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## YANG Data Models for Multiprotocol Label Switching - Transport Profile

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## Abstract

Multi-protocol Label Switching - Transport Profile (MPLS-TP) is a profile of the MPLS protocol that is used in packet switched transport networks and operated in a similar manner to other existing transport technologies (e.g., OTN), as described in RFC5921. This document specifies YANG models for MPLS-TP, which have not been covered by existing models so far. The gap analysis with current relevant traffic-engineering (TE) and MPLS models is also included.

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## 1. Introduction

Multi-protocol Label Switching - Transport Profile (MPLS-TP) is a packet switching technology intended operated in a similar manner to other existing transport technologies (e.g., OTN), as described in [RFC5921], which includes Traffic Engineering (TE) features.

Generic TE models, including the TE topology and tunnel, have been defined in [TE-Topology] and [TE-Tunnel] using the YANG data modeling language and are applicable to any TE technologies including MPLS-TE and OTN and therefore also to MPLS-TP.

The YANG models for MPLS with TE features (MPLS-TE), are provided in [TE-MPLS] as a technology-specific augmentations of the generic TE models. However, technology-specific augmentations for TE label, and TE bandwidth of TE Topology and Tunnel models, have not been covered yet.

This document defines YANG data models for MPLS-TP topologies and tunnels, providing the minimum set of attributes that are required and not yet available in existing TE and MPLS YANG models. See section 3 and 4 for more detailed gap analysis.

The proposed MPLS-TP YANG models can be used as an input to enhance the current MPLS-TE YANG models.

## 2. Considerations on the Augmentation

### 2.1. Modules Relationship

In this draft two models are proposed: one MPLS-TP technology-specific topology model that augments the `ietf-te-topology` YANG module, defined in [TE-Topology], and another MPLS-TP technology-specific tunnel model that augments the `ietf-te` YANG module, defined in [TE-Tunnel].

The following common fundamental models are imported:

- o `ietf-routing-types` defined in [RFC8294]

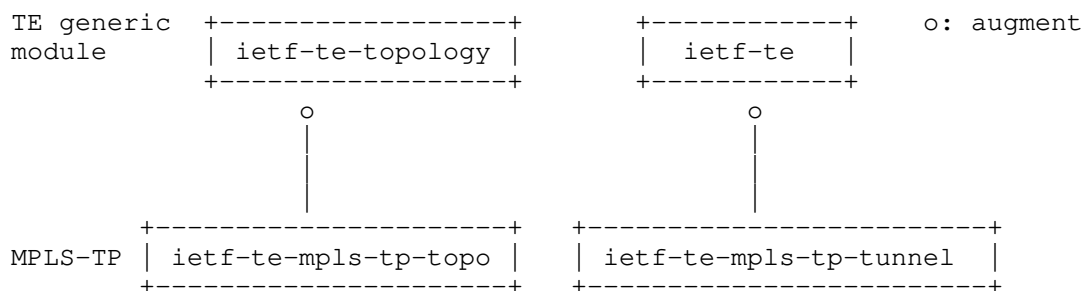


Figure 1: Relationship of MPLS-TP topology and tunnel module with TE generic TE topology and tunnel YANG modules

## 2.2. Prefixes in Model 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
yang	ietf-yang-types	[RFC6991]
inet	ietf-inet-types	[RFC6991]
rt-types	ietf-routing-types	[RFC8294]
tet	ietf-te-topology	[TE-Topology]
te	ietf-te	[TE-Tunnel]
te-mpls	ietf-te-mpls	[TE-MPLS]
mpls-tp-topo	ietf- mpls-tp-topo	This document
mpls-tp-tunnel	ietf- mpls-tp-tunnel	This document

Table 1: Prefixes and corresponding YANG modules

## 3. Gap Analysis for MPLS-TP topology

There are no YANG models that provide MPLS-TE technology-specific augmentations of the generic TE Topology model defined in [TE-Topology].

This section analyses the minimum set of attributes that are required to be specified in an MPLS-TP technology-specific augmentation.

Additional attributes that may be required to support a broader set of MPLS-TP and/or MPLS-TE functions are for further study.

