp-id
+--rw te-tp-id
+--rw node-id
+--rw te-node-id
+--rw hop-type?
+--rw te-hop-type
+--rw direction?
+--rw te-link-direction
+--:(as-number)
+--rw as-number-hop
+--rw as-number
+--rw inet:as-number
+--rw hop-type?
+--rw te-hop-type
+--:(label)
+--rw label-hop
+--rw te-label
+--rw (technology)?
+--:(generic)
+--rw generic?
+--rw rt-types:generalized-label
+--rw direction?
+--rw te-label-direction
+--rw tiebreakers
+--rw tiebreaker* [tiebreaker-type]
+--rw tiebreaker-type
+--rw identityref

```

```

+---:(objective-function)
  {path-optimization-objective-function}?
  +---rw objective-function
    +---rw objective-function-type?
      identityref
+---rw named-path-constraint?          leafref
  | {te-types:named-path-constraints}?
+---rw te-bandwidth
  | +---rw (technology)?
  |   +---:(generic)
  |     +---rw generic?    te-bandwidth
+---rw link-protection?
  | identityref
+---rw setup-priority?                  uint8
+---rw hold-priority?                  uint8
+---rw signaling-type?
  | identityref
+---rw path-metric-bounds
  | +---rw path-metric-bound* [metric-type]
  |   +---rw metric-type    identityref
  |   +---rw upper-bound?   uint64
+---rw path-affinities-values
  | +---rw path-affinities-value* [usage]
  |   +---rw usage          identityref
  |   +---rw value?        admin-groups
+---rw path-affinity-names
  | +---rw path-affinity-name* [usage]
  |   +---rw usage          identityref
  |   +---rw affinity-name* [name]
  |     +---rw name        string
+---rw path-srlgs-lists
  | +---rw path-srlgs-list* [usage]
  |   +---rw usage          identityref
  |   +---rw values*       srlg
+---rw path-srlgs-names
  | +---rw path-srlgs-name* [usage]
  |   +---rw usage          identityref
  |   +---rw names*        string
+---rw disjointness?
  | te-path-disjointness
+---rw explicit-route-objects-always
  | +---rw route-object-exclude-always* [index]
  |   +---rw index          uint32
  |   +---rw (type)?
  |     +---:(numbered-node-hop)
  |       +---rw numbered-node-hop
  |         +---rw node-id    te-node-id
  |         +---rw hop-type?  te-hop-type

```

```

+---:(numbered-link-hop)
|   +---rw numbered-link-hop
|       +---rw link-tp-id      te-tp-id
|       +---rw hop-type?      te-hop-type
|       +---rw direction?
|                               te-link-direction
+---:(unnumbered-link-hop)
|   +---rw unnumbered-link-hop
|       +---rw link-tp-id      te-tp-id
|       +---rw node-id        te-node-id
|       +---rw hop-type?      te-hop-type
|       +---rw direction?
|                               te-link-direction
+---:(as-number)
|   +---rw as-number-hop
|       +---rw as-number      inet:as-number
|       +---rw hop-type?      te-hop-type
+---:(label)
|   +---rw label-hop
|       +---rw te-label
|           +---rw (technology)?
|               +---:(generic)
|                   +---rw generic?
|                       rt-types:generalized-label
|       +---rw direction?
|                               te-label-direction
+---rw route-object-include-exclude* [index]
+---rw explicit-route-usage?
|   identityref
+---rw index                                uint32
+---rw (type)?
+---:(numbered-node-hop)
|   +---rw numbered-node-hop
|       +---rw node-id        te-node-id
|       +---rw hop-type?      te-hop-type
+---:(numbered-link-hop)
|   +---rw numbered-link-hop
|       +---rw link-tp-id      te-tp-id
|       +---rw hop-type?      te-hop-type
|       +---rw direction?
|                               te-link-direction
+---:(unnumbered-link-hop)
|   +---rw unnumbered-link-hop
|       +---rw link-tp-id      te-tp-id
|       +---rw node-id        te-node-id
|       +---rw hop-type?      te-hop-type
|       +---rw direction?
|                               te-link-direction

```

```

+---:(as-number)
|   +---rw as-number-hop
|       +---rw as-number      inet:as-number
|       +---rw hop-type?      te-hop-type
+---:(label)
|   +---rw label-hop
|       +---rw te-label
|           +---rw (technology)?
|               +---:(generic)
|                   +---rw generic?
|                       rt-types:generalized-label
|       +---rw direction?
|                   te-label-direction
+---:(srlg)
|   +---rw srlg
|       +---rw srlg?      uint32
+---rw shared-resources-tunnels
|   +---rw lsp-shared-resources-tunnel*
|       tunnel-ref
+---rw path-in-segment!
|   +---rw label-restrictions
|       +---rw label-restriction* [index]
|           +---rw restriction?      enumeration
|           +---rw index              uint32
|       +---rw label-start
|           +---rw te-label
|               +---rw (technology)?
|                   +---:(generic)
|                       +---rw generic?
|                           rt-types:generalized-label
|       +---rw direction?
|                   te-label-direction
+---rw label-end
|   +---rw te-label
|       +---rw (technology)?
|           +---:(generic)
|               +---rw generic?
|                   rt-types:generalized-label
|       +---rw direction?
|                   te-label-direction
+---rw label-step
|   +---rw (technology)?
|       +---:(generic)
|           +---rw generic?      int32
|       +---rw range-bitmap?      yang:hex-string
+---rw path-out-segment!
|   +---rw label-restrictions
|       +---rw label-restriction* [index]

```



```

+--rw restriction?      enumeration
+--rw index             uint32
+--rw label-start
|   +--rw te-label
|       +--rw (technology)?
|           +--:(generic)
|               +--rw generic?
|                   rt-types:generalized-label
|   +--rw direction?
|       te-label-direction
+--rw label-end
|   +--rw te-label
|       +--rw (technology)?
|           +--:(generic)
|               +--rw generic?
|                   rt-types:generalized-label
|   +--rw direction?
|       te-label-direction
+--rw label-step
|   +--rw (technology)?
|       +--:(generic)
|           +--rw generic?      int32
+--rw range-bitmap?     yang:hex-string
+--ro computed-paths-properties
|   +--ro computed-path-properties* [k-index]
|       +--ro k-index          uint8
|       +--ro path-properties
|           +--ro path-metric* [metric-type]
|               +--ro metric-type
|                   identityref
|               +--ro accumulative-value?      uint64
+--ro path-affinities-values
|   +--ro path-affinities-value* [usage]
|       +--ro usage          identityref
|       +--ro value?         admin-groups
+--ro path-affinity-names
|   +--ro path-affinity-name* [usage]
|       +--ro usage          identityref
|       +--ro affinity-name* [name]
|           +--ro name       string
+--ro path-srlgs-lists
|   +--ro path-srlgs-list* [usage]
|       +--ro usage          identityref
|       +--ro values*       srlg
+--ro path-srlgs-names
|   +--ro path-srlgs-name* [usage]
|       +--ro usage          identityref
|       +--ro names*        string

```

```

+---ro path-route-objects
+---ro path-computed-route-object*
    [index]
+---ro index
    |
    uint32
+---ro (type)?
+---:(numbered-node-hop)
    +---ro numbered-node-hop
        +---ro node-id
            |
            te-node-id
        +---ro hop-type?
            |
            te-hop-type
+---:(numbered-link-hop)
    +---ro numbered-link-hop
        +---ro link-tp-id
            |
            te-tp-id
        +---ro hop-type?
            |
            te-hop-type
        +---ro direction?
            |
            te-link-direction
+---:(unnumbered-link-hop)
    +---ro unnumbered-link-hop
        +---ro link-tp-id
            |
            te-tp-id
        +---ro node-id
            |
            te-node-id
        +---ro hop-type?
            |
            te-hop-type
        +---ro direction?
            |
            te-link-direction
+---:(as-number)
    +---ro as-number-hop
        +---ro as-number
            |
            inet:as-number
        +---ro hop-type?
            |
            te-hop-type
+---:(label)
    +---ro label-hop
        +---ro te-label
            +---ro (technology)?
                |
                +---:(generic)
                    |
                    +---ro generic?
                        |
                        rt-types:generalized
+---ro direction?
    |
    te-label-direction
+---ro shared-resources-tunnels
+---ro lsp-shared-resources-tunnel*
    tunnel-ref

```

| | | | | |
|--------|--|--|--|--|
| | | | | +--ro lsp |
| | | | | +--ro lsp* |
| | | | | [source destination tunnel-id lsp-id extended-tunn |
| el-id] | | | | |
| | | | | +--ro source |
| | | | | te-types:te-node-id |
| | | | | +--ro destination |
| | | | | te-types:te-node-id |
| | | | | +--ro tunnel-id |
| | | | | uint16 |
| | | | | +--ro lsp-id |
| | | | | uint16 |
| | | | | +--ro extended-tunnel-id |
| | | | | yang:dotted-quad |
| | | | | +--ro operational-state? |
| | | | | identityref |
| | | | | +--ro path-setup-protocol? |
| | | | | identityref |
| | | | | +--ro origin-type? |
| | | | | enumeration |
| | | | | +--ro lsp-resource-status? |
| | | | | enumeration |
| | | | | +--ro lockout-of-normal? |
| | | | | boolean |
| | | | | +--ro freeze? |
| | | | | boolean |
| | | | | +--ro lsp-protection-role? |
| | | | | enumeration |
| | | | | +--ro lsp-protection-state? |
| | | | | identityref |
| | | | | +--ro protection-group-ingress-node-id? |
| | | | | te-types:te-node-id |
| | | | | +--ro protection-group-egress-node-id? |
| | | | | te-types:te-node-id |
| | | | | +--ro lsp-shared-resources-tunnel? |
| | | | | tunnel-ref |
| | | | | +--ro lsp-record-route-information |
| | | | | +--ro lsp-record-route-information* |
| | | | | [index] |
| | | | | +--ro index |
| | | | | uint32 |
| | | | | +--ro (type)? |
| | | | | +--:(numbered-node-hop) |
| | | | | +--ro numbered-node-hop |
| | | | | +--ro node-id te-node-id |
| | | | | +--ro flags* |
| | | | | path-attribute-flags |
| | | | | +--:(numbered-link-hop) |
| | | | | +--ro numbered-link-hop |

```

        +---ro link-tp-id      te-tp-id
        +---ro flags*
            path-attribute-flags
+---:(unnumbered-link-hop)
    +---ro unnumbered-link-hop
        +---ro link-tp-id      te-tp-id
        +---ro node-id?
            |
            te-node-id
        +---ro flags*
            path-attribute-flags
+---:(label)
    +---ro label-hop
    +---ro te-label
        |   +---ro (technology)?
        |       +---:(generic)
        |           +---ro generic?
        |               rt-types:generalized-la
bel          |   +---ro direction?
              |       te-label-direction
              +---ro flags*
                  path-attribute-flags
+---ro path-properties
    +---ro path-metric* [metric-type]
        |   +---ro metric-type
        |       |
        |       identityref
        +---ro accumulative-value? uint64
+---ro path-affinities-values
    +---ro path-affinities-value* [usage]
        +---ro usage      identityref
        +---ro value?     admin-groups
+---ro path-affinity-names
    +---ro path-affinity-name* [usage]
        +---ro usage      identityref
        +---ro affinity-name* [name]
            +---ro name      string
+---ro path-srlgs-lists
    +---ro path-srlgs-list* [usage]
        +---ro usage      identityref
        +---ro values*     srlg
+---ro path-srlgs-names
    +---ro path-srlgs-name* [usage]
        +---ro usage      identityref
        +---ro names*     string
+---ro path-route-objects
    +---ro path-computed-route-object*
        [index]
        +---ro index
            |
            uint32

```

```

+--ro (type)?
+--:(numbered-node-hop)
|   +--ro numbered-node-hop
|   |   +--ro node-id
|   |   |   te-node-id
|   |   +--ro hop-type?
|   |       te-hop-type
+--:(numbered-link-hop)
|   +--ro numbered-link-hop
|   |   +--ro link-tp-id
|   |   |   te-tp-id
|   |   +--ro hop-type?
|   |   |   te-hop-type
|   |   +--ro direction?
|   |       te-link-direction
+--:(unnumbered-link-hop)
|   +--ro unnumbered-link-hop
|   |   +--ro link-tp-id
|   |   |   te-tp-id
|   |   +--ro node-id
|   |   |   te-node-id
|   |   +--ro hop-type?
|   |   |   te-hop-type
|   |   +--ro direction?
|   |       te-link-direction
+--:(as-number)
|   +--ro as-number-hop
|   |   +--ro as-number
|   |   |   inet:as-number
|   |   +--ro hop-type?
|   |       te-hop-type
+--:(label)
|   +--ro label-hop
|   |   +--ro te-label
|   |   |   +--ro (technology)?
|   |   |   |   +--:(generic)
|   |   |   |   +--ro generic?
|   |   |       rt-types:generalized
|   |   +--ro direction?
|   |       te-label-direction
+--ro shared-resources-tunnels
+--ro lsp-shared-resources-tunnel*
|   tunnel-ref
+--rw p2p-secondary-reverse-path
|   +--rw secondary-path?   leafref
|   +--rw path-setup-protocol? identityref
+--rw candidate-p2p-secondary-paths
+--rw candidate-p2p-secondary-path*

```

```

[secondary-path]
+--rw secondary-path          leafref
+--rw path-setup-protocol?    identityref
+--ro active?                  boolean
+--rw p2p-secondary-paths
+--rw p2p-secondary-path* [name]
+--rw name                      string
+--rw path-setup-protocol?    identityref
+--rw path-computation-method? identityref
+--rw path-computation-server?
|
|   inet:ip-address
+--rw compute-only?            empty
+--rw use-path-computation?    boolean
+--rw lockdown?                empty
+--ro path-scope?              identityref
+--rw optimizations
+--rw (algorithm)?
+--:(metric) {path-optimization-metric}?
+--rw optimization-metric* [metric-type]
+--rw metric-type
|
|   identityref
+--rw weight?
|
|   uint8
+--rw explicit-route-exclude-objects
+--rw route-object-exclude-object*
|
|   [index]
+--rw index
|
|   uint32
+--rw (type)?
+--:(numbered-node-hop)
+--rw numbered-node-hop
+--rw node-id
|
|   te-node-id
+--rw hop-type?
|
|   te-hop-type
+--:(numbered-link-hop)
+--rw numbered-link-hop
+--rw link-tp-id
|
|   te-tp-id
+--rw hop-type?
|
|   te-hop-type
+--rw direction?
|
|   te-link-direction
+--:(unnumbered-link-hop)
+--rw unnumbered-link-hop
+--rw link-tp-id
|
|   te-tp-id
+--rw node-id

```

[illegible]

[illegible]


```

+--rw path-affinity-names
|   +--rw path-affinity-name* [usage]
|       +--rw usage            identityref
|       +--rw affinity-name* [name]
|           +--rw name         string
+--rw path-srlgs-lists
|   +--rw path-srlgs-list* [usage]
|       +--rw usage            identityref
|       +--rw values*         srlg
+--rw path-srlgs-names
|   +--rw path-srlgs-name* [usage]
|       +--rw usage            identityref
|       +--rw names*          string
+--rw disjointness?
|   te-path-disjointness
+--rw explicit-route-objects-always
|   +--rw route-object-exclude-always* [index]
|       +--rw index            uint32
|       +--rw (type)?
|           +--:(numbered-node-hop)
|               +--rw numbered-node-hop
|                   +--rw node-id      te-node-id
|                   +--rw hop-type?    te-hop-type
|           +--:(numbered-link-hop)
|               +--rw numbered-link-hop
|                   +--rw link-tp-id    te-tp-id
|                   +--rw hop-type?    te-hop-type
|                   +--rw direction?   te-link-direction
|           +--:(unnumbered-link-hop)
|               +--rw unnumbered-link-hop
|                   +--rw link-tp-id    te-tp-id
|                   +--rw node-id      te-node-id
|                   +--rw hop-type?    te-hop-type
|                   +--rw direction?   te-link-direction
|           +--:(as-number)
|               +--rw as-number-hop
|                   +--rw as-number    inet:as-number
|                   +--rw hop-type?    te-hop-type
|           +--:(label)
|               +--rw label-hop
|                   +--rw te-label
|                       +--rw (technology)?
|                           +--:(generic)
|                               +--rw generic?
|                                   rt-types:generalized-label
|                       +--rw direction?
|                           te-label-direction
+--rw route-object-include-exclude* [index]

```

```

+--rw explicit-route-usage?      identityref
+--rw index                       uint32
+--rw (type)?
+--:(numbered-node-hop)
|   +--rw numbered-node-hop
|       +--rw node-id             te-node-id
|       +--rw hop-type?          te-hop-type
+--:(numbered-link-hop)
|   +--rw numbered-link-hop
|       +--rw link-tp-id          te-tp-id
|       +--rw hop-type?          te-hop-type
|       +--rw direction?         te-link-direction
+--:(unnumbered-link-hop)
|   +--rw unnumbered-link-hop
|       +--rw link-tp-id          te-tp-id
|       +--rw node-id             te-node-id
|       +--rw hop-type?          te-hop-type
|       +--rw direction?         te-link-direction
+--:(as-number)
|   +--rw as-number-hop
|       +--rw as-number           inet:as-number
|       +--rw hop-type?          te-hop-type
+--:(label)
|   +--rw label-hop
|       +--rw te-label
|           +--rw (technology)?
|               +--:(generic)
|                   +--rw generic?
|                       rt-types:generalized-label
|           +--rw direction?
|               te-label-direction
+--:(srlg)
|   +--rw srlg
|       +--rw srlg?              uint32
+--rw shared-resources-tunnels
|   +--rw lsp-shared-resources-tunnel*  tunnel-ref
+--rw path-in-segment!
|   +--rw label-restrictions
|       +--rw label-restriction* [index]
|           +--rw restriction?        enumeration
|           +--rw index               uint32
|           +--rw label-start
|               +--rw te-label
|                   +--rw (technology)?
|                       +--:(generic)
|                           +--rw generic?
|                               rt-types:generalized-label
|           +--rw direction?

```

```

|                                     te-label-direction
+--rw label-end
|   +--rw te-label
|       +--rw (technology)?
|           +--:(generic)
|               +--rw generic?
|                   rt-types:generalized-label
+--rw direction?
|   te-label-direction
+--rw label-step
|   +--rw (technology)?
|       +--:(generic)
|           +--rw generic?    int32
+--rw range-bitmap?    yang:hex-string
+--rw path-out-segment!
|   +--rw label-restrictions
|       +--rw label-restriction* [index]
|           +--rw restriction?    enumeration
|           +--rw index          uint32
+--rw label-start
|   +--rw te-label
|       +--rw (technology)?
|           +--:(generic)
|               +--rw generic?
|                   rt-types:generalized-label
+--rw direction?
|   te-label-direction
+--rw label-end
|   +--rw te-label
|       +--rw (technology)?
|           +--:(generic)
|               +--rw generic?
|                   rt-types:generalized-label
+--rw direction?
|   te-label-direction
+--rw label-step
|   +--rw (technology)?
|       +--:(generic)
|           +--rw generic?    int32
+--rw range-bitmap?    yang:hex-string
+--rw protection
|   +--rw enable?                boolean
|   +--rw protection-type?       identityref
|   +--rw protection-reversion-disable? boolean
|   +--rw hold-off-time?         uint32
|   +--rw wait-to-revert?        uint16
|   +--rw aps-signal-id?         uint8
+--rw restoration

```

```

+--rw enable?                               boolean
+--rw restoration-type?
|   identityref
+--rw restoration-scheme?
|   identityref
+--rw restoration-reversion-disable?         boolean
+--rw hold-off-time?                         uint32
+--rw wait-to-restore?                       uint16
+--rw wait-to-revert?                       uint16
+--ro computed-paths-properties
+--ro computed-path-properties* [k-index]
|   +--ro k-index                           uint8
|   +--ro path-properties
|   |   +--ro path-metric* [metric-type]
|   |   |   +--ro metric-type               identityref
|   |   |   +--ro accumulative-value?       uint64
|   |   +--ro path-affinities-values
|   |   |   +--ro path-affinities-value* [usage]
|   |   |   |   +--ro usage                 identityref
|   |   |   |   +--ro value?               admin-groups
|   |   +--ro path-affinity-names
|   |   |   +--ro path-affinity-name* [usage]
|   |   |   |   +--ro usage                 identityref
|   |   |   |   +--ro affinity-name* [name]
|   |   |   |   |   +--ro name              string
|   |   +--ro path-srlgs-lists
|   |   |   +--ro path-srlgs-list* [usage]
|   |   |   |   +--ro usage                 identityref
|   |   |   |   +--ro values*              srlg
|   |   +--ro path-srlgs-names
|   |   |   +--ro path-srlgs-name* [usage]
|   |   |   |   +--ro usage                 identityref
|   |   |   |   +--ro names*              string
|   +--ro path-route-objects
|   |   +--ro path-computed-route-object*
|   |   |   [index]
|   |   |   +--ro index
|   |   |   |   uint32
|   |   |   +--ro (type)?
|   |   |   |   +--:(numbered-node-hop)
|   |   |   |   |   +--ro numbered-node-hop
|   |   |   |   |   |   +--ro node-id       te-node-id
|   |   |   |   |   |   +--ro hop-type?
|   |   |   |   |   |   |   te-hop-type
|   |   |   |   +--:(numbered-link-hop)
|   |   |   |   |   +--ro numbered-link-hop
|   |   |   |   |   |   +--ro link-tp-id    te-tp-id
|   |   |   |   |   |   +--ro hop-type?

```

| | | | | | | | | | | |
|-----|--|--|--|--|--|--|--|--|---|---|
| | | | | | | | | | | te-hop-type +---ro direction? te-link-direction +---:(unnumbered-link-hop) +---ro unnumbered-link-hop +---ro link-tp-id te-tp-id +---ro node-id te-node-id +---ro hop-type? te-hop-type +---ro direction? te-link-direction +---:(as-number) +---ro as-number-hop +---ro as-number inet:as-number +---ro hop-type? te-hop-type +---:(label) +---ro label-hop +---ro te-label +---ro (technology)? +---:(generic) +---ro generic? rt-types:generalized-la |
| bel | | | | | | | | | | +---ro direction? te-label-direction +---ro shared-resources-tunnels +---ro lsp-shared-resources-tunnel* tunnel-ref +---ro lsps +---ro lsp* |
| id] | | | | | | | | | [source destination tunnel-id lsp-id extended-tunnel- | +---ro source te-types:te-node-id +---ro destination te-types:te-node-id +---ro tunnel-id uint16 +---ro lsp-id uint16 +---ro extended-tunnel-id yang:dotted-quad +---ro operational-state? identityref +---ro path-setup-protocol? identityref +---ro origin-type? |

```

|         enumeration
+--ro lsp-resource-status?
|         enumeration
+--ro lockout-of-normal?
|         boolean
+--ro freeze?
|         boolean
+--ro lsp-protection-role?
|         enumeration
+--ro lsp-protection-state?
|         identityref
+--ro protection-group-ingress-node-id?
|         te-types:te-node-id
+--ro protection-group-egress-node-id?
|         te-types:te-node-id
+--ro lsp-shared-resources-tunnel?
|         tunnel-ref
+--ro lsp-record-route-information
|   +--ro lsp-record-route-information* [index]
|   |   +--ro index
|   |   |   uint32
|   |   +--ro (type)?
|   |   |   +--:(numbered-node-hop)
|   |   |   |   +--ro numbered-node-hop
|   |   |   |   |   +--ro node-id      te-node-id
|   |   |   |   |   +--ro flags*
|   |   |   |   |       path-attribute-flags
|   |   |   |   +--:(numbered-link-hop)
|   |   |   |   |   +--ro numbered-link-hop
|   |   |   |   |   +--ro link-tp-id    te-tp-id
|   |   |   |   |   +--ro flags*
|   |   |   |   |       path-attribute-flags
|   |   |   |   +--:(unnumbered-link-hop)
|   |   |   |   |   +--ro unnumbered-link-hop
|   |   |   |   |   +--ro link-tp-id    te-tp-id
|   |   |   |   |   +--ro node-id?     te-node-id
|   |   |   |   |   +--ro flags*
|   |   |   |   |       path-attribute-flags
|   |   |   |   +--:(label)
|   |   |   |   |   +--ro label-hop
|   |   |   |   |   +--ro te-label
|   |   |   |   |   |   +--ro (technology)?
|   |   |   |   |   |   |   +--:(generic)
|   |   |   |   |   |   |   |   +--ro generic?
|   |   |   |   |   |   |   |       rt-types:generalized-label
|   |   |   |   |   |   |   +--ro direction?
|   |   |   |   |   |   |       te-label-direction
|   |   |   |   |   +--ro flags*

```

```

|                                     path-attribute-flags
+--ro path-properties
+--ro path-metric* [metric-type]
|   +--ro metric-type      identityref
|   +--ro accumulative-value? uint64
+--ro path-affinities-values
|   +--ro path-affinities-value* [usage]
|   +--ro usage            identityref
|   +--ro value?          admin-groups
+--ro path-affinity-names
|   +--ro path-affinity-name* [usage]
|   +--ro usage            identityref
|   +--ro affinity-name* [name]
|   +--ro name             string
+--ro path-srlgs-lists
|   +--ro path-srlgs-list* [usage]
|   +--ro usage            identityref
|   +--ro values*         srlg
+--ro path-srlgs-names
|   +--ro path-srlgs-name* [usage]
|   +--ro usage            identityref
|   +--ro names*          string
+--ro path-route-objects
+--ro path-computed-route-object*
|   [index]
+--ro index
|   uint32
+--ro (type)?
+--:(numbered-node-hop)
|   +--ro numbered-node-hop
|   |   +--ro node-id      te-node-id
|   |   +--ro hop-type?
|   |   |   te-hop-type
+--:(numbered-link-hop)
|   +--ro numbered-link-hop
|   |   +--ro link-tp-id    te-tp-id
|   |   +--ro hop-type?
|   |   |   te-hop-type
|   |   +--ro direction?
|   |   |   te-link-direction
+--:(unnumbered-link-hop)
|   +--ro unnumbered-link-hop
|   |   +--ro link-tp-id    te-tp-id
|   |   +--ro node-id
|   |   |   te-node-id
|   |   +--ro hop-type?
|   |   |   te-hop-type
|   |   +--ro direction?

```

```

| | | | | te-link-direction
| | | | | +---:(as-number)
| | | | | | +---ro as-number-hop
| | | | | | | +---ro as-number
| | | | | | | | inet:as-number
| | | | | | | +---ro hop-type?
| | | | | | | | te-hop-type
| | | | | +---:(label)
| | | | | | +---ro label-hop
| | | | | | | +---ro te-label
| | | | | | | | +---ro (technology)?
| | | | | | | | | +---:(generic)
| | | | | | | | | | +---ro generic?
| | | | | | | | | | rt-types:generalized-la
bel | | | | | | | | | | +---ro direction?
| | | | | | | | | | | te-label-direction
| | | | | | | | | | +---ro shared-resources-tunnels
| | | | | | | | | | | +---ro lsp-shared-resources-tunnel*
| | | | | | | | | | | tunnel-ref
| | | | | +---x tunnel-action
| | | | | | +---w input
| | | | | | | +---w action-type? identityref
| | | | | | | +---ro output
| | | | | | | | +---ro action-result? identityref
| | | | | +---x protection-external-commands
| | | | | | +---w input
| | | | | | | +---w protection-external-command?
| | | | | | | | identityref
| | | | | | | +---w protection-group-ingress-node-id?
| | | | | | | | te-types:te-node-id
| | | | | | | +---w protection-group-egress-node-id?
| | | | | | | | te-types:te-node-id
| | | | | | | +---w path-ref? path-ref
| | | | | | | +---w traffic-type?
| | | | | | | | enumeration
| | | | | | | +---w extra-traffic-tunnel-ref? tunnel-ref
+---rw tunnel-p2mp* [name]
+---rw name string
+---rw identifier? uint16
+---rw description? string
+---ro operational-state? identityref
+---ro lsps-state
+---ro lsp*
| | | | | [source destination tunnel-id lsp-id extended-tunnel-id]
+---ro source
| | | | | | te-types:te-node-id
+---ro destination
| | | | | | te-types:te-node-id

```



```

+---ro tunnel-id                               uint16
+---ro lsp-id                                   uint16
+---ro extended-tunnel-id                      yang:dotted-quad
+---ro operational-state?                      identityref
+---ro path-setup-protocol?                    identityref
+---ro origin-type?                           enumeration
+---ro lsp-resource-status?                    enumeration
+---ro lockout-of-normal?                      boolean
+---ro freeze?                                boolean
+---ro lsp-protection-role?                    enumeration
+---ro lsp-protection-state?                   identityref
+---ro protection-group-ingress-node-id?
|   te-types:te-node-id
+---ro protection-group-egress-node-id?
|   te-types:te-node-id
+---ro lsp-record-route-information
+---ro lsp-record-route-information* [index]
+---ro index                                   uint32
+---ro (type)?
+---:(numbered-node-hop)
|   +---ro numbered-node-hop
|   |   +---ro node-id       te-node-id
|   |   +---ro flags*        path-attribute-flags
+---:(numbered-link-hop)
|   +---ro numbered-link-hop
|   |   +---ro link-tp-id    te-tp-id
|   |   +---ro flags*        path-attribute-flags
+---:(unnumbered-link-hop)
|   +---ro unnumbered-link-hop
|   |   +---ro link-tp-id    te-tp-id
|   |   +---ro node-id?     te-node-id
|   |   +---ro flags*        path-attribute-flags
+---:(label)
+---ro label-hop
+---ro te-label
|   +---ro (technology)?
|   |   +---:(generic)
|   |   |   +---ro generic?
|   |   |   |   rt-types:generalized-label
|   |   +---ro direction?
|   |   |   te-label-direction
|   +---ro flags*           path-attribute-flags

rpcs:
+---x globals-rpc
+---x interfaces-rpc
+---x tunnels-rpc
+---w input

```

```

    +---w tunnel-info
      +---w (type)?
        +---:(tunnel-p2p)
          | +---w p2p-id?      tunnel-ref
          +---:(tunnel-p2mp)
            +---w p2mp-id?    tunnel-p2mp-ref
+--ro output
  +--ro result
    +--ro result?    enumeration

notifications:
  +---n globals-notif
  +---n tunnels-notif

```

5.2. YANG Code

```

<CODE BEGINS> file "ietf-flexi-grid-topology@2020-10-21.yang"
module ietf-flexi-grid-media-channel {
  yang-version 1.1;
  namespace
    "urn:ietf:params:xml:ns:yang:ietf-flexi-grid-media-channel";
  prefix "flexi-grid-media-channel";

  import ietf-te {
    prefix "te";
    revision-date "2019-02-15";
    reference
      "I-D.ietf-teas-yang-te-19: A YANG Data Model for Traffic
      Engineering Tunnels and Interfaces. ";
  }

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

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

  import ietf-te-path-computation {
    prefix "tepc";
    revision-date "2019-03-11";
    reference
      "I-D.ietf-teas-yang-path-computation-05: Yang model
      for requesting Path Computation.";
  }

```

```
}

organization
  "IETF CCAMP Working Group";
contact
  "WG Web:  <http://tools.ietf.org/wg/ccamp/>
  WG List:  <mailto:ccamp@ietf.org>
  Editor:    Jorge E. Lopez de Vergara
             <jorge.lopez_vergara@uam.es>
  Editor:    Daniel Perdices
             <daniel.perdices@naudit.es>
  Editor:    Victor Lopez
             <victor.lopez@nokia.com>
  Editor:    Young Lee
             <younglee.tx@gmail.com>";

description
  "This module defines a model for Flex-grid Media Channel
  Services.
  The model fully conforms to the Network Management
  Datastore Architecture (NMDA).