Given the guidance for augmentation in [TE-Topology], the following technology-specific augmentations need to be provided:

- A network-type to indicate that the TE topology is an MPLS-TP Topology, as follow:

```
augment /nw:networks/nw:network/nw:network-types/tet-te-topology:
  +-- rw mpls-tp-topology!
```

- TE Bandwidth Augmentations a described in section 3.1;

- TE Label Augmentations as described in section 3.2;

### 3.1. TE Bandwidth Augmentations

Following TE Bandwidth attributes are needed to be augmented to the module `ietf-te-topology` in [TE-Topology]:

- Augmentations for `te-bandwidth` in the `max-link-bandwidth`, `max-resv-link-bandwidth` and `unreserved-bandwidth` attributes of MPLS-TP TE Links are necessary for `te-link-attributes` and listed as follow. It is worth noting that for `te-bandwidth` in other places, this augment is not necessary.

```
augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-
attributes/tet:max-link-bandwidth/tet:te-bandwidth/tet:technology:
  +--: (mpls-tp)
    +--rw mpls-tp-bandwidth?   uint64
```

```
augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-
attributes/tet:max-resv-link-bandwidth/tet:te-
bandwidth/tet:technology:
  +--: (mpls-tp)
    +--rw mpls-tp-bandwidth?   uint64
```

```
augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-
attributes/tet:unreserved-bandwidth/tet:te-
bandwidth/tet:technology:
  +--: (mpls-tp)
    +--rw mpls-tp-bandwidth?   uint64
```

- Augmentations for the `max-lsp-bandwidth` attribute are necessary for MPLS-TP TE Links and TTPs and listed as following. It is worth noting that for the other '`max-lsp-bandwidth`', this augmentation is not necessary.

```
augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-
attributes/tet:interface-switching-capability/tet:max-lsp-
bandwidth/tet:te-bandwidth/tet:technology:
  +--: (mpls-tp)
    +--rw bandwidth-profile-name?   string
    +--rw bandwidth-profile-type?   identityref
    +--rw CIR?                       uint64
    +--rw EIR?                       uint64
    +--rw CBS?                       uint64
```

```
    +---rw EBS?                               uint64

augment /nw:networks/nw:network/nw:node/nt:termination-
point/tet:te/tet:interface-switching-capability/tet:max-lsp-
bandwidth/tet:te-bandwidth/tet:technology:
  +---:(mpls-tp)
    +---rw bandwidth-profile-name?            string
    +---rw bandwidth-profile-type?            identityref
    +---rw CIR?                               uint64
    +---rw EIR?                               uint64
    +---rw CBS?                               uint64
    +---rw EBS?                               uint64
```

### 3.2. TE Label Augmentations

In MPLS-TP, the label allocation is done by NE, information about label values availability is not necessary to be provided to the controller. Moreover, MPLS-TP tunnels are currently established within a single domain.

Therefore this document does not define any MPLS-TP technology-specific augmentations, of the TE Topology model, for the TE label since no TE label related attributes should be instantiated for MPLS-TP Topologies.

## 4. Gap Analysis for MPLS-TP Tunnel Configuration

MPLS-TE technology-specific augmentations of the generic TE Tunnel model defined in [TE-MPLS].

This section analyses the minimum set of attributes that are required to be specified in an MPLS-TP technology-specific augmentation and not yet available in [TE-MPLS].

Additional attributes that may be required to support a broader set of MPLS-TP and/or MPLS-TE functions are for further study.

Although there are no guidance for augmentation in [TE-Tunnel], the following technology-specific augmentations need to be provided:

- TE Bandwidth Augmentations as described in section 4.1
- TE Label Augmentations as described in section 4.2

#### 4.1. TE Bandwidth Augmentation

Following TE Bandwidth attributes are needed to be augmented for MPLS-TP to the module `ietf-te` in [TE-Tunnel], but are not yet defined in [TE-MPLS]:

- Augmentations for the `te-bandwidth` attribute of TE Tunnels under `te/globals/tunnels` are listed as follow. It is worth noting that for `te-bandwidth` in other places, this augmentation is not necessary.

```
augment /te:te/te:tunnels/te:tunnel/te:te-bandwidth/te:technology:
  +--:(mpls-tp)
    +--rw bandwidth-profile-name?   string
    +--rw bandwidth-profile-type?   identityref
    +--rw CIR?                      uint64
    +--rw EIR?                      uint64
    +--rw CBS?                      uint64
    +--rw EBS?                      uint64
```

#### 4.2. TE Label Augmentation

Following TE Label attributes are needed to be augmented for MPLS-TP to the module `ietf-te` in [TE-Tunnel], but are not yet defined in [TE-MPLS]:

- Augmentations for the `te-label` attribute of MPLS-TP label hops are used to report the computed primary and secondary paths of MPLS-TP TE Tunnels as well as the route and the path of the MPLS-TP LSPs of the primary and secondary paths of MPLS-TP TE Tunnels. These augmentations are listed as follow, and it is worth noting for `te-label` in other places, there is no need to do the augmentation.

```
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:
  +--:(mpls-tp)
    +--ro mpls-label?   rt-types:mpls-label
```

```
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:
```

```
    +--:(mpls-tp)
      +--ro mpls-label?    rt-types:mpls-label

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:
  +--:(mpls-tp)
    +--ro mpls-label?    rt-types:mpls-label

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:
  +--:(mpls-tp)
    +--ro mpls-label?    rt-types:mpls-label
```

## 5. Related YANG Code

### 5.1. YANG Code for MPLS-TP Topology Augmentation

```
<CODE BEGINS>file "ietf-mpls-tp-topology@2019-03-11.yang"
module ietf-mpls-tp-topology {
  //yang-version 1.1;

  namespace "urn:ietf:params:xml:ns:yang:ietf-mpls-tp-topology";
  prefix "mpls-tp-topo";

  import ietf-network {
    prefix "nw";
  }

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

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

  import ietf-mpls-tp-types {
    prefix "mpls-tp-types";
  }

  organization
```



```

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

    ID-draft editor:
        Italo Busi (italo.busi@huawei.com);
        Haomian Zheng (zhenghaomian@huawei.com);
";

description
"This module defines technology-specific MPLS-TP topology
data model.";

revision 2019-03-11 {
    description
        "version -00 as an I-D";
    reference
        "draft-busizheng-teas-mpls-tp-yang";
}

augment "/nw:networks/nw:network/nw:network-types/"
    + "tet:te-topology" {
    container mpls-tp-topology {
        presence "indicates a topology type of MPLS-TP layer.";
        description "mpls-tp te topology type";
    }
    description "augment network types to include mpls-tp
nework";
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
    + "tet:te-link-attributes/"
    + "tet:interface-switching-capability/tet:max-lsp-
bandwidth/"
    + "tet:te-bandwidth/tet:technology" {
    when "../..../nw:network-types/tet:te-topology/"
        + "mpls-tp-topo:mpls-tp-topology" {
        description "MPLS-TP TE bandwidth.";
    }
    description "MPLS-TP bandwidth.";
    case mpls-tp {
        uses mpls-tp-types:mpls-tp-path-bandwidth;
    }
}

```

```

augment "/nw:networks/nw:network/nw:node/nt:termination-point/"
+ "tet:te/tet:interface-switching-capability/"
+ "tet:max-lsp-bandwidth/tet:te-bandwidth/tet:technology"
{
  when "../../../nw:network-types/tet:te-topology/"
  + "mpls-tp-topo:mpls-tp-topology" {
    description "Augment MPLS-TP TE bandwidth";
  }
  description "MPLS-TP bandwidth.";
  case mpls-tp {
    uses mpls-tp-types:mpls-tp-path-bandwidth;
  }
}

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/"
  + "mpls-tp-topo:mpls-tp-topology" {
    description "MPLS-TP TE bandwidth.";
  }
  description "MPLS-TP bandwidth.";
  case mpls-tp {
    uses mpls-tp-types:mpls-tp-bandwidth;
  }
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
+ "tet:te-link-attributes/tet:max-resv-link-bandwidth/"
+ "tet:te-bandwidth/tet:technology" {
  when "../../../nw:network-types/tet:te-topology/"
  + "mpls-tp-topo:mpls-tp-topology" {
    description "MPLS-TP TE bandwidth.";
  }
  description "MPLS-TP bandwidth.";
  case mpls-tp {
    uses mpls-tp-types:mpls-tp-bandwidth;
  }
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
+ "tet:te-link-attributes/tet:unreserved-bandwidth/"
+ "tet:te-bandwidth/tet:technology" {
  when "../../../nw:network-types/tet:te-topology/"
  + "mpls-tp-topo:mpls-tp-topology" {
    description "MPLS-TP TE bandwidth.";
  }
}

```

```
        description "MPLS-TP bandwidth.";
        case mpls-tp {
            uses mpls-tp-types:mpls-tp-bandwidth;
        }
    }
}
<CODE ENDS>
```

## 5.2. YANG Code for MPLS-TP Tunnel Augmentation

```
<CODE BEGINS>file "ietf-mpls-tp-tunnel@2019-03-11.yang"
module iETF-mpls-tp-tunnel {
    //yang-version 1.1;

    namespace "urn:ietf:params:xml:ns:yang:ietf-mpls-tp-tunnel";
    prefix "mpls-tp-tunnel";

    import iETF-te {
        prefix "te";
    }

    import iETF-mpls-tp-types {
        prefix "mpls-tp-types";
    }
    organization
        "Internet Engineering Task Force (IETF) TEAS WG";
    contact
        "
            WG List: <mailto:teas@ietf.org>

            ID-draft editor:
                Italo Busi (italo.busi@huawei.com);
                Haomian Zheng (zhenghaomian@huawei.com);
        ";
    description
        "This module defines technology-specific MPLS-TP tunnel
        data model.";
    revision 2019-03-11 {
        description
            "version -00 as an I-D";
        reference
            "draft-busizheng-teas-mpls-tp-yang";
    }

    augment "/te:te/te:tunnels/te:tunnel/"
        + "te:te-bandwidth/te:technology" {
```

```
description "MPLS-TP bandwidth.";
case mpls-tp {
    uses mpls-tp-types:mpls-tp-path-bandwidth;
}

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 "MPLS-TP label.";
case mpls-tp {
    uses mpls-tp-types:mpls-tp-path-label;
}
}

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 "MPLS-TP label.";
case mpls-tp {
    uses mpls-tp-types:mpls-tp-path-label;
}
}

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 "MPLS-TP label.";
case mpls-tp {
    uses mpls-tp-types:mpls-tp-path-label;
}
}

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 "MPLS-TP label.";
    case mpls-tp {
        uses mpls-tp-types:mpls-tp-path-label;
    }
}
}
<CODE ENDS>

```

### 5.3. MPLS-TP Specific YANG Types

```

<CODE BEGINS>file "ietf-mpls-tp-types@2019-03-11.yang"
module iETF-mpls-tp-types {
    namespace "urn:ietf:params:xml:ns:yang:ietf-mpls-tp-types";
    prefix "mpls-tp-types";

    import iETF-routing-types {
        prefix "rt-types";
    }
    import iETF-eth-tran-types {
        prefix "eth-types";
    }
    organization
        "Internet Engineering Task Force (IETF) TEAS WG";
    contact
        "
            WG List: <mailto:teas@ietf.org>

            ID-draft editor:
                Italo Busi (italo.busi@huawei.com);
                Haomian Zheng (zhenghaomian@huawei.com);
        ";
    description
        "This module defines technology-specific MPLS-TP types
        data model.";
    revision 2019-03-11 {
        description
            "version -00 as an I-D";
        reference
            "draft-busizheng-teas-mpls-tp-yang";
    }
}

```

```
grouping mpls-tp-path-bandwidth {
  description
    "Path bandwidth for MPLS-TP. ";
  leaf bandwidth-profile-name{
    type string;
    description "Name of Bandwidth Profile.";
  }
  leaf bandwidth-profile-type {
    type identityref {
      base etht-types:bandwidth-profile-type;
    }
    description "Type of Bandwidth Profile.";
  }

  leaf CIR {
    type uint64;
    description
      "Committed Information Rate in Kbps";
  }

  leaf EIR {
    type uint64;
    /*
      Need to indicate that EIR is not supported by RFC 2697

      must
        '../bw-profile-type = "etht-types:mef-10-bwp" or ' +
        '../bw-profile-type = "etht-types:rfc-2698-bwp" or ' +
        '../bw-profile-type = "etht-types:rfc-4115-bwp"'

      must
        '../bw-profile-type != "etht-types:rfc-2697-bwp"'
    */
    description
      "Excess Information Rate in Kbps
      In case of RFC 2698, PIR = CIR + EIR";
  }

  leaf CBS {
    type uint64;
    description
      "Committed Burst Size in in KBytes";
  }

  leaf EBS {
    type uint64;
    description
```

```
        "Excess Burst Size in KBytes.  
        In case of RFC 2698, PBS = CBS + EBS";  
    }  
}  
  
grouping mpls-tp-bandwidth {  
    description  
        "Bandwidth for MPLS-TP. ";  
    leaf mpls-tp-bandwidth {  
        type uint64{  
            range "0..100000000000";  
        }  
        units "Kbps";  
        description  
            "Available bandwidth value expressed in kilobits per  
second";  
    }  
}  
  
grouping mpls-tp-path-label {  
    description  
        "Path Label for MPLS-TP. ";  
    leaf mpls-label {  
        type rt-types:mpls-label;  
        description  
            "MPLS-TP Label.";  
    }  
}  
}  
}  
<CODE ENDS>
```