  Copyright (c) 2021 IETF Trust and the persons
  identified as authors of the code. All rights reserved.
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  without modification, is permitted pursuant to, and subject
  to the license terms contained in, the Simplified BSD License
  set forth in Section 4.c of the IETF Trust's Legal Provisions
  Relating to IETF Documents
  (https://trustee.ietf.org/license-info).
  This version of this YANG module is part of RFC XXXX; see
  the RFC itself for full legal notices.";

revision "2021-02-12" {
  description
    "Initial Revision";
  reference
    "RFC XXXX: YANG data model for Flexi-Grid media-channels";
    // RFC Ed.: replace XXXX with actual RFC number, update date
    // information and remove this note
}

/*
 * Data nodes
 */

augment "/te:te/te:tunnels/te:tunnel" {
  description
```

```
    "Augment with additional parameters required for flexi-grid
    media channel.";
    uses l0-types-ext:l0-tunnel-attributes;
}

/*
 * Augment TE label.
 */

/* Augment label hop of route-object-exclude-always of
   named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/"
    + "te:explicit-route-objects-always/"
    + "te:route-object-exclude-always/te:type/te:label/"
    + "te:label-hop/te:te-label/te:technology" {
    description "Flex-grid label.";
    case flexi-grid {
        uses l0-types:flexi-grid-label-hop;
    }
}

/* Augment label hop of route-object-include-exclude of
   named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/"
    + "te:explicit-route-objects-always/"
    + "te:route-object-include-exclude/te:type/te:label/"
    + "te:label-hop/te:te-label/te:technology" {
    description "Flex-grid label.";
    case flexi-grid {
        uses l0-types:flexi-grid-label-hop;
    }
}

/* Augment label restrictions for the forwarding direction of
   path-in-segment of named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/te:path-in-segment/"
    + "te:label-restrictions/te:label-restriction" {
    description "Flex-grid label.";
    uses l0-types:flexi-grid-label-range-info;
}

/* Augment label restrictions start for the forwarding direction of
   path-in-segment of named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/te:path-in-segment/"
```

```
        + "te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "Flex-grid label.";
    case flexi-grid {
        uses l0-types:flexi-grid-label-start-end;
    }
}

/* Augment label restrictions end for the forwarding direction of
   path-in-segment of named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/te:path-in-segment/"
    + "te:label-restrictions/"
    + "te:label-restriction/te:label-end/"
    + "te:te-label/te:technology" {
    description "Flex-grid label.";
    case flexi-grid {
        uses l0-types:flexi-grid-label-start-end;
    }
}

/* Augment label restrictions for the forwarding direction of
   path-out-segment of named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/te:path-out-segment/"
    + "te:label-restrictions/"
    + "te:label-restriction" {
    description "Flex-grid label.";
    uses l0-types:flexi-grid-label-range-info;
}

/* Augment label restrictions start for the forwarding direction of
   path-out-segment of named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/te:path-out-segment/"
    + "te:label-restrictions/"
    + "te:label-restriction/te:label-start/"
    + "te:te-label/te:technology" {
    description "Flex-grid label.";
    case flexi-grid {
        uses l0-types:flexi-grid-label-start-end;
    }
}

/* Augment label restrictions end for the forwarding direction of
   path-out-segment of named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
```

```
    + "te:named-path-constraint/te:path-out-segment/"
    + "te:label-restrictions/"
    + "te:label-restriction/te:label-end/"
    + "te:te-label/te:technology" {
description "Flex-grid label.";
case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
}
}

/* Augment label hop of route-exclude of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:optimizations/te:algorithm/te:metric/"
    + "te:optimization-metric/te:explicit-route-exclude-objects/"
    + "te:route-object-exclude-object/te:type/te:label/"
    + "te:label-hop/te:te-label/te:technology" {
description "Flex-grid label.";
case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
}
}

/* Augment label hop of route-include of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:optimizations/te:algorithm/te:metric/"
    + "te:optimization-metric/te:explicit-route-include-objects/"
    + "te:route-object-include-object/te:type/te:label/"
    + "te:label-hop/te:te-label/te:technology" {
description "Flex-grid label.";
case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
}
}

/* Augment label hop of route-object-exclude-always of
primary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:explicit-route-objects-always/"
    + "te:route-object-exclude-always/te:type/te:label/"
    + "te:label-hop/te:te-label/te:technology" {
description "Flex-grid label.";
case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
}
}
```

```
/* Augment label hop of route-object-include-exclude of
   primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:explicit-route-objects-always/"
  + "te:route-object-include-exclude/te:type/te:label/"
  + "te:label-hop/te:te-label/te:technology" {
  description "Flex-grid label.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
  }
}

/* Augment label restrictions for the path-in-segment of
   primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:path-in-segment/te:label-restrictions/"
  + "te:label-restriction" {
  description "Flex-grid label.";
  uses l0-types:flexi-grid-label-range-info;
}

/* Augment label restrictions start for the forwarding direction of
   path-in-segment of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:path-in-segment/te:label-restrictions/"
  + "te:label-restriction/te:label-start/"
  + "te:te-label/te:technology" {
  description "Flex-grid label.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
  }
}

/* Augment label restrictions end for the forwarding direction of
   path-in-segment of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:path-in-segment/te:label-restrictions/"
  + "te:label-restriction/te:label-end/"
  + "te:te-label/te:technology" {
  description "Flex-grid label.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
  }
}
```

```
/* Augment label restrictions for the forwarding direction of
   path-out-segment of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:path-out-segment/te:label-restrictions/"
  + "te:label-restriction" {
  description "Flex-grid label.";
  uses l0-types:flexi-grid-label-range-info;
}

/* Augment label restrictions start for the forwarding direction of
   path-out-segment of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:path-out-segment/te:label-restrictions/"
  + "te:label-restriction/te:label-start/"
  + "te:te-label/te:technology" {
  description "Flex-grid label.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
  }
}

/* Augment label restrictions end for the forwarding direction of
   path-out-segment of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:path-out-segment/te:label-restrictions/"
  + "te:label-restriction/te:label-end/"
  + "te:te-label/te:technology" {
  description "Flex-grid label.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
  }
}

/* Augment label hop of path-route of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:computed-paths-properties/"
  + "te:computed-path-properties/te:path-properties/"
  + "te:path-route-objects/te:path-computed-route-object/"
  + "te:type/te:label/"
  + "te:label-hop/te:te-label/te:technology" {
  description "Flex-grid label.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
  }
}
```



```
}

/* Augment label hop of record-route of primary LSP */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:lsps/te:lsp/te:lsp-record-route-information/"
  + "te:lsp-record-route-information/te:type/te:label/"
  + "te:label-hop/te:te-label/te:technology" {
  description "Flex-grid label.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
  }
}

/* Augment label hop of path-route of primary LSP */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:lsps/te:lsp/te:path-properties/"
  + "te:path-route-objects/te:path-computed-route-object/"
  + "te:type/te:label/"
  + "te:label-hop/te:te-label/te:technology" {
  description "Flex-grid label.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
  }
}

/* Augment label hop of route-exclude of reverse primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:p2p-primary-reverse-path/"
  + "te:optimizations/te:algorithm/te:metric/"
  + "te:optimization-metric/te:explicit-route-exclude-objects/"
  + "te:route-object-exclude-object/te:type/te:label/"
  + "te:label-hop/te:te-label/te:technology" {
  description "Flex-grid label.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
  }
}

/* Augment label hop of route-include of reverse primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:p2p-primary-reverse-path/"
  + "te:optimizations/te:algorithm/te:metric/"
  + "te:optimization-metric/te:explicit-route-include-objects/"
  + "te:route-object-include-object/te:type/te:label/"
```

```
        + "te:label-hop/te:te-label/te:technology" {
          description "Flex-grid label.";
          case flexi-grid {
            uses l0-types:flexi-grid-label-hop;
          }
        }

/* Augment label hop of route-object-exclude-always of
reverse primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:p2p-primary-reverse-path/"
  + "te:explicit-route-objects-always/"
  + "te:route-object-exclude-always/"
  + "te:type/te:label/"
  + "te:label-hop/te:te-label/te:technology" {
    description "Flex-grid label.";
    case flexi-grid {
      uses l0-types:flexi-grid-label-hop;
    }
  }

/* Augment label hop of route-object-include-exclude of
reverse primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:p2p-primary-reverse-path/"
  + "te:explicit-route-objects-always/"
  + "te:route-object-include-exclude/"
  + "te:type/te:label/"
  + "te:label-hop/te:te-label/te:technology" {
    description "Flex-grid label.";
    case flexi-grid {
      uses l0-types:flexi-grid-label-hop;
    }
  }

/* Augment label restrictions for the forwarding direction of
path-in-segment of reverse primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:p2p-primary-reverse-path/"
  + "te:path-in-segment/te:label-restrictions/"
  + "te:label-restriction" {
    description "Flex-grid label.";
    uses l0-types:flexi-grid-label-range-info;
  }
```

```
/* Augment label restrictions start for the forwarding direction of
   path-in-segment of reverse primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:p2p-primary-reverse-path/"
  + "te:path-in-segment/te:label-restrictions/"
  + "te:label-restriction/te:label-start/"
  + "te:te-label/te:technology" {
  description "Flex-grid label.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
  }
}

/* Augment label restrictions end for the forwarding direction of
   path-in-segment of reverse primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:p2p-primary-reverse-path/"
  + "te:path-in-segment/te:label-restrictions/"
  + "te:label-restriction/te:label-end/"
  + "te:te-label/te:technology" {
  description "Flex-grid label.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
  }
}

/* Augment label restrictions for the forwarding direction of
   path-out-segment of reverse primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:p2p-primary-reverse-path/"
  + "te:path-out-segment/te:label-restrictions/"
  + "te:label-restriction" {
  description "Flex-grid label.";
  uses l0-types:flexi-grid-label-range-info;
}

/* Augment label restrictions start for the forwarding direction of
   path-out-segment of reverse primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:p2p-primary-reverse-path/"
  + "te:path-out-segment/te:label-restrictions/"
  + "te:label-restriction/te:label-start/"
  + "te:te-label/te:technology" {
  description "Flex-grid label.";
```

```
    case flexi-grid {
      uses l0-types:flexi-grid-label-start-end;
    }
  }

  /* Augment label restrictions end for the forwarding direction of
     path-out-segment of reverse primary path */
  augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:p2p-primary-reverse-path/"
    + "te:path-out-segment/te:label-restrictions/"
    + "te:label-restriction/te:label-end/"
    + "te:te-label/te:technology" {
    description "Flex-grid label.";
    case flexi-grid {
      uses l0-types:flexi-grid-label-start-end;
    }
  }

  /* Augment label hop of path-route of reverse primary path */
  augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:p2p-primary-reverse-path/"
    + "te:computed-paths-properties/te:computed-path-properties/"
    + "te:path-properties/te:path-route-objects/"
    + "te:path-computed-route-object/te:type/te:label/"
    + "te:label-hop/te:te-label/te:technology" {
    description "Flex-grid label.";
    case flexi-grid {
      uses l0-types:flexi-grid-label-hop;
    }
  }

  /* Augment label hop of record-route of reverse primary LSP */
  augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:p2p-primary-reverse-path/"
    + "te:lsp/te:lsp/te:lsp-record-route-information/"
    + "te:lsp-record-route-information/te:type/te:label/"
    + "te:label-hop/te:te-label/te:technology" {
    description "Flex-grid label.";
    case flexi-grid {
      uses l0-types:flexi-grid-label-hop;
    }
  }

  /* Augment label hop of path-route of reverse primary LSP */
  augment "/te:te/te:tunnels/te:tunnel/"
```

```
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:p2p-primary-reverse-path/"
    + "te:lsp/te:lsp/te:path-properties/"
    + "te:path-route-objects/te:path-computed-route-object/"
    + "te:type/te:label/"
    + "te:label-hop/te:te-label/te:technology" {
description "Flex-grid label.";
case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
}
}

/* Augment label hop of route-exclude of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:optimizations/te:algorithm/te:metric/"
    + "te:optimization-metric/te:explicit-route-exclude-objects/"
    + "te:route-object-exclude-object/te:type/te:label/"
    + "te:label-hop/te:te-label/te:technology" {
description "Flex-grid label.";
case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
}
}

/* Augment label hop of route-include of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:optimizations/te:algorithm/te:metric/"
    + "te:optimization-metric/te:explicit-route-include-objects/"
    + "te:route-object-include-object/te:type/te:label/"
    + "te:label-hop/te:te-label/te:technology" {
description "Flex-grid label.";
case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
}
}

/* Augment label hop of route-object-exclude-always of
secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:explicit-route-objects-always/"
    + "te:route-object-exclude-always/te:type/te:label/"
    + "te:label-hop/te:te-label/te:technology" {
description "Flex-grid label.";
case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
}
```

```
    }  
  }  
  
  /* Augment label hop of route-object-include-exclude of  
    secondary path */  
  augment "/te:te/te:tunnels/te:tunnel/"  
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"  
    + "te:explicit-route-objects-always/"  
    + "te:route-object-include-exclude/te:type/te:label/"  
    + "te:label-hop/te:te-label/te:technology" {  
    description "Flex-grid label.";  
    case flexi-grid {  
      uses l0-types:flexi-grid-label-hop;  
    }  
  }  
  
  /* Augment label restrictions for the forwarding direction of  
    path-in-segment of secondary path */  
  augment "/te:te/te:tunnels/te:tunnel/"  
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"  
    + "te:path-in-segment/te:label-restrictions/"  
    + "te:label-restriction" {  
    description "Flex-grid label.";  
    uses l0-types:flexi-grid-label-range-info;  
  }  
  
  /* Augment label restrictions start for the forwarding direction of  
    path-in-segment of secondary path */  
  augment "/te:te/te:tunnels/te:tunnel/"  
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"  
    + "te:path-in-segment/te:label-restrictions/"  
    + "te:label-restriction/te:label-start/"  
    + "te:te-label/te:technology" {  
    description "Flex-grid label.";  
    case flexi-grid {  
      uses l0-types:flexi-grid-label-start-end;  
    }  
  }  
  
  /* Augment label restrictions end for the forwarding direction of  
    path-in-segment of secondary path */  
  augment "/te:te/te:tunnels/te:tunnel/"  
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"  
    + "te:path-in-segment/te:label-restrictions/"  
    + "te:label-restriction/te:label-end/"  
    + "te:te-label/te:technology" {  
    description "Flex-grid label.";  
    case flexi-grid {
```

```
        uses l0-types:flexi-grid-label-start-end;
    }
}

/* Augment label restrictions for the forwarding direction of
   path-out-segment of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:path-out-segment/te:label-restrictions/"
    + "te:label-restriction" {
    description "Flex-grid label.";
    uses l0-types:flexi-grid-label-range-info;
}

/* Augment label restrictions start for the forwarding direction of
   path-out-segment of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:path-out-segment/te:label-restrictions/"
    + "te:label-restriction/te:label-start/"
    + "te:te-label/te:technology" {
    description "Flex-grid label.";
    case flexi-grid {
        uses l0-types:flexi-grid-label-start-end;
    }
}

/* Augment label restrictions end for the forwarding direction of
   path-out-segment of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:path-out-segment/te:label-restrictions/"
    + "te:label-restriction/te:label-end/"
    + "te:te-label/te:technology" {
    description "Flex-grid label.";
    case flexi-grid {
        uses l0-types:flexi-grid-label-start-end;
    }
}

/* Augment label hop of path-route of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:computed-paths-properties/"
    + "te:computed-path-properties/"
    + "te:path-properties/te:path-route-objects/"
    + "te:path-computed-route-object/te:type/te:label/"
    + "te:label-hop/te:te-label/te:technology" {
```

```
description "Flex-grid label.";
case flexi-grid {
  uses l0-types:flexi-grid-label-hop;
}
}

/* Augment label hop of record-route of secondary LSP */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-secondary-paths/te:p2p-secondary-path/"
  + "te:lsps/te:lsp/te:lsp-record-route-information/"
  + "te:lsp-record-route-information/te:type/te:label/"
  + "te:label-hop/te:te-label/te:technology" {
  description "Flex-grid label.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
  }
}

/* Augment label hop of path-route of secondary LSP */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-secondary-paths/te:p2p-secondary-path/"
  + "te:lsps/te:lsp/te:path-properties/"
  + "te:path-route-objects/"
  + "te:path-computed-route-object/te:type/te:label/"
  + "te:label-hop/te:te-label/te:technology" {
  description "Flex-grid label.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
  }
}

/* Augment label hop of record-route of LSP */
augment "/te:te/te:lsps-state/"
  + "te:lsp/te:lsp-record-route-information/"
  + "te:lsp-record-route-information/te:type/te:label/"
  + "te:label-hop/te:te-label/te:technology" {
  description "Flex-grid label.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
  }
}

augment "/te:tunnels-rpc/te:input/te:tunnel-info/"
  + "tepc:path-request" {
  description
    "Augment with additional constraints flexi-grid
    media channel.";
  uses l0-types-ext:l0-tunnel-attributes;
}
```



```
    uses 10-types-ext:10-path-constraints;
  }
}
<CODE ENDS>
```

6. 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] or RESTCONF [RFC8040]. 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.

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

- o /te:te/te:tunnels/te:tunnel
- o /te:te/.../te:te-bandwidth/te:technology
- o /te:te/.../te:type/te:label/te:label-hop/te:te-label/te:technology
- o /te:te/.../te:label-restrictions/te:label-restriction/te:label-start/te:te-label/te:technology
- o /te:te/.../te:label-restrictions/te:label-restriction/te:label-end/te:te-label/te:technology
- o /te:te/.../te:label-restrictions/te:label-restriction/

Editors note: we are using simplified description by folding similar branches to avoid repetition.

7. IANA Considerations

To be discussed.

8. Contributors

This work was developed by several additional people, who due to frontpage author restrictions, are listed below:

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10. References

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A YANG Data Model for Flexi-Grid Optical Networks
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Abstract

This document defines a YANG module for managing flexi-grid optical networks. The model defined in this document specifies a flexi-grid traffic engineering database that is used to describe the topology of a flexi-grid network. It is based on and augments existing YANG models that describe network and traffic engineering topologies.

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

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1. Introduction

The flexible grid (flexi-grid) optical network technology defined by the International Telecommunication Union Telecommunication Standardization Sector (ITU-T) and documented in Recommendation G.694.1 [G.694.1] and G.872 [G.872] provides an enhanced Dense Wavelength Division Multiplexing (DWDM) grid by defining a set of nominal central frequencies, slot widths, and the concept of the "frequency slot". This technology increases both transport network scalability and flexibility, allowing the optimization of bandwidth usage.

[RFC7698] provides a framework for GMPLS-Based control of flexi-grid DWDM networks while [RFC7699] defines generalized labels for the use of GMPLS in flexi-grid networks.

This document presents a YANG data model [RFC7950] for flexi-grid objects in the dynamic optical network, including nodes, transponders and links, as well as how such links interconnect nodes. This model is independent of control plane protocols.

This document identifies the flexi-grid components, parameters and their values, characterizes the features and the performances of the flexi-grid elements. For this, it augments [RFC8795], and imports the generic Layer 0 types and use of "media-channel" defined in [RFC9093].

An application example in Section 4 is also provided to better understand the utility of this YANG model.

A partner document defines a second YANG module that described flexi-grid tunnels, i.e., the paths from source to destination through a number of intermediate nodes [I-D.ietf-ccamp-flexigrid-tunnel-yang].

Impairment-aware traffic engineering topology is described in [I-D.ietf-ccamp-optical-impairment-topology-yang].

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

2. Terminology

Refer to [RFC7698] and [RFC7699] 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].

3. Tree Diagram

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

3.1. 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 Figure 1. It uses prefixes from [RFC9093], [RFC8345], and [RFC8795].

| Prefix | YANG module | Reference |
|----------|--------------------------|-----------|
| 10-types | RFC9093 | [RFCXXXX] |
| flexgt | ietf-flexi-grid-topology | [RFCYYYY] |
| nw | ietf-network | [RFC8345] |
| nt | ietf-network-topology | [RFC8345] |
| tet | ietf-te-topology | [RFC8795] |

Figure 1: Prefixes and Corresponding YANG modules

RFC Editor Note: Please replace XXXX with the RFC numbers assigned to [RFC9093]. Please replace YYYY with the RFC number assigned to this document. Please remove this note.

4. Example of Use

In order to explain how this model is used, we provide the following example. An optical network usually has multiple transponders, switches (nodes) and links. Figure 1 shows a simple topology.

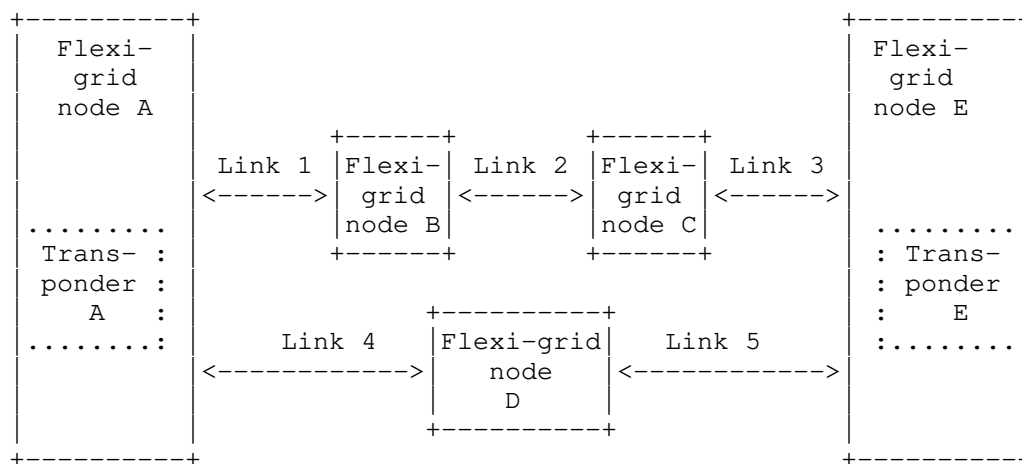


Figure 2: Topology Example

In order to configure a network media channel to interconnect transponders A and E, first of all we have to populate the flexi-grid topology YANG model with all elements in the network:

- * We define the transponders within nodes A and E as tunnel termination points (TTPs) and provide their internal local link connectivity towards the node interfaces. We also provide nodes A and B identifiers, addresses and interfaces.
- * We do the same for the nodes B, C and D, providing their identifiers, addresses and interfaces, as well as the internal connectivity matrix between interfaces.
- * Then, we also define the links 1 to 5 that interconnect nodes, indicating which flexi-grid labels are available.
- * Other information, such as the slot frequency and granularity are also provided.

5. YANG Data Model for Flexi-Grid Topology

5.1. Flexi-Grid Topology Data Model Overview

This document aims to describe the data model for Flexi-Grid topology. As a classic Traffic-engineering (TE) technology, Flexi-Grid provide WDM switching in transport network. Therefore the YANG module presented in this document augments from a more generic Traffic Engineered (TE) network topology data model, i.e., the ietf-te-topology, as specified in [RFC8795], following the guidelines provided in section 6 of [RFC8795].

Common types, identities and groupings defined in [RFC9093] are reused in this document.

The figure below shows the augmentation relationship between YANG models.



Figure 3: Relationship between Flexi-Grid and TE topology models

The entities and TE attributes, such as node, termination points and links, are still applicable for describing an Flexi-Grid topology and the model presented in this document only specifies with technology-specific attributes/information.

The Flexi-Grid specific attributes in [RFC7699], including the grid type, channel spacing, slot width granularity, n and m parameters, can be used to represent the label information. These attributes have been specified in [RFC9093], and used in this document for augmentation of the generic TE topology model.

The YANG module ietf-flexi-grid-topology defined in this document conforms to the Network Management Datastore Architecture (NMDA) defined in [RFC8342].

5.2. Attributes Augmentation

There are a few characteristics augmenting to the generic TE topology.

Following the guidelines in [RFC8795], a flexi-grid-topology network-type is specified as the indicator of Flexi-Grid in the topology as follows.

```
augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
  +--rw flexi-grid-topology!
```

Figure 4: Flexi-Grid Topology Augmentation

A flexi-grid-node presence container is specified, augmenting the generic TE node attributes, to indicate that the TE node is a Flexi-Grid node

```
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:te-node-attributes:
    +--rw flexi-grid-node!
```

Figure 5: Flex-Grid Node Augmentation

It is assumed that all the Flexi-Grid nodes are reconfigurable.

5.3. Bandwidth Augmentation

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

The flexi-grid label resource information described in section 5.4, is sufficient to describe also the spectrum resources within a flexi-grid network. Therefore, the model does not define any augmentation for the te-bandwidth containers defined in [RFC8795].

5.4. Label Augmentation

The model augments all the occurrences of the label-restriction list with flexi-grid technology specific attributes using the flexi-grid-label-range-info grouping defined in [RFC9093].

Moreover, following the guidelines in [RFC8795], the model augments all the occurrences of the te-label container with the flexi-Grid technology specific attributes using the flexi-grid-label-start-end, flexi-grid-label-hop and flexi-grid-label-step groupings defined in [RFC9093].

6. YANG Model (Tree Structure) for Flexi-Grid Topology

```

module: ietf-flexi-grid-topology
  augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
    +--rw flexi-grid-topology!
  augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes:
    +--rw flexi-grid-node!
  augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
    /tet:label-restrictions/tet:label-restriction:
    +--rw grid-type?      identityref
    +--rw priority?       uint8
    +--rw flexi-grid
      +--rw slot-width-granularity?  identityref
      +--rw min-slot-width-factor?   uint16
      +--rw max-slot-width-factor?   uint16
  augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
    /tet:connectivity-matrix/tet:from/tet:label-restrictions
    /tet:label-restriction:
    +--rw grid-type?      identityref
    +--rw priority?       uint8
    +--rw flexi-grid
      +--rw slot-width-granularity?  identityref
      +--rw min-slot-width-factor?   uint16
      +--rw max-slot-width-factor?   uint16
  augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
    /tet:connectivity-matrix/tet:to/tet:label-restrictions
    /tet:label-restriction:
    +--rw grid-type?      identityref
    +--rw priority?       uint8
    +--rw flexi-grid
      +--rw slot-width-granularity?  identityref
      +--rw min-slot-width-factor?   uint16
      +--rw max-slot-width-factor?   uint16
  augment /nw:networks/nw:network/nw:node/tet:te
    /tet:information-source-entry/tet:connectivity-matrices
    /tet:label-restrictions/tet:label-restriction:
    +--ro grid-type?      identityref
    +--ro priority?       uint8

```

```

+--ro flexi-grid
  +--ro slot-width-granularity?  identityref
  +--ro min-slot-width-factor?    uint16
  +--ro max-slot-width-factor?    uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:from/tet:label-restrictions
  /tet:label-restriction:
+--ro grid-type?      identityref
+--ro priority?       uint8
+--ro flexi-grid
  +--ro slot-width-granularity?  identityref
  +--ro min-slot-width-factor?    uint16
  +--ro max-slot-width-factor?    uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:to/tet:label-restrictions
  /tet:label-restriction:
+--ro grid-type?      identityref
+--ro priority?       uint8
+--ro flexi-grid
  +--ro slot-width-granularity?  identityref
  +--ro min-slot-width-factor?    uint16
  +--ro max-slot-width-factor?    uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point
  /tet:local-link-connectivities/tet:label-restrictions
  /tet:label-restriction:
+--rw grid-type?      identityref
+--rw priority?       uint8
+--rw flexi-grid
  +--rw slot-width-granularity?  identityref
  +--rw min-slot-width-factor?    uint16
  +--rw max-slot-width-factor?    uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point
  /tet:local-link-connectivities
  /tet:local-link-connectivity/tet:label-restrictions
  /tet:label-restriction:
+--rw grid-type?      identityref
+--rw priority?       uint8
+--rw flexi-grid
  +--rw slot-width-granularity?  identityref
  +--rw min-slot-width-factor?    uint16
  +--rw max-slot-width-factor?    uint16
augment /nw:networks/nw:network/nt:link/tet:te
  /tet:te-link-attributes/tet:label-restrictions
  /tet:label-restriction:

```

```

+---rw grid-type?      identityref
+---rw priority?       uint8
+---rw flexi-grid
    +---rw slot-width-granularity?  identityref
    +---rw min-slot-width-factor?    uint16
    +---rw max-slot-width-factor?    uint16
augment /nw:networks/nw:network/nt:link/tet:te
    /tet:information-source-entry/tet:label-restrictions
    /tet:label-restriction:
+---ro grid-type?      identityref
+---ro priority?       uint8
+---ro flexi-grid
    +---ro slot-width-granularity?  identityref
    +---ro min-slot-width-factor?    uint16
    +---ro max-slot-width-factor?    uint16
augment /nw:networks/tet:te/tet:templates/tet:link-template
    /tet:te-link-attributes/tet:label-restrictions
    /tet:label-restriction:
+---rw grid-type?      identityref
+---rw priority?       uint8
+---rw flexi-grid
    +---rw slot-width-granularity?  identityref
    +---rw min-slot-width-factor?    uint16
    +---rw max-slot-width-factor?    uint16
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
    /tet:label-restrictions/tet:label-restriction
    /tet:label-start/tet:te-label/tet:technology:
+---:(flexi-grid)
    +---rw flexi-n?     10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
    /tet:label-restrictions/tet:label-restriction
    /tet:label-end/tet:te-label/tet:technology:
+---:(flexi-grid)
    +---rw flexi-n?     10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
    /tet:label-restrictions/tet:label-restriction
    /tet:label-step/tet:technology:
+---:(flexi-grid)
    +---rw flexi-grid-channel-spacing?  identityref
    +---rw flexi-n-step?                 uint8
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
    /tet:underlay/tet:primary-path/tet:path-element/tet:type
    /tet:label/tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)

```

```

    +---rw (single-or-super-channel)?
      +---:(single)
        |   +---rw flexi-n?           10-types:flexi-n
        |   +---rw flexi-m?           10-types:flexi-m
      +---:(super)
        +---rw subcarrier-flexi-n* [flexi-n]
        +---rw flexi-n      10-types:flexi-n
        +---rw flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:te-node-attributes/tet:connectivity-matrices
  /tet:underlay/tet:backup-path/tet:path-element/tet:type
  /tet:label/tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
  +---rw (single-or-super-channel)?
    +---:(single)
      |   +---rw flexi-n?           10-types:flexi-n
      |   +---rw flexi-m?           10-types:flexi-m
    +---:(super)
      +---rw subcarrier-flexi-n* [flexi-n]
      +---rw flexi-n      10-types:flexi-n
      +---rw flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:te-node-attributes/tet:connectivity-matrices
  /tet:optimizations/tet:algorithm/tet:metric
  /tet:optimization-metric
  /tet:explicit-route-exclude-objects
  /tet:route-object-exclude-object/tet:type/tet:label
  /tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
  +---rw (single-or-super-channel)?
    +---:(single)
      |   +---rw flexi-n?           10-types:flexi-n
      |   +---rw flexi-m?           10-types:flexi-m
    +---:(super)
      +---rw subcarrier-flexi-n* [flexi-n]
      +---rw flexi-n      10-types:flexi-n
      +---rw flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:te-node-attributes/tet:connectivity-matrices
  /tet:optimizations/tet:algorithm/tet:metric
  /tet:optimization-metric
  /tet:explicit-route-include-objects
  /tet:route-object-include-object/tet:type/tet:label
  /tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
  +---rw (single-or-super-channel)?
    +---:(single)
      |   +---rw flexi-n?           10-types:flexi-n

```

```

    |   +---rw flexi-m?           10-types:flexi-m
    +---:(super)
        +---rw subcarrier-flexi-n* [flexi-n]
            +---rw flexi-n       10-types:flexi-n
            +---rw flexi-m?      10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
    /tet:path-properties/tet:path-route-objects
    /tet:path-route-object/tet:type/tet:label/tet:label-hop
    /tet:te-label/tet:technology:
+---:(flexi-grid)
    +---ro (single-or-super-channel)?
        +---:(single)
            |   +---ro flexi-n?           10-types:flexi-n
            |   +---ro flexi-m?           10-types:flexi-m
        +---:(super)
            +---ro subcarrier-flexi-n* [flexi-n]
            +---ro flexi-n       10-types:flexi-n
            +---ro flexi-m?      10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
    /tet:connectivity-matrix/tet:from/tet:label-restrictions
    /tet:label-restriction/tet:label-start/tet:te-label
    /tet:technology:
+---:(flexi-grid)
    +---rw flexi-n?      10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
    /tet:connectivity-matrix/tet:from/tet:label-restrictions
    /tet:label-restriction/tet:label-end/tet:te-label
    /tet:technology:
+---:(flexi-grid)
    +---rw flexi-n?      10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
    /tet:connectivity-matrix/tet:from/tet:label-restrictions
    /tet:label-restriction/tet:label-step/tet:technology:
+---:(flexi-grid)
    +---rw flexi-grid-channel-spacing?  identityref
    +---rw flexi-n-step?                uint8
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
    /tet:connectivity-matrix/tet:to/tet:label-restrictions
    /tet:label-restriction/tet:label-start/tet:te-label
    /tet:technology:
+---:(flexi-grid)
    +---rw flexi-n?      10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te

```



```

        /tet:te-node-attributes/tet:connectivity-matrices
        /tet:connectivity-matrix/tet:to/tet:label-restrictions
        /tet:label-restriction/tet:label-end/tet:te-label
        /tet:technology:
    +---:(flexi-grid)
        +---rw flexi-n?      10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
        /tet:te-node-attributes/tet:connectivity-matrices
        /tet:connectivity-matrix/tet:to/tet:label-restrictions
        /tet:label-restriction/tet:label-step/tet:technology:
    +---:(flexi-grid)
        +---rw flexi-grid-channel-spacing?  identityref
        +---rw flexi-n-step?                uint8
augment /nw:networks/nw:network/nw:node/tet:te
        /tet:te-node-attributes/tet:connectivity-matrices
        /tet:connectivity-matrix/tet:underlay/tet:primary-path
        /tet:path-element/tet:type/tet:label/tet:label-hop
        /tet:te-label/tet:technology:
    +---:(flexi-grid)
        +---rw (single-or-super-channel)?
            +---:(single)
                | +---rw flexi-n?          10-types:flexi-n
                | +---rw flexi-m?          10-types:flexi-m
            +---:(super)
                +---rw subcarrier-flexi-n* [flexi-n]
                +---rw flexi-n      10-types:flexi-n
                +---rw flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
        /tet:te-node-attributes/tet:connectivity-matrices
        /tet:connectivity-matrix/tet:underlay/tet:backup-path
        /tet:path-element/tet:type/tet:label/tet:label-hop
        /tet:te-label/tet:technology:
    +---:(flexi-grid)
        +---rw (single-or-super-channel)?
            +---:(single)
                | +---rw flexi-n?          10-types:flexi-n
                | +---rw flexi-m?          10-types:flexi-m
            +---:(super)
                +---rw subcarrier-flexi-n* [flexi-n]
                +---rw flexi-n      10-types:flexi-n
                +---rw flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
        /tet:te-node-attributes/tet:connectivity-matrices
        /tet:connectivity-matrix/tet:optimizations/tet:algorithm
        /tet:metric/tet:optimization-metric
        /tet:explicit-route-exclude-objects
        /tet:route-object-exclude-object/tet:type/tet:label
        /tet:label-hop/tet:te-label/tet:technology:

```

```

+---:(flexi-grid)
  +---rw (single-or-super-channel)?
    +---:(single)
      |   +---rw flexi-n?           10-types:flexi-n
      |   +---rw flexi-m?           10-types:flexi-m
    +---:(super)
      +---rw subcarrier-flexi-n* [flexi-n]
      +---rw flexi-n      10-types:flexi-n
      +---rw flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:te-node-attributes/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:optimizations/tet:algorithm
  /tet:metric/tet:optimization-metric
  /tet:explicit-route-include-objects
  /tet:route-object-include-object/tet:type/tet:label
  /tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
  +---rw (single-or-super-channel)?
    +---:(single)
      |   +---rw flexi-n?           10-types:flexi-n
      |   +---rw flexi-m?           10-types:flexi-m
    +---:(super)
      +---rw subcarrier-flexi-n* [flexi-n]
      +---rw flexi-n      10-types:flexi-n
      +---rw flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:te-node-attributes/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:path-properties
  /tet:path-route-objects/tet:path-route-object/tet:type
  /tet:label/tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
  +---ro (single-or-super-channel)?
    +---:(single)
      |   +---ro flexi-n?           10-types:flexi-n
      |   +---ro flexi-m?           10-types:flexi-m
    +---:(super)
      +---ro subcarrier-flexi-n* [flexi-n]
      +---ro flexi-n      10-types:flexi-n
      +---ro flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:label-restrictions/tet:label-restriction
  /tet:label-start/tet:te-label/tet:technology:
+---:(flexi-grid)
  +---ro flexi-n?     10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:label-restrictions/tet:label-restriction

```

```

        /tet:label-end/tet:te-label/tet:technology:
+---:(flexi-grid)
  +---ro flexi-n?    10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:label-restrictions/tet:label-restriction
  /tet:label-step/tet:technology:
+---:(flexi-grid)
  +---ro flexi-grid-channel-spacing?  identityref
  +---ro flexi-n-step?                uint8
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:underlay/tet:primary-path/tet:path-element/tet:type
  /tet:label/tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
  +---ro (single-or-super-channel)?
    +---:(single)
      | +---ro flexi-n?                10-types:flexi-n
      | +---ro flexi-m?                10-types:flexi-m
    +---:(super)
      +---ro subcarrier-flexi-n* [flexi-n]
      +---ro flexi-n    10-types:flexi-n
      +---ro flexi-m?   10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:underlay/tet:backup-path/tet:path-element/tet:type
  /tet:label/tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
  +---ro (single-or-super-channel)?
    +---:(single)
      | +---ro flexi-n?                10-types:flexi-n
      | +---ro flexi-m?                10-types:flexi-m
    +---:(super)
      +---ro subcarrier-flexi-n* [flexi-n]
      +---ro flexi-n    10-types:flexi-n
      +---ro flexi-m?   10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:optimizations/tet:algorithm/tet:metric
  /tet:optimization-metric
  /tet:explicit-route-exclude-objects
  /tet:route-object-exclude-object/tet:type/tet:label
  /tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
  +---ro (single-or-super-channel)?
    +---:(single)
      | +---ro flexi-n?                10-types:flexi-n
      | +---ro flexi-m?                10-types:flexi-m

```

```

    +---:(super)
      +---ro subcarrier-flexi-n* [flexi-n]
      +---ro flexi-n      10-types:flexi-n
      +---ro flexi-m?    10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:optimizations/tet:algorithm/tet:metric
  /tet:optimization-metric
  /tet:explicit-route-include-objects
  /tet:route-object-include-object/tet:type/tet:label
  /tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
  +---ro (single-or-super-channel)?
    +---:(single)
    |   +---ro flexi-n?          10-types:flexi-n
    |   +---ro flexi-m?          10-types:flexi-m
    +---:(super)
      +---ro subcarrier-flexi-n* [flexi-n]
      +---ro flexi-n      10-types:flexi-n
      +---ro flexi-m?    10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:path-properties/tet:path-route-objects
  /tet:path-route-object/tet:type/tet:label/tet:label-hop
  /tet:te-label/tet:technology:
+---:(flexi-grid)
  +---ro (single-or-super-channel)?
    +---:(single)
    |   +---ro flexi-n?          10-types:flexi-n
    |   +---ro flexi-m?          10-types:flexi-m
    +---:(super)
      +---ro subcarrier-flexi-n* [flexi-n]
      +---ro flexi-n      10-types:flexi-n
      +---ro flexi-m?    10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:from/tet:label-restrictions
  /tet:label-restriction/tet:label-start/tet:te-label
  /tet:technology:
+---:(flexi-grid)
  +---ro flexi-n?    10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:from/tet:label-restrictions
  /tet:label-restriction/tet:label-end/tet:te-label
  /tet:technology:
+---:(flexi-grid)
  +---ro flexi-n?    10-types:flexi-n

```

```

augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:from/tet:label-restrictions
  /tet:label-restriction/tet:label-step/tet:technology:
  +---:(flexi-grid)
    +---ro flexi-grid-channel-spacing?  identityref
    +---ro flexi-n-step?                uint8
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:to/tet:label-restrictions
  /tet:label-restriction/tet:label-start/tet:te-label
  /tet:technology:
  +---:(flexi-grid)
    +---ro flexi-n?  10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:to/tet:label-restrictions
  /tet:label-restriction/tet:label-end/tet:te-label
  /tet:technology:
  +---:(flexi-grid)
    +---ro flexi-n?  10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:to/tet:label-restrictions
  /tet:label-restriction/tet:label-step/tet:technology:
  +---:(flexi-grid)
    +---ro flexi-grid-channel-spacing?  identityref
    +---ro flexi-n-step?                uint8
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:underlay/tet:primary-path
  /tet:path-element/tet:type/tet:label/tet:label-hop
  /tet:te-label/tet:technology:
  +---:(flexi-grid)
    +---ro (single-or-super-channel)?
      +---:(single)
        | +---ro flexi-n?                10-types:flexi-n
        | +---ro flexi-m?                10-types:flexi-m
      +---:(super)
        +---ro subcarrier-flexi-n* [flexi-n]
        +---ro flexi-n  10-types:flexi-n
        +---ro flexi-m?  10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:underlay/tet:backup-path
  /tet:path-element/tet:type/tet:label/tet:label-hop
  /tet:te-label/tet:technology:
  +---:(flexi-grid)

```

```

    +---ro (single-or-super-channel)?
      +---:(single)
        |   +---ro flexi-n?           10-types:flexi-n
        |   +---ro flexi-m?           10-types:flexi-m
      +---:(super)
        +---ro subcarrier-flexi-n* [flexi-n]
        +---ro flexi-n      10-types:flexi-n
        +---ro flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:optimizations/tet:algorithm
  /tet:metric/tet:optimization-metric
  /tet:explicit-route-exclude-objects
  /tet:route-object-exclude-object/tet:type/tet:label
  /tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
  +---ro (single-or-super-channel)?
    +---:(single)
      |   +---ro flexi-n?           10-types:flexi-n
      |   +---ro flexi-m?           10-types:flexi-m
    +---:(super)
      +---ro subcarrier-flexi-n* [flexi-n]
      +---ro flexi-n      10-types:flexi-n
      +---ro flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:optimizations/tet:algorithm
  /tet:metric/tet:optimization-metric
  /tet:explicit-route-include-objects
  /tet:route-object-include-object/tet:type/tet:label
  /tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
  +---ro (single-or-super-channel)?
    +---:(single)
      |   +---ro flexi-n?           10-types:flexi-n
      |   +---ro flexi-m?           10-types:flexi-m
    +---:(super)
      +---ro subcarrier-flexi-n* [flexi-n]
      +---ro flexi-n      10-types:flexi-n
      +---ro flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:path-properties
  /tet:path-route-objects/tet:path-route-object/tet:type
  /tet:label/tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
  +---ro (single-or-super-channel)?
    +---:(single)

```

```

    |   +---ro flexi-n?           10-types:flexi-n
    |   +---ro flexi-m?           10-types:flexi-m
    +---:(super)
        +---ro subcarrier-flexi-n* [flexi-n]
            +---ro flexi-n      10-types:flexi-n
            +---ro flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point
    /tet:local-link-connectivities/tet:label-restrictions
    /tet:label-restriction/tet:label-start/tet:te-label
    /tet:technology:
    +---:(flexi-grid)
        +---rw flexi-n?      10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point
    /tet:local-link-connectivities/tet:label-restrictions
    /tet:label-restriction/tet:label-end/tet:te-label
    /tet:technology:
    +---:(flexi-grid)
        +---rw flexi-n?      10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point
    /tet:local-link-connectivities/tet:label-restrictions
    /tet:label-restriction/tet:label-step/tet:technology:
    +---:(flexi-grid)
        +---rw flexi-grid-channel-spacing?  identityref
        +---rw flexi-n-step?                uint8
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point
    /tet:local-link-connectivities/tet:underlay
    /tet:primary-path/tet:path-element/tet:type/tet:label
    /tet:label-hop/tet:te-label/tet:technology:
    +---:(flexi-grid)
        +---rw (single-or-super-channel)?
        +---:(single)
            |   +---rw flexi-n?           10-types:flexi-n
            |   +---rw flexi-m?           10-types:flexi-m
            +---:(super)
                +---rw subcarrier-flexi-n* [flexi-n]
                    +---rw flexi-n      10-types:flexi-n
                    +---rw flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point
    /tet:local-link-connectivities/tet:underlay
    /tet:backup-path/tet:path-element/tet:type/tet:label
    /tet:label-hop/tet:te-label/tet:technology:
    +---:(flexi-grid)
        +---rw (single-or-super-channel)?

```

```

    +---:(single)
    |   +---rw flexi-n?           10-types:flexi-n
    |   +---rw flexi-m?           10-types:flexi-m
    +---:(super)
        +---rw subcarrier-flexi-n* [flexi-n]
        +---rw flexi-n           10-types:flexi-n
        +---rw flexi-m?          10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point
    /tet:local-link-connectivities/tet:optimizations
    /tet:algorithm/tet:metric/tet:optimization-metric
    /tet:explicit-route-exclude-objects
    /tet:route-object-exclude-object/tet:type/tet:label
    /tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
+---rw (single-or-super-channel)?
+---:(single)
|   +---rw flexi-n?           10-types:flexi-n
|   +---rw flexi-m?           10-types:flexi-m
+---:(super)
    +---rw subcarrier-flexi-n* [flexi-n]
    +---rw flexi-n           10-types:flexi-n
    +---rw flexi-m?          10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point
    /tet:local-link-connectivities/tet:optimizations
    /tet:algorithm/tet:metric/tet:optimization-metric
    /tet:explicit-route-include-objects
    /tet:route-object-include-object/tet:type/tet:label
    /tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
+---rw (single-or-super-channel)?
+---:(single)
|   +---rw flexi-n?           10-types:flexi-n
|   +---rw flexi-m?           10-types:flexi-m
+---:(super)
    +---rw subcarrier-flexi-n* [flexi-n]
    +---rw flexi-n           10-types:flexi-n
    +---rw flexi-m?          10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point
    /tet:local-link-connectivities/tet:path-properties
    /tet:path-route-objects/tet:path-route-object/tet:type
    /tet:label/tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
+---ro (single-or-super-channel)?
+---:(single)
|   +---ro flexi-n?           10-types:flexi-n

```



```

    |   +---ro flexi-m?           10-types:flexi-m
    +---:(super)
        +---ro subcarrier-flexi-n* [flexi-n]
            +---ro flexi-n      10-types:flexi-n
            +---ro flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point
    /tet:local-link-connectivities
    /tet:local-link-connectivity/tet:label-restrictions
    /tet:label-restriction/tet:label-start/tet:te-label
    /tet:technology:
+---:(flexi-grid)
    +---rw flexi-n?      10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point
    /tet:local-link-connectivities
    /tet:local-link-connectivity/tet:label-restrictions
    /tet:label-restriction/tet:label-end/tet:te-label
    /tet:technology:
+---:(flexi-grid)
    +---rw flexi-n?      10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point
    /tet:local-link-connectivities
    /tet:local-link-connectivity/tet:label-restrictions
    /tet:label-restriction/tet:label-step/tet:technology:
+---:(flexi-grid)
    +---rw flexi-grid-channel-spacing?  identityref
    +---rw flexi-n-step?                uint8
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point
    /tet:local-link-connectivities
    /tet:local-link-connectivity/tet:underlay
    /tet:primary-path/tet:path-element/tet:type/tet:label
    /tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
    +---rw (single-or-super-channel)?
        +---:(single)
            |   +---rw flexi-n?           10-types:flexi-n
            |   +---rw flexi-m?           10-types:flexi-m
        +---:(super)
            +---rw subcarrier-flexi-n* [flexi-n]
                +---rw flexi-n      10-types:flexi-n
                +---rw flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point
    /tet:local-link-connectivities
    /tet:local-link-connectivity/tet:underlay/tet:backup-path

```

```

        /tet:path-element/tet:type/tet:label/tet:label-hop
        /tet:te-label/tet:technology:
+---:(flexi-grid)
+---rw (single-or-super-channel)?
+---:(single)
|   +---rw flexi-n?           10-types:flexi-n
|   +---rw flexi-m?           10-types:flexi-m
+---:(super)
+---rw subcarrier-flexi-n* [flexi-n]
+---rw flexi-n      10-types:flexi-n
+---rw flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
        /tet:tunnel-termination-point
        /tet:local-link-connectivities
        /tet:local-link-connectivity/tet:optimizations
        /tet:algorithm/tet:metric/tet:optimization-metric
        /tet:explicit-route-exclude-objects
        /tet:route-object-exclude-object/tet:type/tet:label
        /tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
+---rw (single-or-super-channel)?
+---:(single)
|   +---rw flexi-n?           10-types:flexi-n
|   +---rw flexi-m?           10-types:flexi-m
+---:(super)
+---rw subcarrier-flexi-n* [flexi-n]
+---rw flexi-n      10-types:flexi-n
+---rw flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
        /tet:tunnel-termination-point
        /tet:local-link-connectivities
        /tet:local-link-connectivity/tet:optimizations
        /tet:algorithm/tet:metric/tet:optimization-metric
        /tet:explicit-route-include-objects
        /tet:route-object-include-object/tet:type/tet:label
        /tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
+---rw (single-or-super-channel)?
+---:(single)
|   +---rw flexi-n?           10-types:flexi-n
|   +---rw flexi-m?           10-types:flexi-m
+---:(super)
+---rw subcarrier-flexi-n* [flexi-n]
+---rw flexi-n      10-types:flexi-n
+---rw flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
        /tet:tunnel-termination-point
        /tet:local-link-connectivities

```

```

        /tet:local-link-connectivity/tet:path-properties
        /tet:path-route-objects/tet:path-route-object/tet:type
        /tet:label/tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
+---ro (single-or-super-channel)?
+---:(single)
|   +---ro flexi-n?           10-types:flexi-n
|   +---ro flexi-m?           10-types:flexi-m
+---:(super)
+---ro subcarrier-flexi-n* [flexi-n]
+---ro flexi-n      10-types:flexi-n
+---ro flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nt:link/tet:te
        /tet:te-link-attributes/tet:underlay/tet:primary-path
        /tet:path-element/tet:type/tet:label/tet:label-hop
        /tet:te-label/tet:technology:
+---:(flexi-grid)
+---rw (single-or-super-channel)?
+---:(single)
|   +---rw flexi-n?           10-types:flexi-n
|   +---rw flexi-m?           10-types:flexi-m
+---:(super)
+---rw subcarrier-flexi-n* [flexi-n]
+---rw flexi-n      10-types:flexi-n
+---rw flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nt:link/tet:te
        /tet:te-link-attributes/tet:underlay/tet:backup-path
        /tet:path-element/tet:type/tet:label/tet:label-hop
        /tet:te-label/tet:technology:
+---:(flexi-grid)
+---rw (single-or-super-channel)?
+---:(single)
|   +---rw flexi-n?           10-types:flexi-n
|   +---rw flexi-m?           10-types:flexi-m
+---:(super)
+---rw subcarrier-flexi-n* [flexi-n]
+---rw flexi-n      10-types:flexi-n
+---rw flexi-m?     10-types:flexi-m
augment /nw:networks/nw:network/nt:link/tet:te
        /tet:te-link-attributes/tet:label-restrictions
        /tet:label-restriction/tet:label-start/tet:te-label
        /tet:technology:
+---:(flexi-grid)
+---rw flexi-n?     10-types:flexi-n
augment /nw:networks/nw:network/nt:link/tet:te
        /tet:te-link-attributes/tet:label-restrictions
        /tet:label-restriction/tet:label-end/tet:te-label
        /tet:technology:

```