## 6. Open Issues

A few open issues are listed in this section for discussion with the WG experts:

- The value for 'encoding' in ietf-te-topology and ietf-te should be configured as 'lsp-encoding-packet' for MPLS-TP;
- The value for 'switching-type' in ietf-te-topology and ietf-te should be configured as 'switching-psc1' for MPLS-TP;
- There are still open issues for [TE-Tunnel], so the right directory may need to be confirmed up to the latest module ietf-te after maturity;
- Is it possible to integrate the proposal augmentation into [TE-MPLS]?

If the answer is 'yes', the following open issues need to address in the merged document.

- Some attributes will be needed to understand whether MPLS-TP specific features (such as no ECMP, no PHP, bidirectional LSP and GAL) are supported by the MPLS-TE topology and/or required to be supported by the MPLS-TE tunnel to be setup
- Per Tunnel-Termination-Point (TTP) modeling, one TTP per physical PE node should be sufficient for MPLS-TP;
- An empty container should be set for client-layer-adaption in the topology model for MPLS-TP;

Finally, it is not clear how to generate the inter-layer-lock-id for MPLS-TP and other layers, which may be considered in future.

## 7. Security

TBD.

## 8. Acknowledgements

We thank Loa Andersson and Igor Bryskin for providing useful suggestions for this draft.

## 9. References

### 9.1. Normative References

- [RFC6991] J. Schoenwaelder, "Common YANG Data Types", RFC6991.
- [RFC8294] X. Liu, et. al., "Common YANG Data Types for the Routing Area", RFC8294.
- [TE-Topology] X. Liu, et. al., "YANG Data Model for TE Topologies", draft-ietf-teas-yang-te-topo, work in progress.
- [TE-Tunnel] T. Saad (Editor), "A YANG Data Model for Traffic Engineering Tunnels and Interfaces", draft-ietf-teas-yang-te, work in progress.

### 9.2. Informative References

- [RFC5921] M. Bocci, et., al., "A Framework for MPLS in Transport Networks", RFC5921.



[TE-MPLS] T. Saad, et. al., "A YANG Data Model for MPLS Traffic Engineering Tunnels", draft-ietf-teas-yang-te-mpls, work in progress.

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A YANG model to manage the optical parameters for in a WDM network  
draft-galimbe-ccamp-iv-yang-08

## Abstract

This memo defines a Yang model that translate the information model to support Impairment-Aware (IA) Routing and Wavelength Assignment (RWA) functionality. The information model is defined in draft-ietf-ccamp-wson-iv-info and draft-martinelli-ccamp-wson-iv-encode. This document defines proper encoding and extend to the models defined in draft-lee-ccamp-wson-yang to support Impairment-Aware (IA) Routing and Wavelength Assignment (RWA) functions

The Yang model defined in this memo can be used for Optical Parameters monitoring and/or configuration of the multivendor Endpoints and ROADMs. The use of this model does not guarantee interworking of transceivers over a DWDM. Optical path feasibility and interoperability has to be determined by means outside the scope of this document. The purpose of this model is to program interface parameters to consistently configure the mode of operation of transceivers.

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## 1. Introduction

This memo defines a Yang model that translates the existing mib module defined in draft-ietf-ccamp-wson-iv-info and draft-martinelli-ccamp-wson-iv-encode to provide the network impairment information to an SDN controller. One of the key SDN controller features is to support multivendor network and support the service calculation and deployment in multilayer topologies, for the DWDM layer it is fundamental that the SDN controller is aware of the optical impairments to verify the feasibility of new circuits before their provisioning. Although SDN controller will not apply exhaustive and accurate algorithms and the optical channel feasibility verification may have a degree of unreliability this function can work on a multivendor common set of parameter and algorithms to ensure the operator the best change to set a circuit. This document follows the same impairment definition and applicability of draft-ietf-ccamp-wson-iv-info.