```

    +---:(flexi-grid)
      +---rw flexi-n?    10-types:flexi-n
augment /nw:networks/nw:network/nt:link/tet:te
      /tet:te-link-attributes/tet:label-restrictions
      /tet:label-restriction/tet:label-step/tet:technology:
    +---:(flexi-grid)
      +---rw flexi-grid-channel-spacing?  identityref
      +---rw flexi-n-step?                uint8
augment /nw:networks/nw:network/nt:link/tet:te
      /tet:information-source-entry/tet:label-restrictions
      /tet:label-restriction/tet:label-start/tet:te-label
      /tet:technology:
    +---:(flexi-grid)
      +---ro flexi-n?    10-types:flexi-n
augment /nw:networks/nw:network/nt:link/tet:te
      /tet:information-source-entry/tet:label-restrictions
      /tet:label-restriction/tet:label-end/tet:te-label
      /tet:technology:
    +---:(flexi-grid)
      +---ro flexi-n?    10-types:flexi-n
augment /nw:networks/nw:network/nt:link/tet:te
      /tet:information-source-entry/tet:label-restrictions
      /tet:label-restriction/tet:label-step/tet:technology:
    +---:(flexi-grid)
      +---ro flexi-grid-channel-spacing?  identityref
      +---ro flexi-n-step?                uint8
augment /nw:networks/tet:te/tet:templates/tet:link-template
      /tet:te-link-attributes/tet:underlay/tet:primary-path
      /tet:path-element/tet:type/tet:label/tet:label-hop
      /tet:te-label/tet:technology:
    +---:(flexi-grid)
      +---rw (single-or-super-channel)?
        +---:(single)
          | +---rw flexi-n?                10-types:flexi-n
          | +---rw flexi-m?                10-types:flexi-m
        +---:(super)
          +---rw subcarrier-flexi-n* [flexi-n]
          +---rw flexi-n    10-types:flexi-n
          +---rw flexi-m?   10-types:flexi-m
augment /nw:networks/tet:te/tet:templates/tet:link-template
      /tet:te-link-attributes/tet:underlay/tet:backup-path
      /tet:path-element/tet:type/tet:label/tet:label-hop
      /tet:te-label/tet:technology:
    +---:(flexi-grid)
      +---rw (single-or-super-channel)?
        +---:(single)
          | +---rw flexi-n?                10-types:flexi-n
          | +---rw flexi-m?                10-types:flexi-m

```

```

    +---:(super)
      +---rw subcarrier-flexi-n* [flexi-n]
        +---rw flexi-n    10-types:flexi-n
        +---rw flexi-m?   10-types:flexi-m
augment /nw:networks/tet:te/tet:templates/tet:link-template
  /tet:te-link-attributes/tet:label-restrictions
  /tet:label-restriction/tet:label-start/tet:te-label
  /tet:technology:
+---:(flexi-grid)
  +---rw flexi-n?   10-types:flexi-n
augment /nw:networks/tet:te/tet:templates/tet:link-template
  /tet:te-link-attributes/tet:label-restrictions
  /tet:label-restriction/tet:label-end/tet:te-label
  /tet:technology:
+---:(flexi-grid)
  +---rw flexi-n?   10-types:flexi-n
augment /nw:networks/tet:te/tet:templates/tet:link-template
  /tet:te-link-attributes/tet:label-restrictions
  /tet:label-restriction/tet:label-step/tet:technology:
+---:(flexi-grid)
  +---rw flexi-grid-channel-spacing?  identityref
  +---rw flexi-n-step?                uint8

```

7. The YANG Code for Flexi-grid topology

```

<CODE BEGINS> file "ietf-flexi-grid-topology@2021-10-25.yang"
module ietf-flexi-grid-topology {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-flexi-grid-topology";
  prefix "flexgt";

  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-layer0-types {
  prefix "l0-types";
  reference
    "RFC 9093: A YANG Data Model for Layer 0 Types";
}

organization
  "IETF CCAMP Working Group";
contact
  "WG Web: <http://tools.ietf.org/wg/ccamp/>
  WG List: <mailto:ccamp@ietf.org>
  Editor: Jorge E. Lopez de Vergara
    <mailto:jorge.lopez_vergara@uam.es>
  Editor: Daniel Perdices
    <mailto:daniel.perdices@uam.es>
  Editor: Haomian Zheng
    <mailto:zhenghaomian@huawei.com>
  Editor: Daniel King
    <mailto:d.king@lancaster.ac.uk>
  Editor: Young Lee
    <mailto:younglee.tx@gmail.com>";

description
  "This module provides a YANG data model for the routing and
  wavelength assignment (RWA) Traffic Engineering (TE)
  topology in flexi-grid optical networks. The YANG model
  described in this document is a flexi-grid technology-specific
  YANG model augmenting the generic TE topology module
  (ietf-te-topology, RFC 9795) based on the RFC 7698 and 7699.
  Copyright (c) 2020 IETF Trust and the persons identified
  as authors of the code. All rights reserved.
  Redistribution and use in source and binary forms, with
  or without modification, is permitted pursuant to, and
  subject to the license terms contained in, the Simplified
  BSD License set forth in Section 4.c of the IETF Trust's
  Legal Provisions Relating to IETF Documents
  (http://trustee.ietf.org/license-info).
  This version of this YANG module is part of RFC XXXX; see
  the RFC itself for full legal notices.";

revision 2021-09-30 {
  description
    "Initial Version";
  reference
    "RFC XXXX: A YANG Data Model for Flexi-Grid Optical Networks";
```

```
// RFC Ed.: replace XXXX with actual RFC number, update date
// information and remove this note
}

/*
 * Data nodes
 */

augment "/nw:networks/nw:network/nw:network-types"
  + "/tet:te-topology" {
  description
    "Augment network types to define flexi-grid topology type.";
  container flexi-grid-topology {
    presence
      "Its presence identifies the flexi-grid topology type.";
    description
      "Introduce new network type for flexi-grid topology.";
  }
}

augment "/nw:networks/nw:network/nw:node/tet:te"
  + "/tet:te-node-attributes" {
  when "/nw:networks/nw:network/nw:network-types"
    + "/tet:te-topology/flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
      flexi-grid topology type.";
  }
  description "Augment TE node attributes.";
  container flexi-grid-node {
    presence "The TE node is a flexi-grid node.";
    description
      "Introduce new TE node type for flexi-grid node.";
  }
}

/*
 * Augment TE label range information
 */

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:te-node-attributes/tet:connectivity-matrices/"
  + "tet:label-restrictions/tet:label-restriction" {
  when "../.../nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
      flexi-grid topology type.";
  }
}
```

```

}
description
    "Augment TE label range information for the TE node
    connectivity matrices.";
uses l0-types:flexi-grid-label-range-info;
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:te-node-attributes/tet:connectivity-matrices/"
+ "tet:connectivity-matrix/tet:from/"
+ "tet:label-restrictions/tet:label-restriction" {
when "../../../../../../../../../../../nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
    "Augment TE label range information for the source Link
    Termination Point (LTP) of the connectivity matrix entry.";
uses l0-types:flexi-grid-label-range-info;
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:te-node-attributes/tet:connectivity-matrices/"
+ "tet:connectivity-matrix/tet:to/"
+ "tet:label-restrictions/tet:label-restriction" {
when "../../../../../../../../../../../nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
    "Augment TE label range information for the destination LTP
    of the connectivity matrix entry.";
uses l0-types:flexi-grid-label-range-info;
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:information-source-entry/"
+ "tet:connectivity-matrices/tet:label-restrictions/"
+ "tet:label-restriction" {
when "../../../../../../../../../../../nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}

```



```

description
    "Augment TE label range information for the TE node
        connectivity matrices information source.";
uses l0-types:flexi-grid-label-range-info;
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:information-source-entry/tet:connectivity-matrices/"
+ "tet:connectivity-matrix/"
+ "tet:from/tet:label-restrictions/tet:label-restriction" {
when "../.../../.../../.../../.../../nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
        flexi-grid topology type.";
}
description
    "Augment TE label range information for the source LTP
        of the connectivity matrix entry information source.";
uses l0-types:flexi-grid-label-range-info;
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:information-source-entry/tet:connectivity-matrices/"
+ "tet:connectivity-matrix/"
+ "tet:to/tet:label-restrictions/tet:label-restriction" {
when "../.../../.../../.../../.../../nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
        flexi-grid topology type.";
}
description
    "Augment TE label range information for the destination LTP
        of the connectivity matrix entry information source.";
uses l0-types:flexi-grid-label-range-info;
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:tunnel-termination-point/"
+ "tet:local-link-connectivities/"
+ "tet:label-restrictions/tet:label-restriction" {
when "../.../../.../../.../../nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
        flexi-grid topology type.";
}

```

```

description
  "Augment TE label range information for the Tunnel
  Termination Point (TTP) Local Link Connectivities.";
  uses l0-types:flexi-grid-label-range-info;
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:tunnel-termination-point/"
+ "tet:local-link-connectivities/"
+ "tet:local-link-connectivity/"
+ "tet:label-restrictions/tet:label-restriction" {
  when "../..../..../..../nw:network-types/tet:te-topology/"
  + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
      flexi-grid topology type.";
  }
  description
    "Augment TE label range information for the TTP
    Local Link Connectivity entry.";
  uses l0-types:flexi-grid-label-range-info;
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
+ "tet:te-link-attributes/"
+ "tet:label-restrictions/tet:label-restriction" {
  when "../..../..../nw:network-types/tet:te-topology/"
  + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
      flexi-grid topology type.";
  }
  description
    "Augment TE label range information for the TE link.";
  uses l0-types:flexi-grid-label-range-info;
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
+ "tet:information-source-entry/"
+ "tet:label-restrictions/tet:label-restriction" {
  when "../..../..../nw:network-types/tet:te-topology/"
  + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
      flexi-grid topology type.";
  }
  description
    "Augment TE label range information for the TE link

```

```

        information source.";
    uses l0-types:flexi-grid-label-range-info;
}

augment "/nw:networks/tet:te/tet:templates/"
    + "tet:link-template/tet:te-link-attributes/"
    + "tet:label-restrictions/tet:label-restriction" {
    description
        "Augment TE label range information for the TE link template.";
    uses l0-types:flexi-grid-label-range-info;
}

/*
 * Augment TE label
 */

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:label-restrictions/tet:label-restriction/"
    + "tet:label-start/"
    + "tet:te-label/tet:technology" {
    when "../..//../..//../..//../..//nw:network-types/tet:te-topology/"
        + "flexgt:flexi-grid-topology" {
        description
            "Augmentation parameters apply only for networks with
            flexi-grid topology type.";
    }
    description
        "Augment TE label range start for the TE node
        connectivity matrices.";
    case flexi-grid {
        uses l0-types:flexi-grid-label-start-end;
    }
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:label-restrictions/"
    + "tet:label-restriction/tet:label-end/"
    + "tet:te-label/tet:technology" {
    when "../..//../..//../..//../..//nw:network-types/tet:te-topology/"
        + "flexgt:flexi-grid-topology" {
        description
            "Augmentation parameters apply only for networks with
            flexi-grid topology type.";
    }
    description
        "Augment TE label range end for the TE node

```

```

connectivity matrices.";
case flexi-grid {
  uses l0-types:flexi-grid-label-start-end;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:te-node-attributes/tet:connectivity-matrices/"
+ "tet:label-restrictions/"
+ "tet:label-restriction/tet:label-step/"
+ "tet:technology" {
when "../..../..../..../nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
  description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
  "Augment TE label range step for the TE node
  connectivity matrices.";
case flexi-grid {
  uses l0-types:flexi-grid-label-step;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:te-node-attributes/tet:connectivity-matrices/"
+ "tet:underlay/tet:primary-path/tet:path-element/"
+ "tet:type/tet:label/tet:label-hop/"
+ "tet:te-label/tet:technology" {
when "../..../..../..../nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
  description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
  "Augment TE label hop for the underlay primary path of the
  TE node connectivity matrices.";
case flexi-grid {
  uses l0-types:flexi-grid-label-hop;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:te-node-attributes/tet:connectivity-matrices/"
+ "tet:underlay/tet:backup-path/tet:path-element/"

```

```

    + "tet:type/tet:label/tet:label-hop/"
    + "tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../"
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
    "Augment TE label hop for the underlay backup path of the
    TE node connectivity matrices.";
case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:optimizations/tet:algorithm/tet:metric/"
    + "tet:optimization-metric/"
    + "tet:explicit-route-exclude-objects/"
    + "tet:route-object-exclude-object/"
    + "tet:type/tet:label/tet:label-hop/"
    + "tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../"
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
    "Augment TE label hop for the explicit route objects excluded
    by the path computation of the TE node connectivity
    matrices.";
case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:optimizations/tet:algorithm/tet:metric/"
    + "tet:optimization-metric/"
    + "tet:explicit-route-include-objects/"
    + "tet:route-object-include-object/"
    + "tet:type/tet:label/tet:label-hop/"

```

```

    + "tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
    "Augment TE label hop for the explicit route objects included
    by the path computation of the TE node connectivity
    matrices.";
case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:path-properties/tet:path-route-objects/"
    + "tet:path-route-object/tet:type/tet:label/tet:label-hop/"
    + "tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
    "Augment TE label hop for the computed path route objects
    of the TE node connectivity matrices.";
case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/tet:from/"
    + "tet:label-restrictions/tet:label-restriction/"
    + "tet:label-start/"
    + "tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with

```

```

        flexi-grid topology type.";
    }
    description
        "Augment TE label range start for the source LTP
        of the connectivity matrix entry.";
    case flexi-grid {
        uses l0-types:flexi-grid-label-start-end;
    }
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:te-node-attributes/tet:connectivity-matrices/"
+ "tet:connectivity-matrix/tet:from/"
+ "tet:label-restrictions/tet:label-restriction/"
+ "tet:label-end/"
+ "tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../..."
+ "nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
    description
        "Augmentation parameters apply only for networks with
        flexi-grid topology type.";
}
description
    "Augment TE label range end for the source LTP
    of the connectivity matrix entry.";
case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:te-node-attributes/tet:connectivity-matrices/"
+ "tet:connectivity-matrix/tet:from/"
+ "tet:label-restrictions/tet:label-restriction/"
+ "tet:label-step/"
+ "tet:technology" {
when "../.../.../.../.../.../.../.../.../..."
+ "nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
    description
        "Augmentation parameters apply only for networks with
        flexi-grid topology type.";
}
description
    "Augment TE label range step for the source LTP
    of the connectivity matrix entry.";
case flexi-grid {

```

```

    uses l0-types:flexi-grid-label-step;
  }
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:te-node-attributes/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/tet:to/"
  + "tet:label-restrictions/tet:label-restriction/"
  + "tet:label-start/"
  + "tet:te-label/tet:technology" {
  when "../.../.../.../.../.../.../.../.../..."
  + "nw:network-types/tet:te-topology/"
  + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
        flexi-grid topology type.";
  }
  description
    "Augment TE label range start for the destination LTP
      of the connectivity matrix entry.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
  }
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:te-node-attributes/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/tet:to/"
  + "tet:label-restrictions/tet:label-restriction/"
  + "tet:label-end/"
  + "tet:te-label/tet:technology" {
  when "../.../.../.../.../.../.../.../.../..."
  + "nw:network-types/tet:te-topology/"
  + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
        flexi-grid topology type.";
  }
  description
    "Augment TE label range end for the destination LTP
      of the connectivity matrix entry.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
  }
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:te-node-attributes/tet:connectivity-matrices/"

```



```

    + "tet:connectivity-matrix/tet:to/"
    + "tet:label-restrictions/tet:label-restriction/"
    + "tet:label-step/"
    + "tet:technology" {
when "../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
    "Augment TE label range step for the destination LTP
    of the connectivity matrix entry.";
case flexi-grid {
    uses l0-types:flexi-grid-label-step;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/"
    + "tet:underlay/tet:primary-path/tet:path-element/"
    + "tet:type/tet:label/tet:label-hop/"
    + "tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
    "Augment TE label hop for the underlay primary path
    of the connectivity matrix entry.";
case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/"
    + "tet:underlay/tet:backup-path/tet:path-element/"
    + "tet:type/tet:label/tet:label-hop/"
    + "tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"

```

```

    + "flexgt:flexi-grid-topology" {
      description
        "Augmentation parameters apply only for networks with
         flexi-grid topology type.";
    }
  description
    "Augment TE label hop for the underlay backup path
     of the connectivity matrix entry.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
  }
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:te-node-attributes/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/tet:optimizations/"
  + "tet:algorithm/tet:metric/tet:optimization-metric/"
  + "tet:explicit-route-exclude-objects/"
  + "tet:route-object-exclude-object/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
  when "../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
       flexi-grid topology type.";
  }
  description
    "Augment TE label hop for the explicit route objects excluded
     by the path computation of the connectivity matrix entry.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
  }
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:te-node-attributes/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/tet:optimizations/"
  + "tet:algorithm/tet:metric/tet:optimization-metric/"
  + "tet:explicit-route-include-objects/"
  + "tet:route-object-include-object/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
  when "../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
       flexi-grid topology type.";
  }
}

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    }
    description
      "Augment TE label hop for the explicit route objects included
      by the path computation of the connectivity matrix entry.";
    case flexi-grid {
      uses l0-types:flexi-grid-label-hop;
    }
  }

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:te-node-attributes/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/"
  + "tet:path-properties/tet:path-route-objects/"
  + "tet:path-route-object/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
  when "../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
      flexi-grid topology type.";
  }
  description
    "Augment TE label hop for the computed path route objects
    of the connectivity matrix entry.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
  }
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/"
  + "tet:connectivity-matrices/tet:label-restrictions/"
  + "tet:label-restriction/"
  + "tet:label-start/tet:te-label/tet:technology" {
  when "../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
      flexi-grid topology type.";
  }
  description
    "Augment TE label range start for the TE node connectivity
    matrices information source.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
  }
}

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    }

    augment "/nw:networks/nw:network/nw:node/tet:te/"
      + "tet:information-source-entry/"
      + "tet:connectivity-matrices/tet:label-restrictions/"
      + "tet:label-restriction/"
      + "tet:label-end/tet:te-label/tet:technology" {
    when "../.../.../.../.../.../.../.../..."
      + "nw:network-types/tet:te-topology/"
      + "flexgt:flexi-grid-topology" {
      description
        "Augmentation parameters apply only for networks with
        flexi-grid topology type.";
    }
    description
      "Augment TE label range end for the TE node connectivity
      matrices information source.";
    case flexi-grid {
      uses l0-types:flexi-grid-label-start-end;
    }
  }

  augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:information-source-entry/"
    + "tet:connectivity-matrices/tet:label-restrictions/"
    + "tet:label-restriction/"
    + "tet:label-step/tet:technology" {
  when "../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
      flexi-grid topology type.";
  }
  description
    "Augment TE label range step for the TE node connectivity
    matrices information source.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-step;
  }
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:underlay/tet:primary-path/tet:path-element/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
  when "../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"

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    + "flexgt:flexi-grid-topology" {
      description
        "Augmentation parameters apply only for networks with
         flexi-grid topology type.";
    }
  description
    "Augment TE label hop for the underlay primary path
     of the TE node connectivity matrices of the information
     source entry.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
  }
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:underlay/tet:backup-path/tet:path-element/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
  when "../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
       flexi-grid topology type.";
  }
  description
    "Augment TE label hop for the underlay backup path
     of the TE node connectivity matrices of the information
     source entry.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
  }
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:optimizations/tet:algorithm/tet:metric/"
  + "tet:optimization-metric/"
  + "tet:explicit-route-exclude-objects/"
  + "tet:route-object-exclude-object/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
  when "../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
       flexi-grid topology type.";
  }
}

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    description
      "Augment TE label hop for the explicit route objects excluded
      by the path computation of the TE node connectivity matrices
      information source.";
    case flexi-grid {
      uses l0-types:flexi-grid-label-hop;
    }
  }

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:optimizations/tet:algorithm/tet:metric/"
  + "tet:optimization-metric/"
  + "tet:explicit-route-include-objects/"
  + "tet:route-object-include-object/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
  when "../.../.../.../.../.../.../.../..."
  + "nw:network-types/tet:te-topology/"
  + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
      flexi-grid topology type.";
  }
  description
    "Augment TE label hop for the explicit route objects included
    by the path computation of the TE node connectivity matrices
    information source.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
  }
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:path-properties/tet:path-route-objects/"
  + "tet:path-route-object/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
  when "../.../.../.../.../.../.../.../..."
  + "nw:network-types/tet:te-topology/"
  + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
      flexi-grid topology type.";
  }
  description
    "Augment TE label hop for the computed path route objects
    of the TE node connectivity matrices information source.";
  case flexi-grid {

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    uses l0-types:flexi-grid-label-hop;
  }
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/"
  + "tet:from/tet:label-restrictions/"
  + "tet:label-restriction/"
  + "tet:label-start/tet:te-label/tet:technology" {
  when "../.../.../.../.../.../.../.../.../..."
  + "nw:network-types/tet:te-topology/"
  + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
       flexi-grid topology type.";
  }
  description
    "Augment TE label range start for the source LTP
     of the connectivity matrix entry information source.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
  }
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/"
  + "tet:from/tet:label-restrictions/"
  + "tet:label-restriction/"
  + "tet:label-end/tet:te-label/tet:technology" {
  when "../.../.../.../.../.../.../.../.../..."
  + "nw:network-types/tet:te-topology/"
  + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
       flexi-grid topology type.";
  }
  description
    "Augment TE label range end for the source LTP
     of the connectivity matrix entry information source.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
  }
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/"

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    + "tet:from/tet:label-restrictions/"
    + "tet:label-restriction/"
    + "tet:label-step/tet:technology" {
when "../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
    "Augment TE label range step for the source LTP
    of the connectivity matrix entry information source.";
case flexi-grid {
    uses l0-types:flexi-grid-label-step;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:information-source-entry/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/"
    + "tet:to/tet:label-restrictions/tet:label-restriction/"
    + "tet:label-start/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
    "Augment TE label range start for the destination LTP
    of the connectivity matrix entry information source.";
case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:information-source-entry/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/"
    + "tet:to/tet:label-restrictions/tet:label-restriction/"
    + "tet:label-end/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with

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        flexi-grid topology type.";
    }
    description
        "Augment TE label range end for the destination LTP
        of the connectivity matrix entry information source.";
    case flexi-grid {
        uses l0-types:flexi-grid-label-start-end;
    }
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:information-source-entry/tet:connectivity-matrices/"
+ "tet:connectivity-matrix/"
+ "tet:to/tet:label-restrictions/tet:label-restriction/"
+ "tet:label-step/tet:technology" {
when "../.../.../.../.../.../.../.../"
+ "nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
    description
        "Augmentation parameters apply only for networks with
        flexi-grid topology type.";
}
description
    "Augment TE label range step for the destination LTP
    of the connectivity matrix entry information source.";
case flexi-grid {
    uses l0-types:flexi-grid-label-step;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:information-source-entry/tet:connectivity-matrices/"
+ "tet:connectivity-matrix/"
+ "tet:underlay/tet:primary-path/tet:path-element/tet:type/"
+ "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../"
+ "nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
    description
        "Augmentation parameters apply only for networks with
        flexi-grid topology type.";
}
description
    "Augment TE label hop for the underlay primary path
    of the connectivity matrix entry information source.";
case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
}
}

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}

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/"
  + "tet:underlay/tet:backup-path/tet:path-element/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../..."
  + "nw:network-types/tet:te-topology/"
  + "flexgt:flexi-grid-topology" {
  description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
  "Augment TE label hop for the underlay backup path
  of the connectivity matrix entry information source.";
case flexi-grid {
  uses l0-types:flexi-grid-label-hop;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/"
  + "tet:optimizations/tet:algorithm/tet:metric/"
  + "tet:optimization-metric/"
  + "tet:explicit-route-exclude-objects/"
  + "tet:route-object-exclude-object/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../..."
  + "nw:network-types/tet:te-topology/"
  + "flexgt:flexi-grid-topology" {
  description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
  "Augment TE label hop for the explicit route objects excluded
  by the path computation of the connectivity matrix entry
  information source.";
case flexi-grid {
  uses l0-types:flexi-grid-label-hop;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"

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    + "tet:connectivity-matrix/"
    + "tet:optimizations/tet:algorithm/tet:metric/"
    + "tet:optimization-metric/"
    + "tet:explicit-route-include-objects/"
    + "tet:route-object-include-object/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
    "Augment TE label hop for the explicit route objects included
    by the path computation of the connectivity matrix entry
    information source.";
case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:information-source-entry/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/"
    + "tet:path-properties/tet:path-route-objects/"
    + "tet:path-route-object/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
    "Augment TE label hop for the computed path route objects
    of the connectivity matrix entry information source.";
case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:tunnel-termination-point/"
    + "tet:local-link-connectivities/"
    + "tet:label-restrictions/tet:label-restriction/"
    + "tet:label-start/"

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    + "tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
    "Augment TE label range start for the TTP
    Local Link Connectivities.";
case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:tunnel-termination-point/"
    + "tet:local-link-connectivities/"
    + "tet:label-restrictions/tet:label-restriction/"
    + "tet:label-end/"
    + "tet:te-label/tet:technology"{
when "../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
    "Augment TE label range end for the TTP
    Local Link Connectivities.";
case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:tunnel-termination-point/"
    + "tet:local-link-connectivities/"
    + "tet:label-restrictions/tet:label-restriction/"
    + "tet:label-step/"
    + "tet:technology"{
when "../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with

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        flexi-grid topology type.";
    }
    description
        "Augment TE label range step for the TTP
        Local Link Connectivities.";
    case flexi-grid {
        uses l0-types:flexi-grid-label-step;
    }
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:tunnel-termination-point/"
+ "tet:local-link-connectivities/"
+ "tet:underlay/tet:primary-path/tet:path-element/tet:type/"
+ "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../..."
+ "nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
    description
        "Augmentation parameters apply only for networks with
        flexi-grid topology type.";
}
description
    "Augment TE label hop for the underlay primary path
    of the TTP Local Link Connectivities.";
case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:tunnel-termination-point/"
+ "tet:local-link-connectivities/"
+ "tet:underlay/tet:backup-path/tet:path-element/tet:type/"
+ "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../..."
+ "nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
    description
        "Augmentation parameters apply only for networks with
        flexi-grid topology type.";
}
description
    "Augment TE label hop for the underlay backup path
    of the TTP Local Link Connectivities.";
case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
}
}

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}

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:tunnel-termination-point/"
  + "tet:local-link-connectivities/"
  + "tet:optimizations/tet:algorithm/tet:metric/"
  + "tet:optimization-metric/"
  + "tet:explicit-route-exclude-objects/"
  + "tet:route-object-exclude-object/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../..."
  + "nw:network-types/tet:te-topology/"
  + "flexgt:flexi-grid-topology" {
  description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
  "Augment TE label hop for the explicit route objects excluded
  by the path computation of the TTP Local Link
  Connectivities.";
case flexi-grid {
  uses l0-types:flexi-grid-label-hop;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:tunnel-termination-point/"
  + "tet:local-link-connectivities/"
  + "tet:optimizations/tet:algorithm/tet:metric/"
  + "tet:optimization-metric/"
  + "tet:explicit-route-include-objects/"
  + "tet:route-object-include-object/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../..."
  + "nw:network-types/tet:te-topology/"
  + "flexgt:flexi-grid-topology" {
  description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
  "Augment TE label hop for the explicit route objects included
  by the path computation of the TTP Local Link
  Connectivities.";
case flexi-grid {
  uses l0-types:flexi-grid-label-hop;
}
}

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    }

    augment "/nw:networks/nw:network/nw:node/tet:te/"
      + "tet:tunnel-termination-point/"
      + "tet:local-link-connectivities/"
      + "tet:path-properties/tet:path-route-objects/"
      + "tet:path-route-object/tet:type/"
      + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
    when "../.../.../.../.../.../.../.../.../"
      + "nw:network-types/tet:te-topology/"
      + "flexgt:flexi-grid-topology" {
      description
        "Augmentation parameters apply only for networks with
        flexi-grid topology type.";
    }
    description
      "Augment TE label hop for the computed path route objects
      of the TTP Local Link Connectivities.";
    case flexi-grid {
      uses l0-types:flexi-grid-label-hop;
    }
  }

  augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:tunnel-termination-point/"
    + "tet:local-link-connectivities/"
    + "tet:local-link-connectivity/"
    + "tet:label-restrictions/tet:label-restriction/"
    + "tet:label-start/tet:te-label/tet:technology" {
  when "../.../.../.../.../.../.../.../.../"
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
      flexi-grid topology type.";
  }
  description
    "Augment TE label range start for the TTP
    Local Link Connectivity entry.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
  }
}

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

```

```

    + "tet:label-restrictions/tet:label-restriction/"
    + "tet:label-end/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
    "Augment TE label range end for the TTP
    Local Link Connectivity entry.";
case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:tunnel-termination-point/"
    + "tet:local-link-connectivities/"
    + "tet:local-link-connectivity/"
    + "tet:label-restrictions/tet:label-restriction/"
    + "tet:label-step/tet:technology" {
when "../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
    "Augment TE label range step for the TTP
    Local Link Connectivity entry.";
case flexi-grid {
    uses l0-types:flexi-grid-label-step;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:tunnel-termination-point/"
    + "tet:local-link-connectivities/"
    + "tet:local-link-connectivity/"
    + "tet:underlay/tet:primary-path/tet:path-element/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
description

```



```

        "Augmentation parameters apply only for networks with
        flexi-grid topology type.";
    }
    description
        "Augment TE label hop for the underlay primary path
        of the TTP Local Link Connectivity entry.";
    case flexi-grid {
        uses l0-types:flexi-grid-label-hop;
    }
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:tunnel-termination-point/"
+ "tet:local-link-connectivities/"
+ "tet:local-link-connectivity/"
+ "tet:underlay/tet:backup-path/tet:path-element/tet:type/"
+ "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../..."
+ "nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
    description
        "Augmentation parameters apply only for networks with
        flexi-grid topology type.";
}
description
    "Augment TE label hop for the underlay backup path
    of the TTP Local Link Connectivity entry.";
case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:tunnel-termination-point/"
+ "tet:local-link-connectivities/"
+ "tet:local-link-connectivity/"
+ "tet:optimizations/tet:algorithm/tet:metric/"
+ "tet:optimization-metric/"
+ "tet:explicit-route-exclude-objects/"
+ "tet:route-object-exclude-object/tet:type/"
+ "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../..."
+ "nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
    description
        "Augmentation parameters apply only for networks with
        flexi-grid topology type.";
}
}

```

```

    description
      "Augment TE label hop for the explicit route objects excluded
      by the path computation of the TTP Local Link
      Connectivity entry.";
    case flexi-grid {
      uses l0-types:flexi-grid-label-hop;
    }
  }

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:tunnel-termination-point/"
+ "tet:local-link-connectivities/"
+ "tet:local-link-connectivity/"
+ "tet:optimizations/tet:algorithm/tet:metric/"
+ "tet:optimization-metric/"
+ "tet:explicit-route-include-objects/"
+ "tet:route-object-include-object/tet:type/"
+ "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../..."
+ "nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
  description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
  "Augment TE label hop for the explicit route objects included
  by the path computation of the TTP Local Link
  Connectivity entry.";
case flexi-grid {
  uses l0-types:flexi-grid-label-hop;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:tunnel-termination-point/"
+ "tet:local-link-connectivities/"
+ "tet:local-link-connectivity/"
+ "tet:path-properties/tet:path-route-objects/"
+ "tet:path-route-object/tet:type/"
+ "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../..."
+ "nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
  description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
}

```

```
description
  "Augment TE label hop for the computed path route objects
  of the TTP Local Link Connectivity entry.";
case flexi-grid {
  uses l0-types:flexi-grid-label-hop;
}
}
augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:te-link-attributes/"
  + "tet:underlay/tet:primary-path/tet:path-element/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
  when "../../../../../../../../../../../"
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
      flexi-grid topology type.";
  }
  description
    "Augment TE label hop for the underlay primary path
    of the TE link.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
  }
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:te-link-attributes/"
  + "tet:underlay/tet:backup-path/tet:path-element/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
  when "../../../../../../../../../../../"
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
    description
      "Augmentation parameters apply only for networks with
      flexi-grid topology type.";
  }
  description
    "Augment TE label hop for the underlay backup path
    of the TE link.";
  case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
  }
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:te-link-attributes/"
  + "tet:label-restrictions/tet:label-restriction/"
```

```
+ "tet:label-start/tet:te-label/tet:technology" {
when "../../../nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
    "Augment TE label range start for the TE link.";
case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
}
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
+ "tet:te-link-attributes/"
+ "tet:label-restrictions/tet:label-restriction/"
+ "tet:label-end/tet:te-label/tet:technology" {
when "../../../nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
    "Augment TE label range end for the TE link.";
case flexi-grid {
    uses l0-types:flexi-grid-label-start-end;
}
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
+ "tet:te-link-attributes/"
+ "tet:label-restrictions/tet:label-restriction/"
+ "tet:label-step/tet:technology" {
when "../../../nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
    "Augment TE label range step for the TE link.";
case flexi-grid {
    uses l0-types:flexi-grid-label-step;
}
}
```

```

augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:information-source-entry/"
  + "tet:label-restrictions/tet:label-restriction/"
  + "tet:label-start/tet:te-label/tet:technology" {
when "../..../..../..../nw:network-types/tet:te-topology/"
  + "flexgt:flexi-grid-topology" {
description
  "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
  "Augment TE label range start for the TE link
    information source.";
case flexi-grid {
  uses l0-types:flexi-grid-label-start-end;
}
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:information-source-entry/"
  + "tet:label-restrictions/tet:label-restriction/"
  + "tet:label-end/tet:te-label/tet:technology" {
when "../..../..../..../nw:network-types/tet:te-topology/"
  + "flexgt:flexi-grid-topology" {
description
  "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
  "Augment TE label range end for the TE link
    information source.";
case flexi-grid {
  uses l0-types:flexi-grid-label-start-end;
}
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:information-source-entry/"
  + "tet:label-restrictions/tet:label-restriction/"
  + "tet:label-step/tet:technology" {
when "../..../..../..../nw:network-types/tet:te-topology/"
  + "flexgt:flexi-grid-topology" {
description
  "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
description
  "Augment TE label range step for the TE link
    information source.";
}

```

```
        information source.";
    case flexi-grid {
        uses l0-types:flexi-grid-label-step;
    }
}

augment "/nw:networks/tet:te/tet:templates/"
+ "tet:link-template/tet:te-link-attributes/"
+ "tet:underlay/tet:primary-path/tet:path-element/tet:type/"
+ "tet:label/tet:label-hop/tet:te-label/tet:technology" {
    description
        "Augment TE label hop for the underlay primary path
        of the TE link template.";
    case flexi-grid {
        uses l0-types:flexi-grid-label-hop;
    }
}

augment "/nw:networks/tet:te/tet:templates/"
+ "tet:link-template/tet:te-link-attributes/"
+ "tet:underlay/tet:backup-path/tet:path-element/tet:type/"
+ "tet:label/tet:label-hop/tet:te-label/tet:technology" {
    description
        "Augment TE label hop for the underlay backup path
        of the TE link template.";
    case flexi-grid {
        uses l0-types:flexi-grid-label-hop;
    }
}

augment "/nw:networks/tet:te/tet:templates/"
+ "tet:link-template/tet:te-link-attributes/"
+ "tet:label-restrictions/tet:label-restriction/"
+ "tet:label-start/tet:te-label/tet:technology" {
    description
        "Augment TE label range start for the TE link template.";
    case flexi-grid {
        uses l0-types:flexi-grid-label-start-end;
    }
}

augment "/nw:networks/tet:te/tet:templates/"
+ "tet:link-template/tet:te-link-attributes/"
+ "tet:label-restrictions/tet:label-restriction/"
+ "tet:label-end/tet:te-label/tet:technology" {
    description
        "Augment TE label range end for the TE link template.";
    case flexi-grid {
```

```
        uses 10-types:flexi-grid-label-start-end;
    }
}

augment "/nw:networks/tet:te/tet:templates/"
+ "tet:link-template/tet:te-link-attributes/"
+ "tet:label-restrictions/tet:label-restriction/"
+ "tet:label-step/tet:technology" {
    description
        "Augment TE label range step for the TE link template.";
    case flexi-grid {
        uses 10-types:flexi-grid-label-step;
    }
}
}
}
<CODE ENDS>
```

8. 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 Transport Layer Security (TLS) [RFC8446].

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. The NETCONF Protocol SSH [RFC6242] describes a method for invoking and running NETCONF within a SSH session as an SSH subsystem. 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.

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.

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

```
/nw:networks/nw:network/nw:network-types/tet:te-topology
/nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes
/nw:networks/nw:network/nw:node/nt:termination-point/tet:te
/nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
/te-connectivity-matrices/te-connectivity-matrix/tet:path-
constraints/tet:te-bandwidth/tet:technology
/nw:networks/nw:network/nw:node/tet:te
/tet:tunnel-termination-point/tet:local-link-connectivities
/tet:label-restrictions/tet:label-restriction
```

9. IANA Considerations

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

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

IANA is requested to assign a new YANG module name in the "YANG Module Names" registry [RFC6020] as follows:

```
Name: ietf-flexi-grid-topology
Namespace: urn:ietf:params:xml:ns:yang:ietf-flexi-grid-topology
Prefix: flexi-grid-topology
Reference: [This.I-D]
```

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A YANG Data Model for Layer 0 Types - Revision 2
draft-ietf-ccamp-layer0-types-ext-01

Abstract

This document defines a collection of common data types and groupings in the YANG data modeling language, which are used in several YANG modules for wavelength Division multiplexing (WDM) transport networks. The YANG module ietf-layer0-types-ext updates ietf-layer0-types defined in [RFC9093], which has been reduced in scope prior to publication to only cover spectrum management related aspects required for the YANG module ietf-wson-topology defined in [RFC9094].

To be completed

Status of This Memo

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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 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.

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

1.2. Terminology

2. Extensions for the Layer 0 Types Module

This document defines YANG module extensions for common Layer 0 types. named `ietf-layer0-types-ext`. This module can be used for both WSON and Flexi-grid DWDM networks but in particular is adding common types used in the context of optical impairment aware topology model in WSON and SSONs. The `ietf-layer0-types-ext` module contains the following YANG identities, types and groupings that can be reused in other YANG modules:

`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 $\text{penalty} = f(\text{CD}, \text{PMD})$.

[Editor's note: There is still stuff from the xml template that needs to be removed]

3. Layer0 Types Revision 2 YANG CODE

The YANG code is developed on GitHub and can also be found in the following CCAMP repository:

<https://github.com/ietf-ccamp-wg/ietf-ccamp-layer0-types-ext>

[Editor's note: YANG code below always has to be updated before submitting a new revision!]

```
<CODE BEGINS> file "ietf-layer0-types-ext@2021-10-18.yang"
module ietf-layer0-types-ext {
  namespace "urn:ietf:params:xml:ns:yang:ietf-layer0-types-ext";
  prefix "l0-types-ext";

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

    Editor: Dieter Beller
      <mailto:Dieter.Beller@nokia.com>

    Editor: Sergio Belotti
      <mailto:Sergio.Belotti@nokia.com>

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

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

  // Additional contacts TBA (contributors)

  description
    "Description to be added!!!"

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  as authors of the code. All rights reserved.

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  or without modification, is permitted pursuant to, and
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  BSD License set forth in Section 4.c of the IETF Trust's
```


Legal Provisions Relating to IETF Documents
(<http://trustee.ietf.org/license-info>).

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

```
revision "2021-10-18" {
  description
    "Initial Version";
  reference
    "RFC XXXX: A YANG Data Model for Layer 0 Types - Revision 2";
}

/*
 * Identities
 */

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

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

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

identity QAM8 {
  base modulation;
  description
    "8QAM (8-State Quadrature Amplitude Modulation) modulation";
}

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

identity DP-QAM8 {
  base modulation;
```

```
    description
      "DP-QAM8 (Dual Polarization Quadrature Amplitude Modulation)";
  }

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

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

  identity DC-DP-QAM16 {
    base modulation;
    description
      "DC DP-QAM16 (Dual Carrier 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 unspecified-wavelength-assignment {
    base wavelength-assignment;
    description
      "No method specified";
  }

  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 operational-mode {
    type string;
    description
        "Organization/vendor specific mode that guarantees
        interoperability.";
    reference "ITU-T G.698.2 (11/2018)";
}

typedef standard-mode {
    type string;
    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 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";
    reference
        "RFC6205: Generalized Labels for
        Lambda-Switch-Capable (LSC) Label Switching Routers";
}

typedef frequency-ghz {
    type decimal64 {
        fraction-digits 3;
    }
    units GHz;
    description
        "The DWDM frequency in GHz, e.g., 193112.500";
    reference
        "RFC6205: Generalized Labels for
        Lambda-Switch-Capable (LSC) Label Switching Routers";
}

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 fiber-type {
    type enumeration {
        enum G.652 {
            description "G.652 Standard Singlemode Fiber";
        }
        enum G.654 {
            description "G.654 Cutoff Shifted Fiber";
        }
        enum G.653 {
            description "G.653 Dispersion Shifted Fiber";
        }
    }
}
```



```
    }
    enum G.655 {
        description "G.655 Non-Zero Dispersion Shifted Fiber";
    }
    enum G.656 {
        description "G.656 Non-Zero Dispersion for Wideband
            Optical Transport";
    }
    enum G.657 {
        description "G.657 Bend-Insensitive Fiber";
    }
}
description
    "ITU-T based fiber-types";
}

/*
 * Groupings
 */

/* 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-capabilities {
    description
        "This grouping is intended to be use 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.";
}
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
} // list supported-modes
} // container supported-modes
} // grouping transceiver-capabilities

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 recommendation";

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 cd-pmd-penalty {
  description "entries of table; triplet chromatic
    dispersion, polarization mode dispersion and
    associated penalty";

  leaf chromatic-dispersion {
    type decimal64 {
      fraction-digits 2;
      range "0..max";
    }
    units "ps/nm";
    config false;
    mandatory true;
    description "chromatic dispersion";
  }
  leaf polarization-mode-dispersion {
    type decimal64 {
      fraction-digits 2;
      range "0..max";
    }
    units "ps";
    config false;
    mandatory true;
    description "Polarization mode dispersion";
  }
  leaf penalty {
    type decimal64 {
      fraction-digits 2;
      range "0..max";
    }
    units "dB";
    config false;
    mandatory true;
    description "Associated penalty on the receiver";
  }
}

grouping pdl-penalty {
  description
    "entries of table; pair of values polarization dependent loss
```

```
        and associated penalty";

    leaf max-polarization-dependent-loss {
        type decimal64 {
            fraction-digits 2;
        }
        units "dB";
        config false;
        mandatory true;
        description
            "Maximum acceptable accumulate polarization dependent loss";
    }
    leaf penalty {
        type uint8;
        units "dB";
        config false;
        mandatory true;
        description "Associated penalty on 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 optical tributary signal";
        reference
            "ITU-T G.698.2 section 7.1.2";
    }
    leaf max-polarization-mode-dispersion {
        type decimal64 {
            fraction-digits 2;
            range "0..max";
        }
        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-and-polarization-dispersion-penalty {
    config false;
    description
        "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).";
    uses cd-pmd-penalty ;
}
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).";
    uses pdl-penalty ;
}
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

grouping common-organizational-explicit-mode {
    description "Common capability attributes limit range
    in case of operational mode and explicit mode.
    These attributes are supported separately in
    case of application codes";

    /* 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.";
    }

/* transmitter-tunability-grid */

    leaf central-frequency-step {
      type frequency-ghz;
      config false;
      description
        "This parameter indicates the transmitter tunability grid as
        the distance between two adjacent carrier frequencies of
        the transmitter tuning range.";
    }

/* 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 otsi-carrier-frequency {
        type frequency-thz;
        description
            "OTSi carrier frequency, equivalent to the
            actual configured transmitter frequency";
    }
    leaf tx-channel-power {
        type dbm-t;
        description "The current channel transmit power";
    }
    leaf rx-channel-power {
        type dbm-t;
        config false;
        description "The current channel received power ";
    }
    leaf rx-total-power {
        type dbm-t;
        config false;
        description "Current total received power";
    }
} // grouping for configured attributes out of mode

grouping l0-tunnel-attributes {
    description
        "Parameters for Layer0 (WSN or Flexi-Grid) Tunnels.";
    leaf fec-type {
        type identityref {
            base fec-type;
        }
    }
}
```

```
        description
            "FEC type.";
    }
    leaf termination-type {
        type identityref {
            base term-type;
        }
        description
            "Termination type.";
    }
    leaf bit-stuffing {
        type boolean;
        description
            "Bit stuffing enabled/disabled.";
    }
}

grouping l0-path-constraints {
    description
        "Global named path constraints configuration
        grouping for Layer0 (WSON or Flexi-Grid) paths.";
    leaf wavelength-assignment {
        type identityref {
            base wavelength-assignment;
        }
        description "Wavelength Allocation Method";
    }
}

grouping frequency-range {
    description
        "The parameters that define a frequency range.";
    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.";
    }
}
}
<CODE ENDS>
```

Figure 1

4. Acknowledgements

To be added if any.

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6. IANA Considerations

This memo includes no request to IANA.

All drafts are required to have an IANA considerations section (see Guidelines for Writing an IANA Considerations Section in RFCs [RFC5226] for a guide). If the draft does not require IANA to do anything, the section contains an explicit statement that this is the case (as above). If there are no requirements for IANA, the section will be removed during conversion into an RFC by the RFC Editor.

7. Security Considerations

All drafts are required to have a security considerations section. See RFC 3552 [RFC3552] for a guide.

8. References

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<<https://www.rfc-editor.org/info/rfc5226>>.

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A YANG Data Model for Microwave Topology
draft-ietf-ccamp-mw-topo-yang-02

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.

RFC Ed. Note

// RFC Ed.: replace all XXXX throughout the document with actual RFC numbers and remove this note

Status of This Memo

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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-snr?        decimal64
      |   +--ro actual-transmitted-level? power
augment /nw:networks/nw:network/nt:link/tet:te/
  tet:te-link-attributes/tet:max-link-bandwidth/
  tet:te-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 leafs in the Data Model for Traffic Engineering (TE) Topologies augmented by the microwave topology model are not applicable. An example of which leafs are considered applicable can be found in appendix "Examples of the application of the Topology Models" in this document. //Add a proper reference to the appendix

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@2021-10-22.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>"

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           <mailto:daniela.spreafico@nokia.com>
";

// Note to RFC Editor: replace XXXX with actual RFC number and
// remove this note.
description
    "This is a module for microwave topology.

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    authors of the code. All rights reserved.
    Redistribution and use in source and binary forms, with or
```

```
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forth in Section 4.c of the IETF Trust's Legal Provisions
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(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 2021-10-22 {
  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.";

  // Any attributes to be included?
}

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.";
        reference
            "RFC 8561: A YANG Data Model for Microwave Radio Link";
    }
    leaf actual-snr {
        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-snr 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/"
    + "tet:te" {
    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 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";
      }
    }
  }
}
```

```

    }
  }
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "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@2021-10-22.yang"
module ietf-bandwidth-availability-topology {
  yang-version 1.1;
  namespace
    "urn:ietf:params:xml:ns:yang:ietf-bandwidth-availability-topology";

  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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    <mailto:Italo.Busi@huawei.com>
  Editor: Xi Li
    <mailto:Xi.Li@neclab.eu>
  Editor: Daniela Spreafico
    <mailto:daniela.spreafico@nokia.com>
  ";

// 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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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 2021-10-22 {
  description
    "First rough draft.";
  reference "";
}

/*
 * Groupings
 */
grouping link-bw-availability-table {

  description "Grouping used for bandwidth availability.";

  list link-availability{
    key "availability";
    description
      "Table describing the bandwidths available at corresponding
      availability level for a link.";

    leaf availability {
      type decimal64 {
        fraction-digits 4;
        range "0..99.9999";
      }
      description "Availability level";
    }

    leaf link-bandwidth {
      type uint64;
      units "Kbps";
    }
  }
}
```

```

        description
            "The link bandwidth corresponding to the availability
            level";
    }
}
leaf actual-bandwidth{
    type yang:gauge64;
    units "bits/second";
    config false;
    description
        "An estimate of the link's current bandwidth in bits per
        second. Related to the data node speed in RFC 8343.";
    reference
        "RFC 8343: A YANG Data Model for Interface Management";
}
}
/*
 * Data nodes
 */

augment "/nw:networks/nw:network/nt:link/tet:te/"
    + "tet:te-link-attributes" {
    description
        "Augmenting link with link bandwidth availability matrix.";
    uses link-bw-availability-table;
}
}
<CODE ENDS>

```

5. Termination Point to Interface Reference YANG Data Model

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/if:interface/if:name

```

5.2. Termination Point to Interface Reference YANG Data Module

```
<CODE BEGINS>
file "ietf-tp-interface-reference-topology@2021-10-22.yang"
module iETF-tp-interface-reference-topology {
  yang-version 1.1;
  namespace
    "urn:ietf:params:xml:ns:yang:ietf-tp-interface-reference-topology";

  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?
  Editor: Jonas Ahlberg
         <mailto:jonas.ahlberg@ericsson.com>
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  Editor: Xi Li
         <mailto:Xi.Li@neclab.eu>
  Editor: Daniela Spreafico
```



```
        <mailto:daniela.spreafico@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.

        Copyright (c) 2020 IETF Trust and the persons identified as
        authors of the code. All rights reserved.
        Redistribution and use in source and binary forms, with or
        without modification, is permitted pursuant to, and subject to
        the license terms contained in, the Simplified BSD License set
        forth in Section 4.c of the IETF Trust's Legal Provisions
        Relating to IETF Documents
        (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 2021-10-22 {
        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;  
  }  
}  
<CODE ENDS>
```

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 a 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:

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

URI: urn:ietf:params:xml:ns:yang:ietf-bandwidth-availability-topology
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
Namespace: urn:ietf:params:xml:ns:yang:ietf-microwave-topology
Prefix: mwtopo
Reference: RFC XXXX

Name: ietf-bandwidth-availability-topology
Maintained by IANA?: N
Namespace:
urn:ietf:params:xml:ns:yang:ietf-bandwidth-availability-topology
Prefix: bwavtopo
Reference: RFC XXXX

8. References

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8.2. Informative References

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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.

```

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
          | -> ../../../../supporting-network/network-ref
        +--rw node-ref         -> /networks/network/node/node-id
      +--rw nt:termination-point* [tp-id]
        +--rw nt:tp-id          tp-id
        +--rw nt:supporting-termination-point*
          | [network-ref node-ref tp-ref]
          +--rw nt:network-ref
            | -> ../../../../nw:supporting-node/network-ref
          +--rw nt:node-ref
            | -> ../../../../nw:supporting-node/node-ref
          +--rw nt:tp-ref
            | -> /nw:networks/network[nw:network-id=current ()
            |   ../../network-ref]/node[nw:node-id=current ()
            |   ../../node-ref]/termination-point/tp-id
        +--rw tet:te!
          +--rw tet:name?        string
          +--ro tet:geolocation
            | +--ro tet:altitude?  int64
            | +--ro tet:latitude?  geographic-coordinate-degree
            | +--ro tet:longitude? geographic-coordinate-degree
          +--rw ifref:tp-to-interface-path?
            | -> /if:interfaces/if:interface/if:name
          +--rw mwtopo:mw-tp-choice
            +--rw (mwtopo:mw-tp-option)?
              +--: (mwtopo:microwave-rltp)
              | +--rw mwtopo:microwave-rltp!
              +--: (mwtopo:microwave-ctp)
              | +--rw mwtopo:microwave-ctp!
      +--rw nt:link* [link-id]
        +--rw nt:link-id          link-id
        +--rw nt:source
          | +--rw nt:source-node?  -> ../../../../nw:node/node-id
          | +--rw nt:source-tp?
            | -> ../../../../nw:node[nw:node-id=current ()
            |   ../../source-node]/termination-point/tp-id

```

```

+--rw nt:destination
|   +--rw nt:dest-node?    -> ../../../../nw:node/node-id
|   +--rw nt:dest-tp?
|       -> ../../../../nw:node[nw:node-id=current()
|           /../../dest-node]/termination-point/tp-id
+--rw tet:te!
|   +--rw (tet:bundle-stack-level)?
|   |   +--:(tet:bundle)
|   |   |   +--rw tet:bundled-links
|   |   |   |   +--rw tet:bundled-link* [sequence]
|   |   |   |   |   +--rw tet:sequence          uint32
|   |   |   |   |   +--rw tet:src-tp-ref?    -> ../../../../nw:node[nw:node-id current() /../../nt:source/source-node]/
|   |   |   |   |       termination-point/tp-id
|   |   |   |   |   +--rw tet:des-tp-ref?    -> ../../../../nw:node[nw:node-id = current() /../../nt:destination/dest-node]/
|   |   |   |   |       termination-point/tp-id
|   |   +--rw tet:te-link-attributes
|   |   |   +--rw tet:name?                string
|   |   |   +--rw tet:admin-status?        te-types:te-admin-status
|   |   |   +--rw tet:max-link-bandwidth
|   |   |   |   +--rw tet:te-bandwidth
|   |   |   |   |   +--rw (tet:technology)?
|   |   |   |   |   |   +--:(mwtopo:microwave)
|   |   |   |   |   |   +--ro mwtopo:mw-bandwidth? uint64
|   |   |   +--rw mwtopo:mw-link-choice
|   |   |   |   +--rw (mwtopo:mw-link-option)?
|   |   |   |   |   +--:(mwtopo:microwave-radio-link)
|   |   |   |   |   |   +--rw mwtopo:microwave-radio-link!
|   |   |   |   |   |   |   +--rw mwtopo:mode?    identityref
|   |   |   |   |   +--:(mwtopo:microwave-carrier)
|   |   |   |   |   |   +--rw mwtopo:microwave-carrier!
|   |   |   |   |   |   |   +--rw mwtopo:tx-frequency?    uint32
|   |   |   |   |   |   |   +--rw mwtopo:rx-frequency?    uint32
|   |   |   |   |   |   |   +--rw mwtopo:channel-separation? uint32
|   |   |   |   |   |   |   +--ro actual-tx-cm?            identityref
|   |   |   |   |   |   |   +--ro actual-snr?              decimal64
|   |   |   |   |   |   |   +--ro actual-transmitted-level? power
|   |   |   +--rw bwatopo:link-availability* [availability]
|   |   |   |   +--rw bwatopo:availability          decimal64
|   |   |   |   +--rw bwatopo:link-bandwidth?      uint64
|   |   |   +--ro bwatopo:actual-bandwidth?        yang:gauge64
|   +--ro tet:oper-status?                te-types:te-oper-status

```

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 in Figure 3 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].

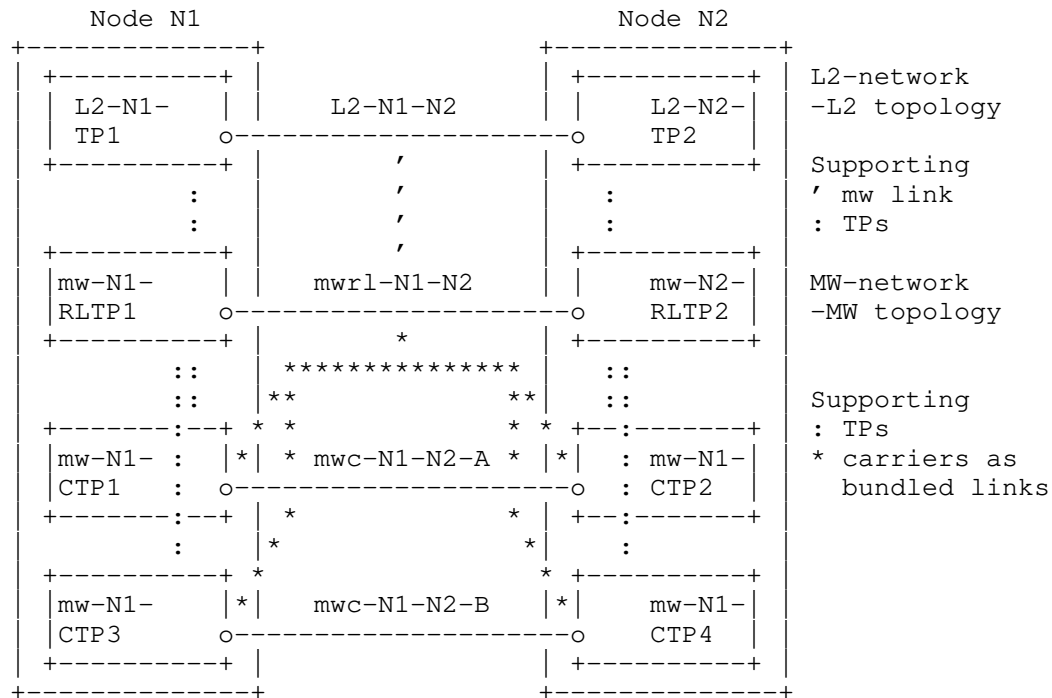
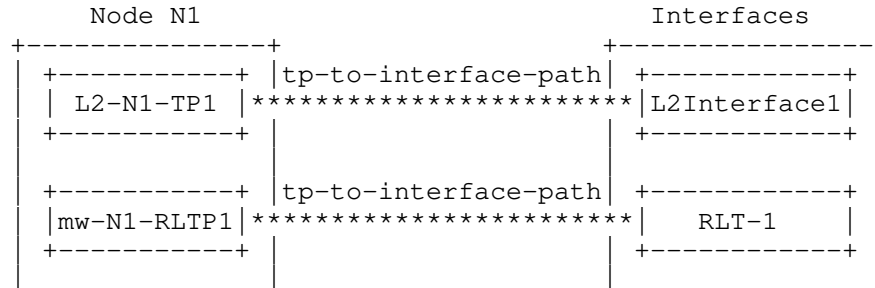


Figure 3: L2 transported over a (2+0) microwave radio link



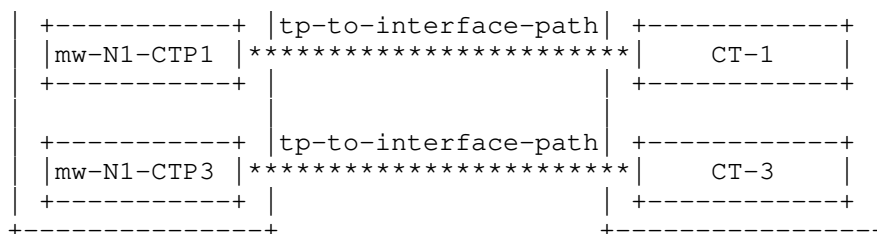


Figure 4: References from the topology model information to the associated interface management model information

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 "example.json"
{
  "ietf-network:networks": {
    "network": [
      {
        "network-id": "L2-network",
        "network-types": {
          "ietf-l2-topology:l2-topology": {
          }
        },
        "supporting-network": [
          {
            "network-ref": "mw-network"
          }
        ],
        "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": "mwrl1-N1-N2"
      }
    ]
  }
]
},

```

```

{
  "network-id": "mw-network",
  "network-types": {
    "ietf-te-topology:te-topology": {
      "ietf-microwave-topology:mw-topology": {
        }
      }
    },
  "node": [
    {
      "node-id": "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"
          }
        },
        {
          "tp-id": "mw-N1-CTP1",
          "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-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",
    "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"
    }
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Note that the example above just shows one particular link (unidirectional) and not a complete network topology.

Appendix B. Contributors

TBD

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A YANG Data Model for Optical Impairment-aware Topology
draft-ietf-ccamp-optical-impairment-topology-yang-09

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.

| Prefix | YANG module | Reference |
|------------------|----------------------------------|-----------------------------------|
| optical-imp-topo | ietf-optical-impairment-topology | [RFCXXXX] |
| layer0-types | ietf-layer0-types | [RFC9093] |
| l0-types-ext | ietf-layer0-types-ext | [I-D.ietf-ccamp-layer0-types-ext] |
| nw | ietf-network | [RFC8345] |
| nt | ietf-network-topology | [RFC8345] |
| tet | ietf-te-topology | [RFC8795] |

Table 1: Prefixes and corresponding YANG modules

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

2. Reference Architecture

2.1. Control Plane Architecture

Figure 1 shows the control plane architecture.

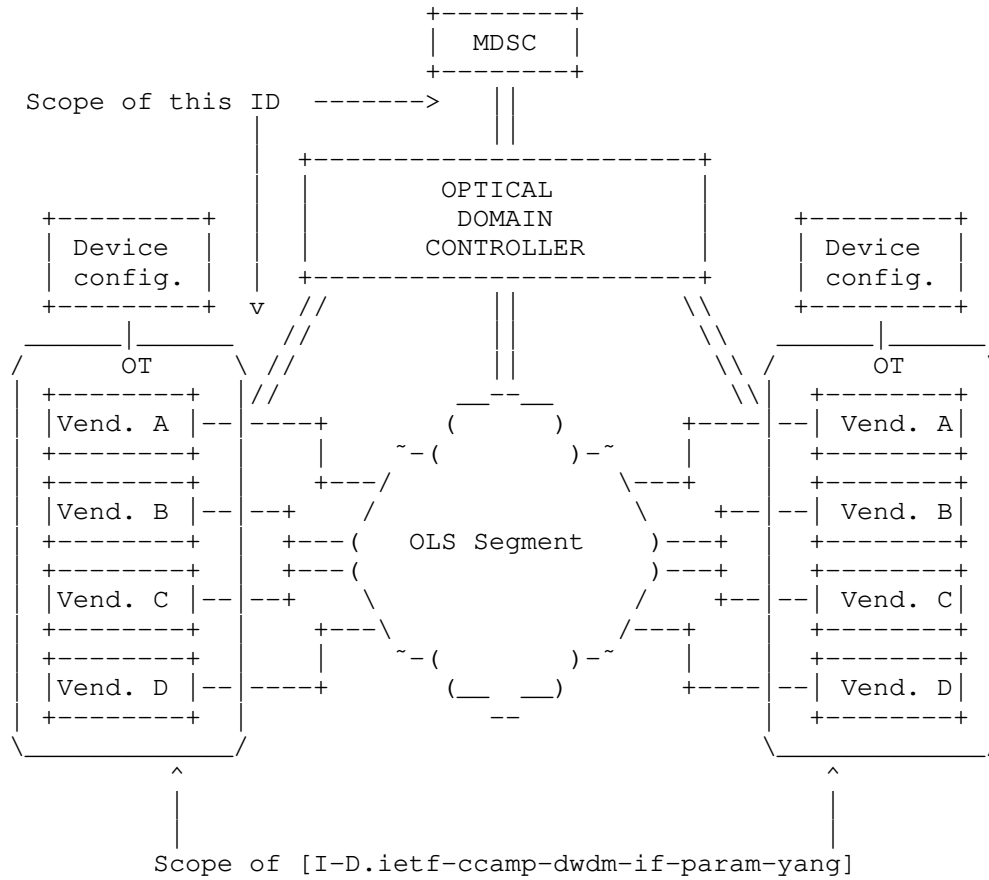


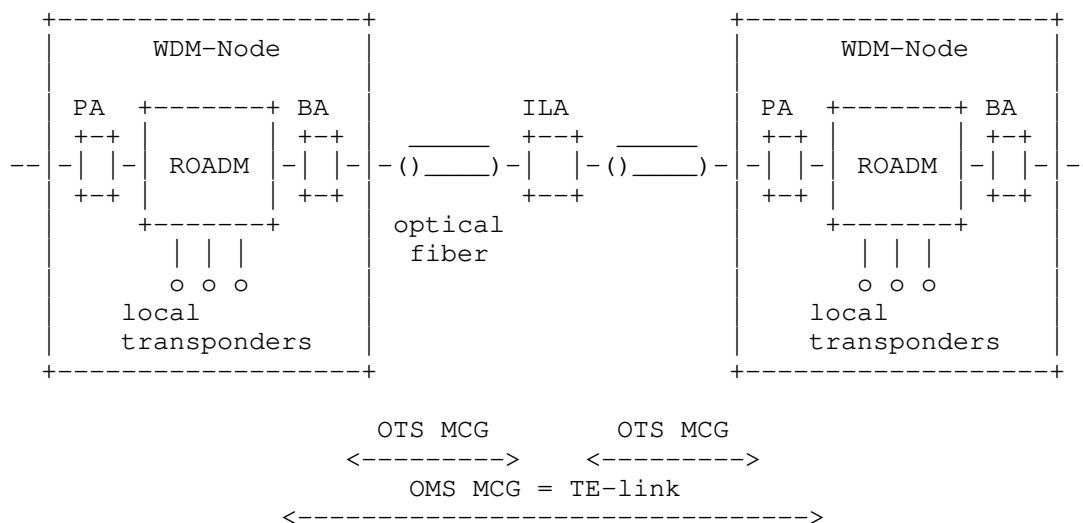
Figure 1: Scope of draft-ietf-ccamp-dwdm-if-param-yang

The 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 engress 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.

[Editor's note: text below related to [G.807] needs to be revised based on the published [G.807] revision!]

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.

2.3.2. Optical Tributary Signal Group (OTSiG)

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

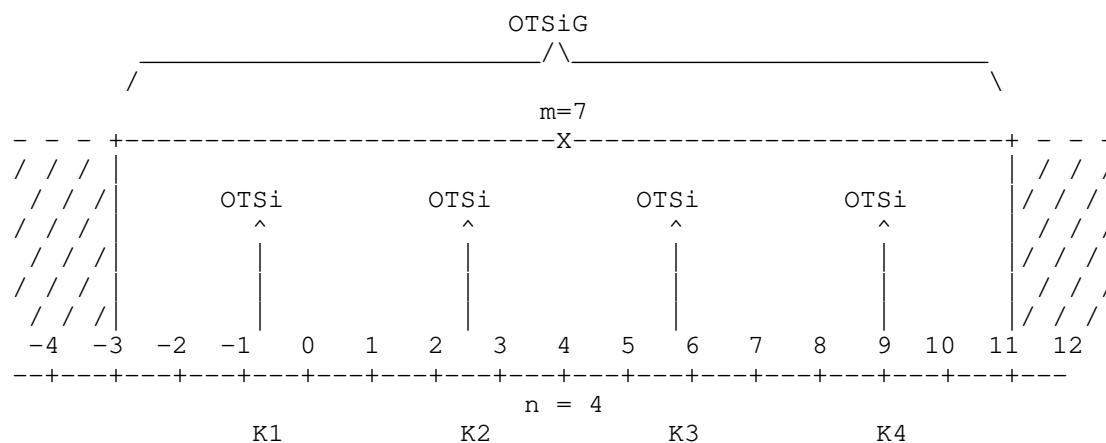


Figure 3: MC Example containing all 4 OTSi signals of an OTSiG

2.3.3. Media Channel (MC)

[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.

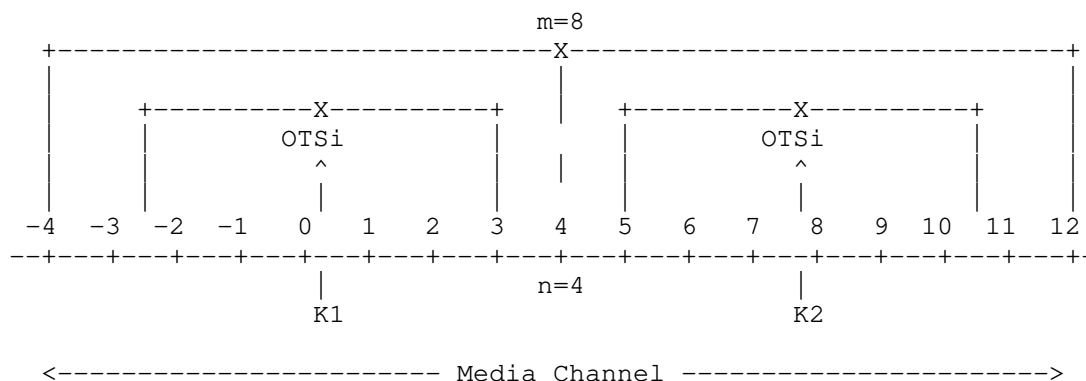


Figure 4: Figure Caption TBA

The frequency slot of the MC is defined by the n value defining the central frequency of the MC and the m value that defines the width of the MC following the flexible grid definition in ITU-T Recommendation G.694.1 [G.694.1]. In this model, the effective frequency slot as defined in ITU-T draft Recommendation G.807 is equal to the frequency slot of this end-to-end MC. It is also assumed that 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.

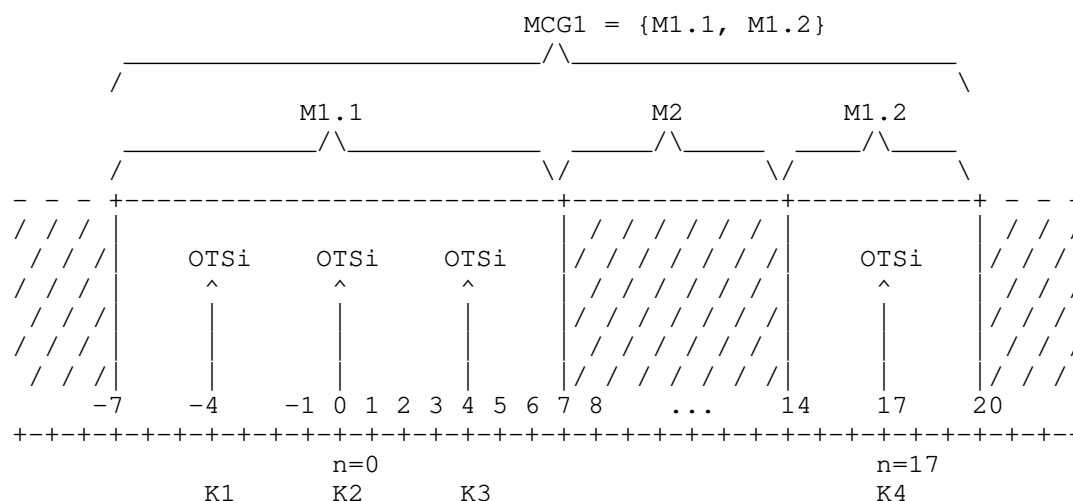


Figure 5: Figure Caption TBA

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

2.4. Amplifiers

Optical amplifiers are 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. 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, $\text{Power_in (@ ROADM Booster)} = \text{Power_out (@ ROADM Pre-Amplifier)} - \text{Power_loss (@ ROADM WSS/Filter)}$.

2.5. Transponders

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

A Transponder is the element that sends and receives the optical signal from a DWDM network. A transponder can comprise one or more 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 grid, the 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

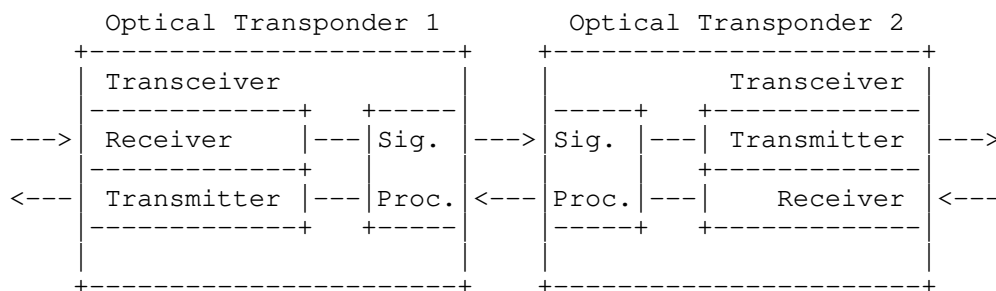
2.6. 3R Regenerators

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 regeneration compound 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:

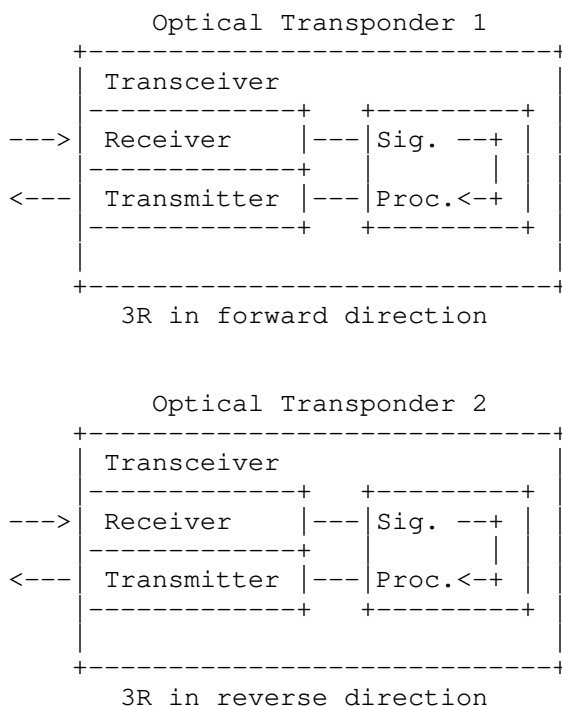
- * The two transponders can be operated in a back-to-back configuration where the transceiver of each optical transponder receives and transmits the optical signal from/to the same segment of the end-to-end tunnel. This means that each transceiver is operated in a bi-directional mode.



Sig. Proc. = Signal Processing

Figure 6: Back-to-back 3R Regenerator Example

- * 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 a uni-directional mode.



Sig. Proc. = Signal Processing

Figure 7: Cross-3R Regenerator Example

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 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.

More text to be added here!

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, pmd, connectors (in/out).

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

2.9. 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.

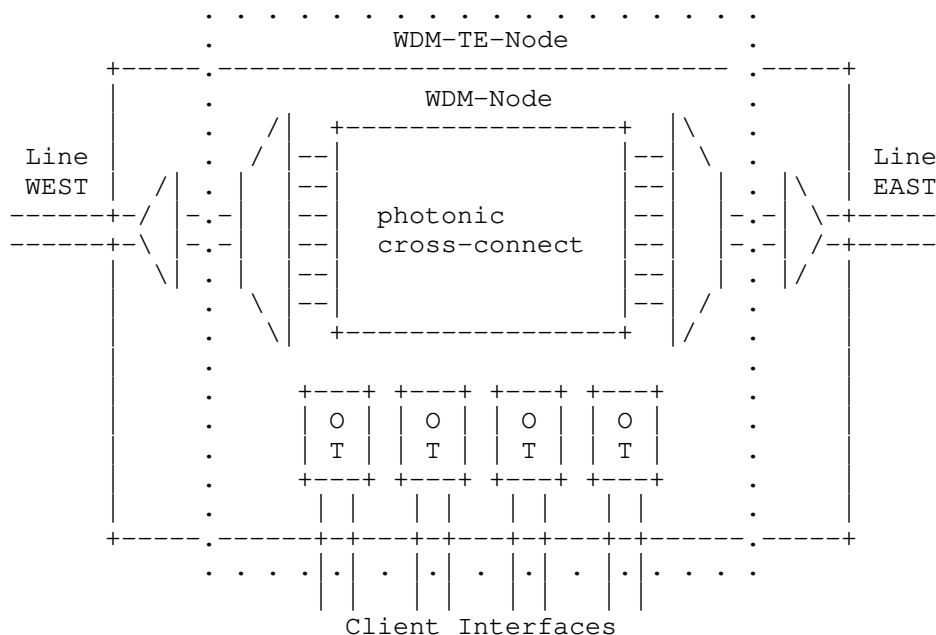


Figure 8: Integrated WDM-node Architectiure with Local Transponders

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].

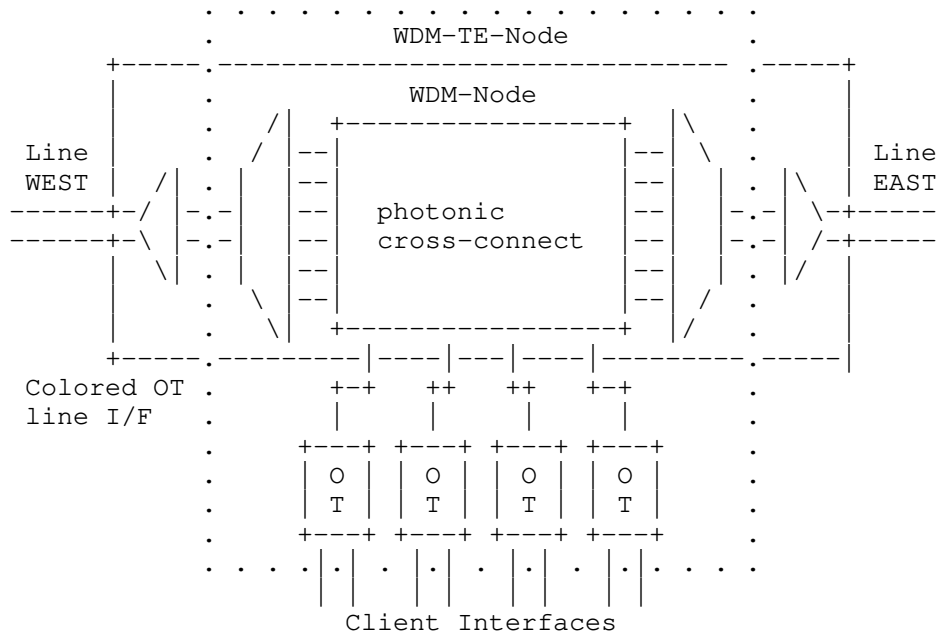


Figure 9: Integrated WDM-node Architectiure with Remote Transponders

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.

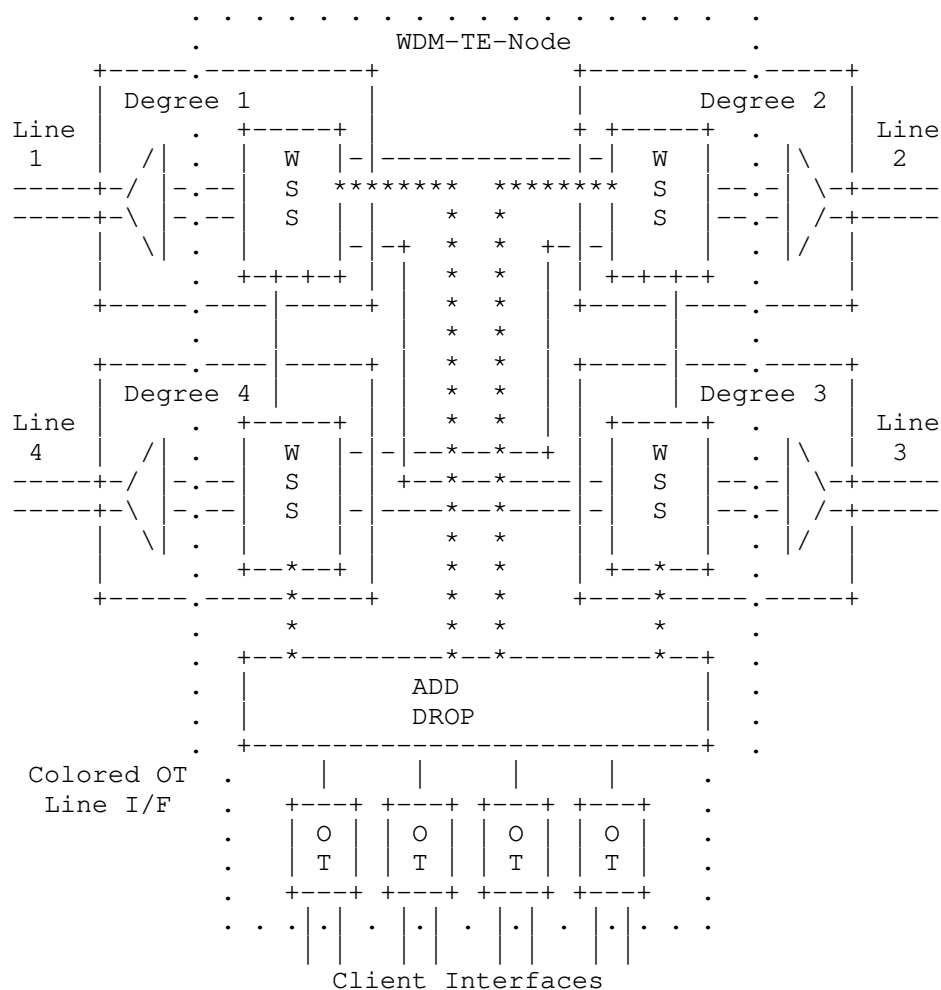


Figure 10: Disaggregated WDM-TE-node Architecture with Remote Transponders

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]

3. YANG Model (Tree Structure)

[Editor's note: tree view below always has to be updated before submitting a new revision!]

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 tx-channel-power?    union
      +--ro rx-channel-power?    union
      +--ro rx-total-power?      union
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
      +--ro (mode)
        +--:(G.698.2)
          | +--ro standard-mode? standard-mode
        +--:(organizational-mode)
          | +--ro organizational-mode
          |   +--ro operational-mode?
          |   |   operational-mode
          |   +--ro organization-identifier?
          |   |   organization-identifier
          |   +--ro min-central-frequency?
          |   |   frequency-thz
          |   +--ro max-central-frequency?
          |   |   frequency-thz
          |   +--ro central-frequency-step?
          |   |   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?
          |   |   decimal64
          |   +--ro max-chromatic-dispersion?
          |   |   decimal64
          |   +--ro chromatic-and-polarization-dispersion-penalty* []
          |   |   +--ro chromatic-dispersion
          |   |   |   union
          |   |   +--ro polarization-mode-dispersion
          |   |   |   union
          |   +--ro penalty

```

```

|
|
|
|         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
|         |         |         union
|         +---ro available-modulation-type?
|         |         identityref
|         +---ro min-OSNR?
|         |         snr
|         +---ro min-Q-factor?
|         |         int32
|         +---ro available-baud-rate?
|         |         uint32
|         +---ro roll-off?
|         |         decimal64
|         +---ro min-carrier-spacing?
|         |         frequency-ghz
|         +---ro available-fec-type?
|         |         identityref
|         +---ro fec-code-rate?
|         |         decimal64
|         +---ro fec-threshold?
|         |         decimal64
|         +---ro min-central-frequency?
|         |         frequency-thz
|         +---ro max-central-frequency?
|         |         frequency-thz
|         +---ro central-frequency-step?
|         |         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
+---ro configured-mode?
|         -> ../supported-modes/supported-mode/mode-id
+---ro outgoing-otsi
|         +---ro otsi-group-ref?
|         |         -> ../../../../otsi-group/otsi-group-id
+---ro otsi-ref?         leafref

```



```

    |
    |   +--ro incoming-otsi
    |   |   +--ro otsi-group-ref?
    |   |   |   -> ../../../../otsi-group/otsi-group-id
    |   |   +--ro otsi-ref?          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 equalization-mode         identityref
    +--ro (power-param)?
    |   +--:(channel-power)
    |   |   +--ro nominal-carrier-power?
    |   |   |   10-types:power-in-dbm-or-null
    |   +--:(power-spectral-density)
    |   |   +--ro nominal-power-spectral-density?  union
+--ro media-channel-group* [i]
    +--ro i          int16
    +--ro media-channels* [flexi-n]
    |   +--ro flexi-n          10-types:flexi-n
    |   +--ro flexi-m?         10-types:flexi-m
    |   +--ro otsi-group-ref?
    |   |   -> /nw:networks/network/otsi-group/otsi-group-id
    |   +--ro otsi-ref*        leafref
    |   +--ro delta-power?     10-types:power-in-dbm-or-null
+--ro OMS-elements* [elt-index]
    +--ro elt-index          uint16
    +--ro oms-element-uid?    union
    +--ro reverse-element-ref
    |   +--ro link-ref?
    |   |   -> ../../../../nt:link/link-id
    |   +--ro oms-element-ref*  leafref
+--ro (element)
    +--:(amplifier)
    |   +--ro geolocation
    |   |   +--ro altitude?      int64
    |   |   +--ro latitude?      geographic-coordinate-degree
    |   |   +--ro longitude?     geographic-coordinate-degree
    |   +--ro amplifier
    |   |   +--ro type-variety    string
    |   |   +--ro operational
    |   |   |   +--ro amplifier-element* []
    |   |   |   |   +--ro name?
    |   |   |   |   |   string

```

```

    +---ro frequency-range
    |   +---ro lower-frequency    frequency-thz
    |   +---ro upper-frequency    frequency-thz
    +---ro actual-gain
    |   10-types:power-in-db-or-null
    +---ro tilt-target
    |   10-types:decimal-2-digits-or-null
    +---ro out-voa
    |   10-types:power-in-db-or-null
    +---ro in-voa
    |   10-types:power-in-db-or-null
    +---ro total-output-power
    |   10-types:power-in-db-or-null
    +---ro (power-param)?
    |   +---:(channel-power)
    |   |   +---ro nominal-carrier-power?
    |   |   |   10-types:power-in-dbm-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
          +--ro roadm-pmd?                union
          +--ro roadm-cd?                 union
          +--ro roadm-pdl?
            | 10-types:power-in-db-or-null
          +--ro roadm-inband-crosstalk?
            | 10-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?
            | 10-types:power-in-db-or-null
          +--ro roadm-inband-crosstalk?
            | 10-types:power-in-db-or-null
          +--ro roadm-maxloss?
            | 10-types:power-in-db-or-null
          +--ro roadm-pmax?
            | 10-types:power-in-dbm-or-null
          +--ro roadm-osnr?                10-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?
            | 10-types:power-in-db-or-null
          +--ro roadm-inband-crosstalk?

```

```

        |          10-types:power-in-db-or-null
    +--ro roadm-maxloss?
        |          10-types:power-in-db-or-null
    +--ro roadm-minloss?
        |          10-types:power-in-db-or-null
    +--ro roadm-typlloss?
        |          10-types:power-in-db-or-null
    +--ro roadm-pmin?
        |          10-types:power-in-dbm-or-null
    +--ro roadm-pmax?
        |          10-types:power-in-dbm-or-null
    +--ro roadm-ptyp?
        |          10-types:power-in-dbm-or-null
    +--ro roadm-osnr?          10-types:snr-or-null
    +--ro roadm-noise-figure?      union
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:information-source-entry/tet:connectivity-matrices:
    +--ro roadm-path-impairments?  leafref
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:information-source-entry/tet:connectivity-matrices
    /tet:connectivity-matrix:
    +--ro roadm-path-impairments?  leafref
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices:
    +--ro roadm-path-impairments?
        -> ../../roadm-path-impairments/roadm-path-impairments-id
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
    /tet:connectivity-matrix:
    +--ro roadm-path-impairments?  leafref
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point
    /tet:local-link-connectivities:
    +--ro add-path-impairments?    leafref
    +--ro drop-path-impairments?  leafref
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point
    /tet:local-link-connectivities
    /tet:local-link-connectivity:
    +--ro add-path-impairments?    leafref
    +--ro drop-path-impairments?  leafref
    +--ro llc-transceiver* [ttp-transponder-ref ttp-transceiver-ref]
        +--ro ttp-transponder-ref
            |          -> ../../../../ttp-transceiver/transponder-ref
        +--ro ttp-transceiver-ref
            |          -> ../../../../ttp-transceiver/transceiver-ref
        +--ro is-allowed?          boolean
        +--ro add-path-impairments?  leafref

```

```
+--ro drop-path-impairments?  leafref
```

4. Optical Impairment Topology YANG Model

[Editor's note: YANG code below always has to be updated before submitting a new revision!]

<CODE BEGINS>

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

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

  prefix "optical-imp-topo";

  import ietf-network {
    prefix "nw";
  }

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

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

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

  organization
    "IETF CCAMP Working Group";

  contact
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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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License set forth in Section 4.c of the IETF Trust's Legal
Provisions Relating to IETF Documents
(<http://trustee.ietf.org/license-info>).

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

// 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 2022-03-07 {  
  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 10-types:frequency-range;
}
leaf actual-gain {
    type 10-types:power-in-db-or-null;
    mandatory true ;
    description "..";
}
leaf tilt-target {
    type 10-types:decimal-2-digits-or-null;
    mandatory true ;
    description "..";
}
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 10-types:power-in-db-or-null;
        mandatory true ;
        description
            "includes all losses: fiber loss and conn-in and
             conn-out losses";
    }
    leaf pmd{
        type 10-types:decimal-2-digits-or-null;
        units sqrt(ps);
        description "pmd of the fiber";
    }
    leaf conn-in{
        type 10-types:power-in-db-or-null;
        description "connector-in";
    }
    leaf conn-out{
        type 10-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 {
    type l0-types:power-in-db-or-null;
    description "Polarization dependent loss";
  }
  leaf roadm-inband-crosstalk {
    type l0-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 l0-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 constraints.
        The max value correspond to worst case expected loss,
        including amplifier gain ripple or uncertainty.
        It is the maximum output power of the drop
        amplifier.";
}
leaf roadm-minloss {
    type 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
        constraints.
        The min value correspond to best case expected loss,
        including amplifier gain ripple or uncertainty.";
```

```
}
leaf roadm-typlloss {
  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 constraints.
     The typ value correspond to typical case
     expected loss.";
}
leaf roadm-pmin {
  type 10-types:power-in-dbm-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-dbm-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-dbm-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
             ( $P_{\text{carrier}} =$ 
              $P_{\text{ref}} + 10 \log(\text{carrier-baudrate} / \text{ref-baud}) + \text{delta-power}$ )
             and the input inferred NF ( $\text{NF}_{\text{drop}}$ ),
             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 {
      when "/nw:networks/nw:network/nt:link/tet:te
        /tet:te-link-attributes/OMS-attributes
        /equalization-mode='carrier-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{
      when "/nw:networks/nw:network/nt:link/tet:te
        /tet:te-link-attributes/OMS-attributes
        /equalization-mode='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 : 3.9 E-14, resolution 0.1nW/MHz";
    }
  }
}

grouping oms-general-optical-params {
  description "OMS link optical parameters";
  leaf generalized-snr {
    type 10-types:snr;
    description "generalized snr";
  }
  leaf equalization-mode {
    type identityref {
      base 10-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";
    }
    uses 10-types:common-transceiver-configured-param;
  } // OTSi list
} // OTSiG grouping

grouping media-channel-groups {
  description "media channel groups";
```

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

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

    // this grouping add both n.m values
    uses 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";
    }
    leaf-list otsi-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 list supporting
        the related OTSiG to get otsi identifier";
    }
    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.";
    }
}

/* Data nodes */

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

```

```
augment "/nw:networks/nw:network" {
  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 10-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.";
    }
    container outgoing-otsi {
        description
            "The OTSi generated by the transceiver's transmitter.";
        uses otsi-ref;
    }
    container incoming-otsi {
        description
            "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 a
        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.";
          container frequency-range {
            description
              "The frequency range for which these optical
              impairments apply.";
            uses l0-types:frequency-range;
          }
          uses roadm-express-path;
        }
      }
      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.";
          container frequency-range {
            description
              "The frequency range for which these optical
```

```
        impairments apply.";
        uses l0-types:frequency-range;
    }
    uses roadm-add-path;
}
}
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 l0-types:frequency-range;
        }
        uses roadm-drop-path;
    }
}
} // list path impairments
} // augmentation for optical-impairment ROADM

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

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

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

```
    }
  } // augmentation connectivity-matrices information-source

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

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

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

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

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

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

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

    description
        "Augment TE node connectivity matrix entry.";

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

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

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

    description
        "Augment default TTP LLC.";
    leaf add-path-impairments {
        type leafref {
            path "../../../tet:te-node-attributes/"
                + "roadm-path-impairments/roadm-path-impairments-id" ;
        }
    }
}
```

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

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

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

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

```
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 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
```



```
}  
<CODE ENDS>
```

5. Security Considerations

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

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

6. IANA Considerations

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

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

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

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

7. Acknowledgments

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

8. References

8.1. Normative References

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8.2. Informative References

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Accessing Cloud via Optical Network Problem Statement
draft-liu-rtgwg-optical2cloud-problem-statement-00

Abstract

This document describes the scenarios and requirements for the Cloud accessing through optical network, as a complementary functionality of the network and cloud coordination. The problem from optical perspective is different with packet, and statement is made in this document.

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

The cloud-related applications is becoming popular and wider deployed, in enterprises and vertical industries. Companies with multi-campus are interconnected together with the remote cloud, for the purpose of storage and computation. Such cloud services require high-level experiences including high availability, low latency, on-demand adjustment and so on.

Optical is playing an important role in the transport network, with its own large bandwidth and low latency feature. Based on the TDM switching technology, the data transportation in optical networks does not have any queuing problem to solve and can perfectly avoid congestion. Such features can drastically improve the users experience on the service quality.

Optical network is considered as the transportation solution for long-distance. This feature is also suitable for the cloud interconnections, especially when there is demand for large bandwidth.

[I-D.ietf-rtgwg-net2cloud-problem-statement] and [I-D.ietf-rtgwg-net2cloud-gap-analysis] gave a detailed description on the coordination requirements between the network and the cloud, and

it is expected the description in this document can be used as a complementary from the optical perspective.

1.1. 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.

2. Scenarios

With the prevalence of cloud services, enterprises services, home services such as AR/VR, accessing clouds with optical networks is increasingly attractive and becoming an option for the users. Following scenarios provide a few typical applications.

2.1. Multi-cloud accessing

Cloud services are usually supported by multiple interconnected data centers (DCs). Besides the on-demand, scalable, high available and uses-based billing, mentioned in [I-D.ietf-rtgwg-net2cloud-problem-statement], there are also needs for Data Centre Interconnect (DCI) about high requirements on capacity, latency, and flexible scheduling. This use case requires specific capabilities of advanced OTN (Optical Transport Network) for DCIs.

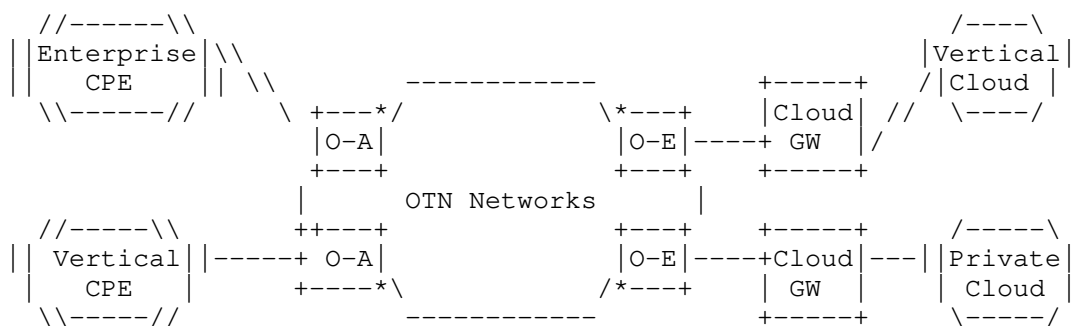


Figure 1: Cloud Accessing through Optical Network

A data center is a physical facility consisting of multiple bays of interconnected servers, that performs computing, storage, and communication needed for cloud services. Infrastructure-as-a-service

may be deployed in both public and private clouds, where virtual servers and other virtual resources are made available to users on demand and by self-service.

One typical scenario is the intra-city DCs, which communicate with each other via the intra-city DCI network to meet the high availability requirements. The active-active and Virtual Machine (VM) migration services which require low latency are provided by the intra-city DCI network. The intra-city DCI network supports the public and/or the private cloud services, such as video, games, desktop cloud, and cloud Internet cafe services. To ensure low latency, intra-city DCI network is deployed in the same city or adjacent cities. The distance is typically less than 100 km and more likely less than 50km. One city may have several large DCs.

DCs are ideally interconnected through Layer 2/3 switches or routers with full mesh connectivity. However, to improve interaction efficiency as well as service experience, OTN is also evaluated as an option to be used for DC interconnection.

There are three kinds of the connection relationship, point to point access, single to multiple point access, and multiple to multiple point access. Different types of connections are referring different shapes, single point accessing single cloud, single point accessing multiple clouds and multiple points accessing multiple clouds.

2.2. High-quality leased line

The high quality private line provides high security and reliability and is suitable to ensure the end-to-end user experience for large enterprises such as financial, medical centers and education customers. The main advantages and drivers of the high quality private line are as follows.

- o High quality private lines provide large bandwidth, low latency, secure and reliable for any type of connection.
- o Accelerate the deployment of cloud services. The high-quality and high-security of the private line connecting to the cloud can enable enterprises to move more core assets to the cloud and use low-latency services on the cloud. Cloud-based deployment helps enterprises reduce heavy asset allocation and improve energy saving, so that enterprises can focus on their major business.
- o Reduce operator's CAPEX and OPEX. The end-to-end service provisioning system enables quick provisioning of private line services and improves user experience. Fault management can be done from the device level to reduce the complexity of location.

- o Enable operators to develop value-added services by providing enterprise users with latency maps, availability maps, comprehensive SLA reports, customized latency levels, and dynamic bandwidth adjustment packages.

2.3. Cloud virtual reality

Cloud Virtual Reality (VR) offloads computing and cloud rendering in VR services from local dedicated hardware to a shared cloud infrastructure. Cloud rendered video and audio outputs are encoded, compressed, and transmitted to user terminals through fast and stable networks. In contrast to current VR services, where good user experience primarily relies on the end user purchasing expensive high-end PCs for local rendering, cloud VR promotes the popularization of VR services by allowing users to enjoy various VR services where rendering is carried out in the cloud.

Cloud VR service experience is impacted by several factors that influence the achieved sense of reality, interaction, and immersion, which are related to the network properties, e.g. bandwidth, latency and packet loss. The network performance indicators, such as bandwidth, latency, and packet loss rate, need to meet the requirements to realize a pleasurable experience.

The current network may be able to support early versions of cloud VR (e.g. 4K VR) with limited user experience, but will not meet the requirements for large scale deployment of cloud VR with enhanced experience (e.g. Interactive VR applications, cloud games). To support more applications and ensure a high-quality experience, much higher available and guaranteed bandwidth (e.g. larger than 1 Gbps), lower latency (e.g. less than 10 ms) and lower jitter (e.g. less than 5 ms) are required.

3. Requirement and Problem statement

3.1. LxVPN of optical networks for multiple-to-multiple access

To establish MP2MP connections, TDM transport technologies, like OTN, are adopting packet features. Some OTN equipments have adopted packet processing functions, such as packet switching, MPLS VPN, etc., which could provide an underlay performance guaranteed TDM channel for cloud accessing, as an alternative of packet-based connections.

3.2. Small Granularity Switching

According to the ITU-T G.709 recommendation, the OTN is providing TDM based connection with a granularity 1.25Gbps, which is more than the demand for normal user. Most of the leased line is requesting a bandwidth less than 10Mbps, and the request from big enterprises are usually on the level of 100Mbps. Therefore, most of the leased lines are with small granularity in the field.

The SDH was a good complementary of OTN for small granularity solution, but SDH devices are gradually removed from the network due to End of Services. As SDH networks gradually phase out, service providers start to think about how to utilize OTN networks to transmit small-granularity high-value SDH services. The OSU (optical service unit) is proposed to solve the problem.

At ITU-T, two work items, G.sub1G.sup and G.OSU, have been initiated aiming to enable OTN to support small-granularity services of 2M-1Gb/s. For G.OSU, the general idea is to put small granularity services into OSU containers, and then put OSU containers into OPU payload areas. OSU containers are flagged by Tributary Port Number (TPN) tags located at the overhead of the OSU containers. At the intermediate nodes, OSUs can be switched to different directions based on the TPN tags in the overhead. Given the development of OSU, the OTN is expected to be able to carry small granularity service and create end-to-end optical connections.

3.3. High-performance and high-reliability

To support the above-mentioned applications some of the network properties are critical to promise the Quality of Services (QoS). For instance, high bandwidth (e.g. larger than 1 Gbps), low latency (e.g. no more than 10 ms) and low jitter (e.g. no more than 5 ms), are required for Cloud VR. In addition, small-granularity container is required to improve the efficiency of the networks.

It is also critical to support highly reliable DCI for cloud services. With advanced optical transport network protection and automatic recovery technologies, services can still run properly even fiber cuts occur in the DCI network. Specific protection and restoration schemes are required, to provide high reliability for the networks.

4. Manageability Considerations

TBD.

5. Security Considerations

TBD.

6. IANA Considerations

This document requires no IANA actions.

7. References

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A YANG Data Model for Optical Network Inventory
draft-yg3bp-ccamp-optical-inventory-yang-00

Abstract

This document defines a YANG data model for optical network 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 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 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 inventory data model.

For optical network 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 analysed to cover the requirements and use cases for Optical Network 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

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].

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

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

Network Element: a device installed on one or several shelves and can afford some specific transmission function independently.

Cabinet: 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 equipments of the network element, including rack, shelf, slot, sub-slot, board and port.

Board/Card: a pluggable equipment on the network element and can afford a specific transmission function independently.

Port: an interface on board

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 the following table.

| Prefix | Yang Module | Reference |
|--------|------------------------|-----------|
| ianahw | iana-hardware | [RFC8348] |
| ni | ietf-network-inventory | RFCXXX |
| yang | ietf-yang-types | [RFC6991] |

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 Optical Network 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, shelf, 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:

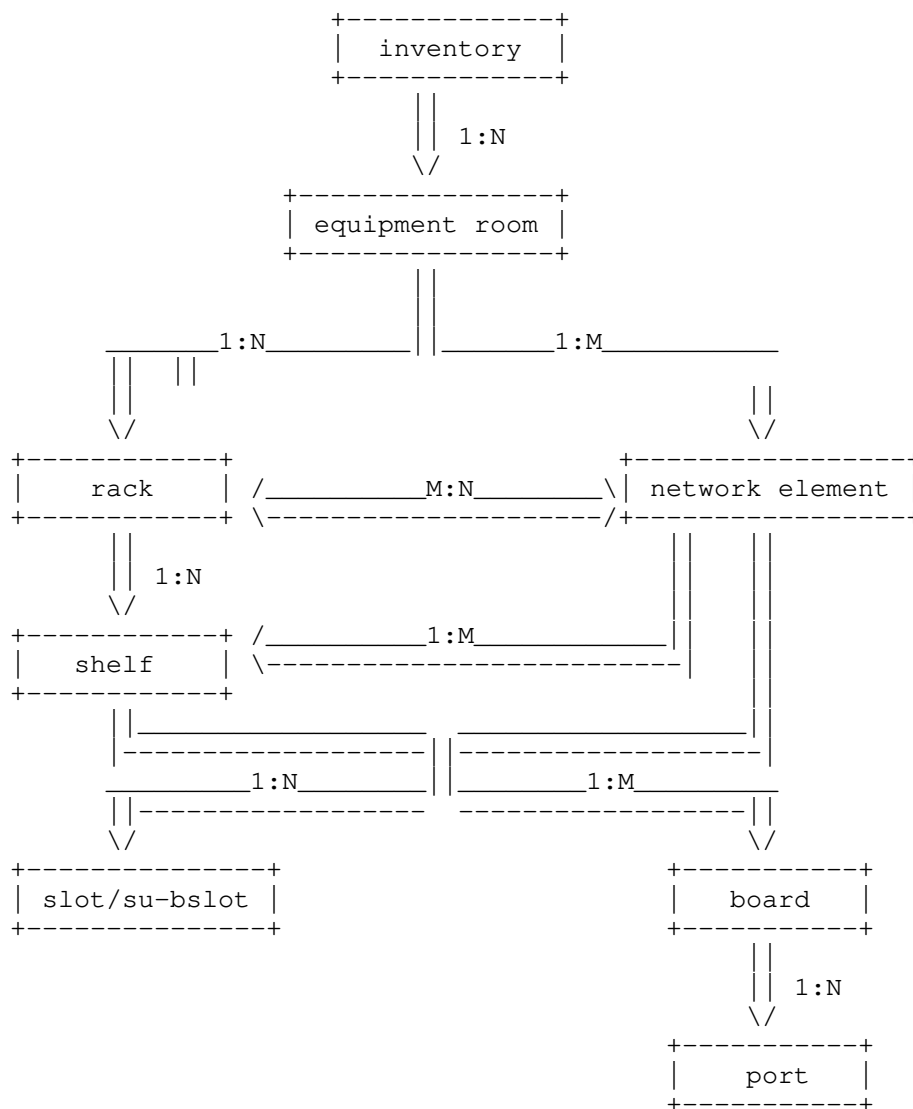


Figure 1: Relationship between inventory objects

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

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 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 inventory model when the controller uses the YANG data model defined in [RFC8348] to retrieve the hardware configuration from the network elements under its control.

Note: review in future versions of this document which attributes from [RFC8348] are required also for network inventory and whether there are attributes not defined in [RFC8348] which are required for network 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 rack* [uuid]
      +--ro uuid          yang:uuid
      .....
    +--ro shelves* [uuid]
      +--ro uuid          yang:uuid
      .....
    +--ro chassis-ref
      +--ro ne-ref?       leafref
      +--ro component-ref? leafref
  +--ro network-elements
    +--ro network-element* [uuid]
      +--ro uuid          yang:uuid
      .....
    +--ro components
      +--ro component* [uuid]
        +--ro uuid          yang:uuid
        .....

```

The YANG data model for network inventory follows the same approach of [RFC8348] and reports the network inventory as a list of components of different types (e.g., chassis, module, port).

```

+--ro components
  +--ro component* [uuid]
    +--ro uuid          yang:uuid
    +--ro name?         string
    +--ro description?  string
    +--ro class?        identityref
    +--ro parent-rel-pos? int32
    +--ro children* [child-ref]
      | +--ro child-ref  -> ../../../../uuid
    +--ro parent
      +--ro parent-ref? -> ../../../../uuid

```

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

However, 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 shelves in the rack should have some reference information to the component.

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 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 analysed 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. Optical Network Inventory Tree Diagram

Figure 2 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 location?     string
      +--ro rack* [uuid]
        +--ro uuid          yang:uuid
        +--ro name?         string
        +--ro row-number?   uint32
        +--ro rack-number?  uint32
        +--ro shelves* [uuid]
          +--ro uuid          yang:uuid
          +--ro name?         string
          +--ro shelf-number? uint8
          +--ro chassis-ref
            +--ro ne-ref?      leafref
            +--ro component-ref? leafref
      +--ro network-elements
        +--ro network-element* [uuid]
          +--ro uuid          yang:uuid
          +--ro name?         string
          +--ro components
            +--ro component* [uuid]
              +--ro uuid          yang:uuid
              +--ro name?         string
              +--ro description?   string
              +--ro class?         identityref
              +--ro parent-rel-pos? int32
              +--ro children* [child-ref]
              | +--ro child-ref   -> ../../../../uuid
              +--ro parent
                +--ro parent-ref? -> ../../../../uuid

```

Figure 2: Network inventory tree diagram

4. YANG Model for Optical Network Inventory

```

<CODE BEGINS> file "ietf-network-inventory@2021-10-25.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.";
}

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

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description
  "This module defines a model for retrieving network inventory.

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

  Copyright (c) 2021 IETF Trust and the persons
  identified as authors of the code.  All rights reserved.

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  (https://trustee.ietf.org/license-info).
```

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

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 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.";
    }
}
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;
            uses components-grouping;
        }
    }
}

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";
            }
        }
        list rack {
            key uuid;
            description
                "The list of racks within an equipment room.";
            uses common-entity-attributes;
            leaf row-number {
                type uint32;
                description
                    "Identifies the row within the equipment room where
```

```

    the rack is located.";
}
leaf rack-number {
    type uint32;
    description
        "Identifies the physical location of the rack within
        the row.";
}
list shelves {
    key uuid;
    description
        "The list of shelves within a rack.";
    uses common-entity-attributes;
    leaf shelf-number {
        type uint8;
        description
            "Identifies the location of the shelf within the
            rack.";
    }
    container chassis-ref {
        description
            "The reference to the network element component
            representing this shelf.";
        leaf ne-ref {
            type leafref {
                path "/ni:network-inventory/ni:network-elements"
                    + "/ni:network-element/ni:uuid";
            }
            description
                "The reference to the network element containing
                the component.";
        }
        leaf component-ref {
            type leafref {
                path "/ni:network-inventory/ni:network-elements"
                    + "/ni:network-element[ni:uuid]"
                    + "=current()/../ne-ref[/ni:components]"
                    + "/ni:component/ni:uuid";
            }
            description
                "The reference to the component within the network
                element.";
        }
    }
}
}
}
}

```

```
}

groupings 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 description {
        type string;
        description
          "A textual description of the component.";
        reference
          "RFC 8348: A YANG Data Model for Hardware Management.";
      }
      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 parent-rel-pos {
        type int32 {
          range "0 .. 2147483647";
        }
        description
          "An indication of the relative position of this child
           component among all its sibling components. Sibling
           components are defined as components that:

              o share the same value of the 'parent' node and

              o share a common base identity for the 'class' node.";
        reference
          "RFC 8348: A YANG Data Model for Hardware Management.";
      }
      list children {
        key child-ref;
        description
```

```

    "The child components that are physically contained by
    this component.";

    leaf child-ref {
      type leafref {
        path "../..../..../ni:uuid";
      }
      description
        "The reference to the child component.";
    }
  }
  container parent {
    description
      "The parent component that physically contains this
      component.

      If this container is not instantiated, it indicates
      that this component is not contained in any other
      component.

      In the event that a physical component is contained by
      more than one physical component (e.g., double-wide
      modules), this container contains the data of one of
      these components.  An implementation MUST use the same
      component every time this container is instantiated.";
    leaf parent-ref {
      type leafref {
        path "../..../..../ni:uuid";
      }
      description
        "The reference to the parent component.";
    }
  }
}
}
}
}
}
<CODE ENDS>

```

Figure 3: 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>

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A YANG Data Model for WDM management in Front-Haul NBI
draft-zhaosun-ccamp-front-haul-wdm-yang-01

Abstract

This document introduces an architecture of semi-active fronthaul WDM system and explains how the semi-active devices can be managed by a transmission controller. This document also specifies a YANG data model for the WDM devices in front-haul scenario, which is defined in G.owdm. The model is expected to be used in the Northbound of controller.

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1. Introduction

In the 5G era, great change of the basic wireless network architecture from RRU-BBU to AAU-DU-CU brings the change of 5G transport network from fronthaul-backhaul to fronthaul-middlehaul-backhaul network. Moreover, to avoid excessive transmission bandwidth requirement, the CPRI interface evolves to eCPRI interface.

Contemporaneously, the Centralized, Collaborative, Cloud and Clean Radio Access Network architecture (C-RAN) have been actively deployed instead of the previous D-RAN architecture by several operators. For example, the medium-scale C-RAN centralized with 10 base stations will become the main scenario for 5G network, according to the statistics of different provinces in China. It is noted that the transmission distance will be increased from a few hundred meters for D-RAN to up to 10km for C-RAN (typically 5~10km). As the degree of centralization increases and the distance from AAU to DU becomes longer, the complexity of control and operation and maintenance will greatly increased.

The traditional front-haul solutions will not meet the requirements of C-RAN, such as the traditional fibre direct connection solution which requires 12 fibres for six duplex modules of one base station and occupies large fiber resources for medium and large scale C-RAN. However, if using WDM technology, a basic fronthaul requirement of a 5G base station with 12-channels can be satisfied by one fiber. A lot of fiber resource would be saved.

For 5G C-RAN front-haul network, several front-haul transport schemes based on WDM technology have been proposed to solve the lack of fiber core, including passive WDM, active WDM, and semi-active WDM.

The passive WDM system is composed of WDM optical modules and a pair of passive de/multiplexer at both AAU and DU sides, which has the advantages of low cost, flexible deployment, etc. However, the passive equipments cannot support on-line management. The potential fault points should be manually processed one by one, including optical modules, WDM de/multiplexer, branch fibers between optical modules and WDM de/multiplexer, trunk fibers between a pair of WDM de/multiplexer. This result in long fault detection and service disruption time.

The active WDM scheme is composed of a pair of active WDM equipments at both AAU and DU sides and can perform powerful OAM functions, but the system cost is sharply increased and the deployment of the active equipment at AAU side is limited by power supply.

The semi-active WDM solution with a passive AAU side and active DU side not only greatly reduces the pressure of optical fiber resources, but also has the advantages in cost (compared with the active solution), management and protection of the front-haul network (compared with the passive solution). It helps operators to build 5G fronthaul networks with low cost, high bandwidth and fast deployment. A centralized transmission controller could manage all the semi-active WDM systems in a large zone.

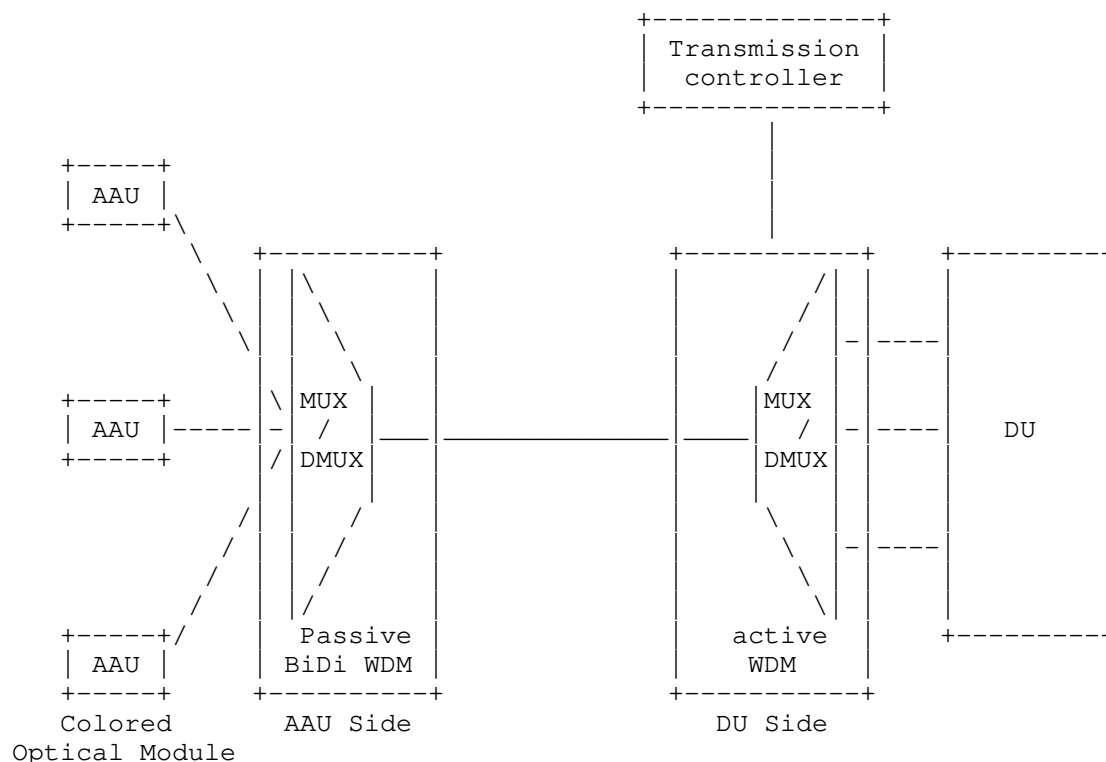


Figure 1: Figure 1:Semi-active WDM solution

1.1. 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.

2. Architecture for Semi-active Front-haul WDM

The semi-active WDM system is composed by a passive AAU side with colored optical modules and passive BiDi WDM like MUX/DEMUX, and an active DU side with active WDM equipment and modules. The active WDM equipment should be composed by passive BiDi WDM, microprocessor unit and OAM modulation/demodulation unit. There are some management challenges of semi-active WDM system that need to be resolved. Since the the AAU and DU are both wireless devices and could not be managed by transmission controller, the management of optical modules at AAU/

DU side is difficult and special. Because of the passive AAU side, the management of passive AAU side have to be done through the active DU side.

One of workable solutions is introduced below. An OAM channel in the semi-active WDM solution could be implemented by service signal overhead or pilot tone with the low modulation depth of the optical channel signal. The OAM channel is used to transmit management and control information between the AAU side and the DU side. The active WDM equipment could send management requests to the AAU and manage the optical modules within the AAU, including query and configuration. The optical modules within the AAU can receive management requests from the active WDM equipment and then send the OAM information of AAU and the optical modules to the active WDM equipment automatically or at regular time intervals once the optical modules are powered on, including the wavelength, driving voltage, driving current, launch power of the transmitter, transceiver optical receive power, etc. The WDM optical modules can add the OAM information with the service signals and transport together in the same optical channel. The detection unit in the active WDM equipment can demodulate the OAM information, obtain the transmission performance of AAU and modules, and then report it to the transmission controller.

The centralized transmission controller for the semi-active WDM systems could display of the network topology, equipment, and module information, and support fault monitoring of the fronthaul network. Fig.2 shows the link failure monitoring functions. These failures could be monitored at branch fibers between optical modules and WDM de/multiplexer in AAU side as 1 and 2, branch fibers between optical modules and WDM de/multiplexer in DU side as 4 and 5, fiber link as 3, modules as 6 illustrated in Figure 2.

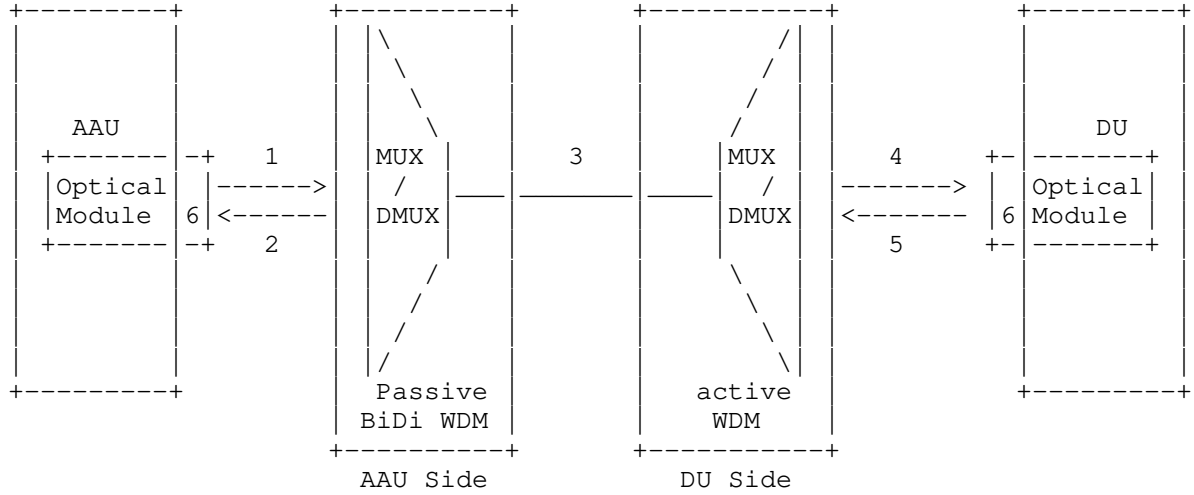


Figure 2: Figure 2: Illustration of potential failures analysis

There is also a requirement for protection in the semi-active WDM solution. By introducing a splitter and a switch between the remote and local part as figure 3, the semi-active WDM system is of OLP protection like capability.

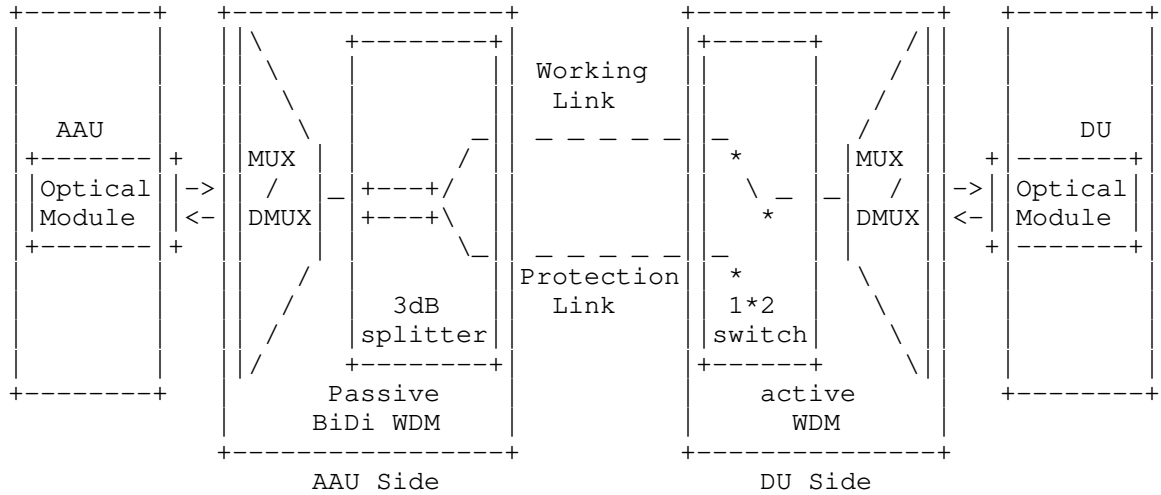


Figure 3: Figure 3: Protection of semi-active WDM system

3. Model Relationship

In the semi-active WDM solution, transmission controller is preferred to manage WDM equipments and the optical models on AAU and DU. Though there are some data models have been defined for the WDM management, consider that the AAU and DU are both wireless devices, some extensions are needed for the transmission controller to manage them.

For a full-lifecycle management, the traditional NMS function and SDN control plane are both required, includes tunnel, topology, inventory, alarm and performance management.

For daily maintenance, e.g. fault location, there is a requirement of viewing the whole signal flow. So the tunnel and topology model are necessary in the semi-active WDM system management. The WDM related models existing, like RFC9094, draft-ietf-ccamp-wson-tunnel-model and draft-ietf-ccamp-flexgrid-yang etc. are all considered useable in semi-active WDM system management.

It is suggested that the solution and data model in draft-yg3bp-ccamp-optical-inventory-yang can be used for inventory management. The inventory model is in the first I-D draft version state, let's keep tracing on this model.

Solution and data model in RFC8632 should be used for alarm management. We will do more research on whether is there special requirements of semi-active system on alarm management.

For the performance management, e.g. OAM and loop-back operations, is also required for the semi-active WDM system management. The draft-ietf-teas-actn-pm-telemetry-autonomics defines a generic performance management framework. And the draft-zheng-ccamp-client-pm-yang defines an Ethernet over OTN service level performance monitoring. We consider that both of these two models can be used in the semi-active WDM management model in the future.

4. YANG Tree

We will provide some augmentations on the existing tunnel, topology, inventory, alarm and performance models based on our further investigation.

5. YANG Code for Front-haul WDM

We will provide some augmentations on the existing tunnel, topology, inventory, alarm and performance models based on our further investigation.

6. Security Considerations

TBD

7. IANA Considerations

This document does not have any requirement on IANA allocation.

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Framework and Data Model for OTN Network Slicing
draft-zheng-ccamp-yang-otn-slicing-03

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. 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.

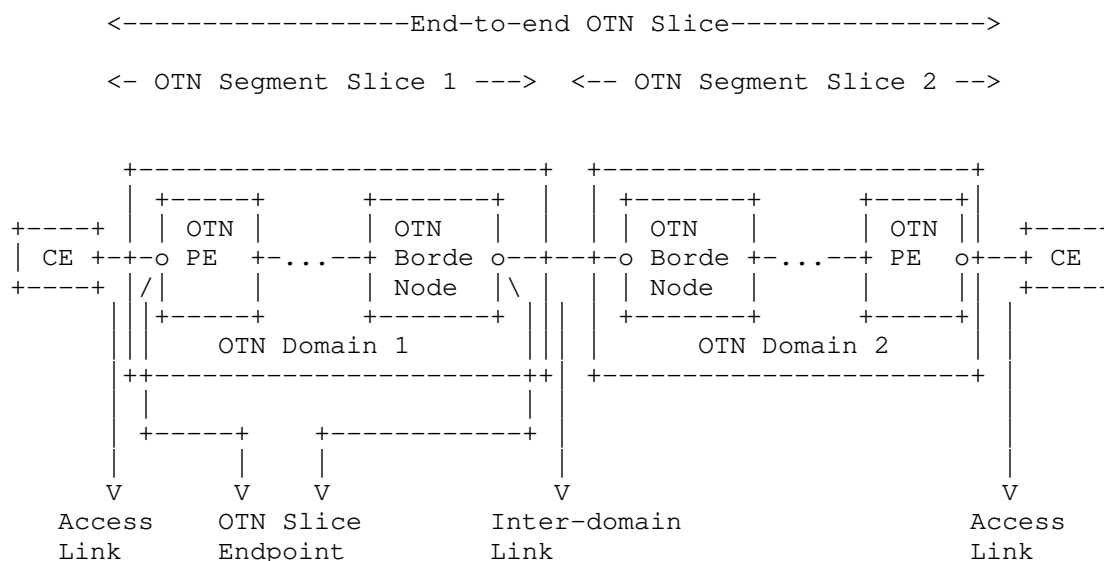


Figure 1: OTN Slice

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 connectivities 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, whose 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-blockable 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.

When realizing OTN slices, the OTN-SC may translate a connectivity-based OTN slice into a set of end-to-end tunnels using the Traffic-engineering(TE) tunnel interface defined in [I-D.ietf-teas-yang-te]. For a resource-based OTN slice, the OTN-SC may translate the abstract topology representing the slice into a colored graph on an abstract TE topology using the TE topology interface defined in [RFC8795].

The OTN-SC NBI is technology-specific, while the IETF NSC-NBI is technology-agnostic. An IETF NSC may translate its customer's technology-agnostic slice request into an OTN slice request and utilize the OTN-SC NBI to realize the IETF network slice. Alternatively, the IETF NSC may translate the slicing request into tunnel or topology configuration commands and communicate directly with the underlying PNC or MDSC to provision the IETF network slice.

Figure 2 illustrates the OTN slicing control hierarchy and the positioning of the OTN slicing interfaces.

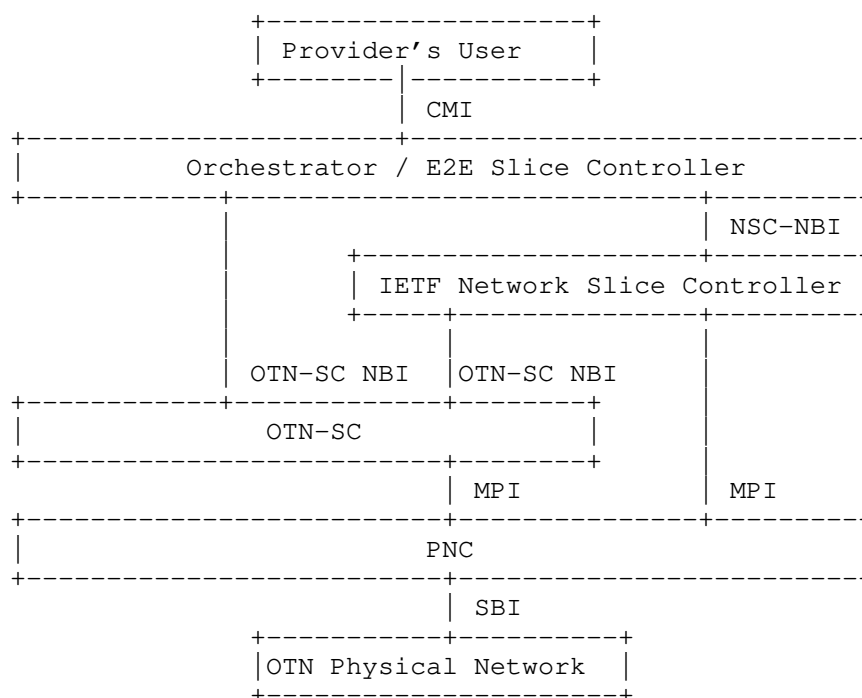


Figure 2: Positioning of OTN Slicing Interfaces

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.

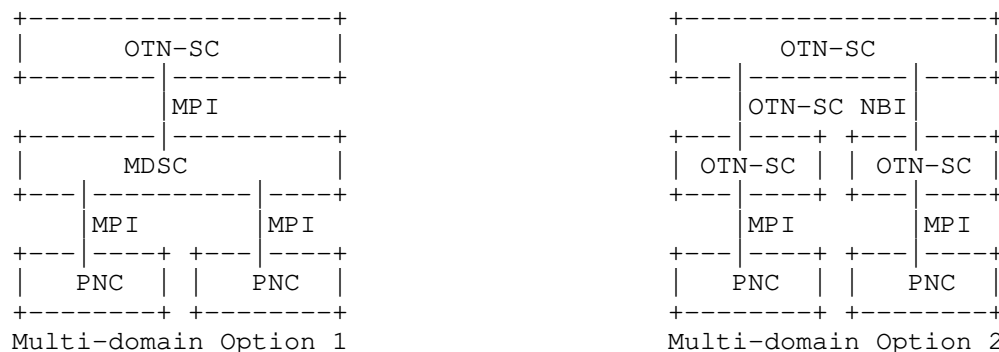


Figure 3: OTN-SC for multi-domain

OTN-SC functionalities are logically independent and may be deployed in different combinations to cater to the realization needs. In reference with 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. YANG Data Model for OTN Slicing Configuration

4.1. OTN Slicing YANG Model for MPI

4.1.1. 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.

4.1.2. MPI YANG Model Tree

module: ietf-otn-slice

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

Figure 4: OTN slicing tree diagram

4.1.3. MPI YANG Code

```
<CODE BEGINS> file "ietf-otn-slice@2021-10-22.yang"
module ietf-otn-slice {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-otn-slice";
  prefix "otnslice";

  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 "otntopo";
    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>

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    Editor: Victor Lopez
           <mailto:victor.lopezalvarez@telefonica.com>;

  description
    "This module defines a YANG data model to configure an OTN
    network slice realization.

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

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```
revision "2021-10-22" {
  description
    "Latest revision of MPI YANG model for OTN slicing.";
  reference
    "draft-zheng-ccamp-yang-otn-slicing-03: 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 ll-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.";
}
}
}
}
}
/*
 * Augments
 */
augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:te-link-attributes" {
  when "../.../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description
      "Augmentation parameters apply only for networks with
       OTN topology type.";
  }
  description
    "Augment OTN TE link attributes with slicing profile.";
  uses otn-link-slice-profile;
}
}

```

<CODE ENDS>

Figure 5: OTN slicing YANG model

4.2. OTN Slicing YANG Model for OTN-SC NBI

4.2.1. 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.

4.2.2. NBI YANG Model Tree for Transport Network Slice

```

module: ietf-transport-network-slice
  +--rw network-slices
    +--rw network-slice* [ns-id]
      +--rw ns-id                string
      +--rw ns-name?             string
      +--rw ns-description?      string
      +--rw customer-name*       string

```

```

+--rw slo
|   +--rw optimization-criterion?  identityref
|   +--rw delay-tolerance?         boolean
|   +--rw periodicity*             uint64
|   +--rw isolation-level?         identityref
+--rw endpoints
|   +--rw endpoint* [endpoint-id]
|       +--rw endpoint-id         string
+--rw network-topologies
|   +--rw network-topology* [topology-id]
|       +--rw topology-id         string
|       +--rw node* [node-id]
|           +--rw node-id         inet:uri
|           +--rw slo
|               +--rw isolation-level?  identityref
|           +--rw termination-point* [tp-id]
|               +--rw tp-id         inet:uri
|               +--rw endpoint-id?    leafref
+--rw link* [link-id]
|   +--rw link-id                 inet:uri
|   +--rw slo
|       +--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
+--rw connectivity-matrices
|   +--rw connectivity-matrix* [connectivity-matrix-id]
|       +--rw connectivity-matrix-id  uint32
|       +--rw topology-id?            leafref
|       +--rw src-endpoint?
|           -> ../../../../endpoints/endpoint/endpoint-id
|       +--rw dst-endpoint?
|           -> ../../../../endpoints/endpoint/endpoint-id
|       +--rw slo
|       +--rw explicit-path* [tp-id]
|           +--rw tp-id              leafref

```

Figure 6: Tree diagram for transport network slice

4.2.3. NBI YANG Code for Transport Network Slice


```
<CODE BEGINS> file "ietf-transport-network-slice@2021-10-22.yang"
module ietf-transport-network-slice {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-transport-network-slice";
  prefix "tns";

  import ietf-inet-types {
    prefix inet;
    reference "RFC 6991";
  }

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

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

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            <mailto:aihuaguo.ietf@gmail.com>

    Editor: Victor Lopez
            <mailto:victor.lopezalvarez@telefonica.com>";

  description
    "This module defines a YANG data model to configure an OTN
    network slice realization.

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

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revision "2021-10-22" {
  description
    "Latest revision of NBI YANG model for OTN slicing.";
  reference
    "draft-zheng-ccamp-yang-otn-slicing-03: 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 ns-generic-info {
    description
        "Generic configuration of a network slice";
    leaf ns-name {
        type string;
        description
            "Name of the specific network slice";
    }
    leaf ns-description {
        type string;
        description
            "Description regarding the specific network slice";
    }
    leaf-list customer-name {
        type string;
        description
            "List of customers using the slice";
    }
}
```

```
    }  
  }  
  
  grouping ns-slo {  
    description  
      "SLO configuration of a network slice";  
  
    container slo {  
      description  
        "SLO configuration of a network slice";  
  
      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 node-slo {
  description
    "Node SLO";
  container slo {
    description
      "SLO configuration of a node";
    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 link-slo {
  description
    "Link SLO";
  container slo {
    description
      "SLO configuration of a link";
    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 connectivity-matrix-slo {
    description
        "SLO configuration of a path within a network slice";

    container slo {
        description
            "Path SLO configuration";
    }
    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 connectivity-matrix-entry-slo {
    description
```

```
        "SLO configuration of a connectivity matrix entry within a
        network slice";

    container slo {
        description
            "SLO configuration of a connectivity matrix entry";
    }
}

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 "/network-slices/network-slice[ns-id=current() "+
                    "/../../../../../../../../ns-id]/network-topologies"+
                    "/network-topology[topology-id=current() "+
                    "/../../../../topology-id]/node/termination-point/tp-id";
            }
            description
                "Relative reference to TP id.";
        }
    }
}

grouping network-topology-def {
    description
        "Network topology definition";
    list node {
        key "node-id";
        description
            "The inventory of nodes of this topology.";
        leaf node-id {
            type inet:uri;
            description
                "Node identifier.";
        }
    }
    uses node-slo;
    list termination-point {
        key "tp-id";
        description
            "TP identifier";
        leaf tp-id {
```

```
        type inet:uri;
        description
            "Termination point identifier.";
    }
    leaf endpoint-id {
        type leafref {
            path "/network-slices/network-slice[ns-id=current()"+
                ".../ns-id]/endpoints/endpoint/"+
                "endpoint-id";
        }
        description
            "Relative reference to TP id.";
    }
}
list link {
    key "link-id";
    description
        "Link identifier.";
    leaf link-id {
        type inet:uri;
        description
            "Link identifier.";
    }
    uses link-slo;
    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 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.";
    }
  }
}

/*
 * Configuration data nodes
 */
container network-slices {
  description
    "Generic network slice configurations";
  list network-slice {
    key "ns-id";
    description
      "Network slice identifier";
    leaf ns-id {
      type string;
      description
        "A unique network slice identifier across a slice controller";
    }
    uses ns-generic-info;
    uses ns-slo;

    container endpoints {
      description
        "Endpoints of a network slice";

      list endpoint {
        key "endpoint-id";
        description
          "List of endpoints";
        leaf endpoint-id {
          type string;
        }
      }
    }
  }
}
```

```

        description
            "Endpoint identifier";
    }
}
}
container network-topologies {
    description
        "A network slice is described as a network topology";

    list network-topology {
        key "topology-id";
        description
            "List of network topologies";
        leaf topology-id {
            type string;
            description
                "Topology identifier";
        }
        uses network-topology-def;
    }
}
container connectivity-matrices {
    description
        "Connectivity matrices";

    list connectivity-matrix {
        key "connectivity-matrix-id";
        description
            "List of connectivity matrix entities";
        leaf connectivity-matrix-id {
            type uint32;
            description
                "Connectivity matrix identifier";
        }
        leaf topology-id {
            type leafref {
                path "../../network-topologies/network-topology/topology-id";
            }
            description
                "Relative reference to network topology id.";
        }
        leaf src-endpoint {
            type leafref {
                path "../../endpoints/endpoint/endpoint-id";
            }
            description
                "Relative reference to endpoint id.";
        }
    }
}

```

```
    leaf dst-endpoint {
      type leafref {
        path "../../endpoints/endpoint/endpoint-id";
      }
      description
        "Relative reference to endpoint id.";
    }
    uses connectivity-matrix-entry-slo;
    uses explicit-path;
  } //connectivity-matrix
} //connectivity-matrices
} //network-slice
} //network slices
}
<CODE ENDS>
```

Figure 7: YANG model for transport network slice

4.2.4. NBI YANG Model Tree for OTN slice

TBD.

4.2.5. NBI YANG Code for OTN Slice

TBD.

5. 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.

6. Security Considerations

<Add any security considerations>

7. IANA Considerations

<Add any IANA considerations>

8. References

8.1. Normative References

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