The optical impairments related to the DWDM Transceiver are described by draft draft-dharini-ccamp-if-param-yang. Applications are defined in G.698.2 [ITU.G698.2] using optical interface parameters at the single-channel connection points between optical transmitters and the optical multiplexer, as well as between optical receivers and the optical demultiplexer in the DWDM system. This Recommendation uses a methodology which explicitly specify the details of the optical network between reference point Ss and Rs, e.g., the passive and active elements or details of the design.

This draft refers and supports the draft-ietf-ccamp-dwdm-if-mng-ctrl-fwk

The building of a yang model describing the optical parameters allows the different vendors and operator to retrieve, provision and exchange information across multi-vendor domains in a standardized way. In addition to the parameters specified in ITU recommendations the Yang models support also the "vendor specific parameters".

## 2. The Internet-Standard Management Framework

For a detailed overview of the documents that describe the current Internet-Standard Management Framework, please refer to section 7 of RFC 3410 [RFC3410].

This memo specifies a Yang model for optical interfaces.

### 3. Conventions

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]. In the description of OIDs the convention: Set (S) Get (G) and Trap (T) conventions will describe the action allowed by the parameter.

### 4. Definition

For a detailed definition this draft refers to draft-ietf-ccamp-wson-iv-info.

### 5. Applicability

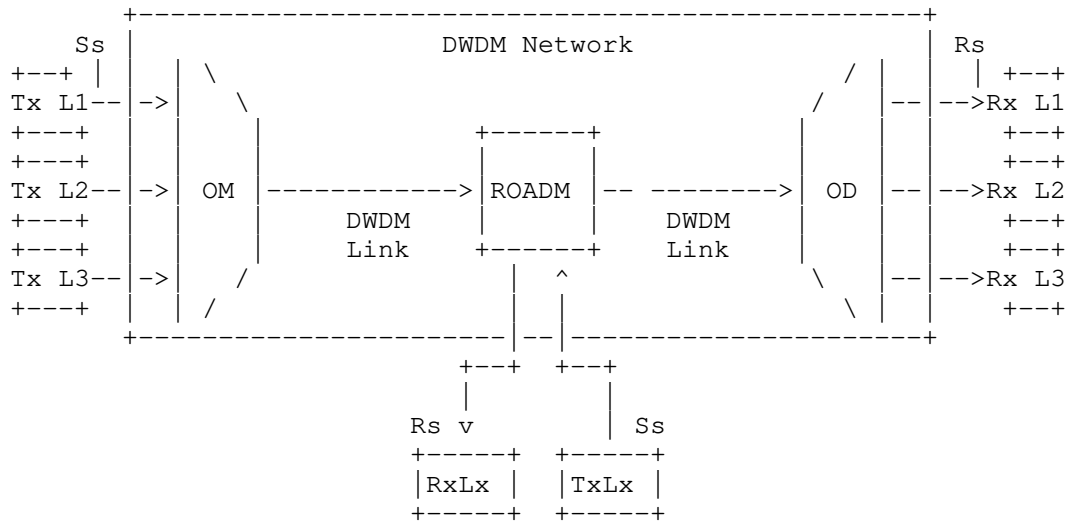
This document targets at Scenario C defined in [RFC6566] section 4.1.1. as approximate impairment estimation. The Approximate concept refers to the fact that this Information Model covers information mainly provided by [ITU.G680] Computational Model. Although the [RFC6566] provides no or little approximation the parameters described in this draft can be applied to the algorithms verifying the circuit feasibility in the new coherent non compensated DWDM networks. In this case the impairments verification can reach a good reliability and accuracy. This draft does not address computational matters but provides all the information suitable to cover most of the full coherent network algorithms, not being exhaustive the information can give a acceptable or even good approximation in term of connection feasibility. This may not be true for legacy compensated network.

### 6. Properties

For the signal properties this draft refers to draft-ietf-ccamp-wson-iv-info Ch.2.3 with some extension of the parameters.

### 7. Overview

Figure 1 shows a set of reference points, for single-channel connection between transmitters (Tx) and receivers (Rx). Here the DWDM network elements include an OM and an OD (which are used as a pair with the opposing element), one or more optical amplifiers and may also include one or more OADMs.



Ss = reference point at the DWDM network element tributary output  
Rs = reference point at the DWDM network element tributary input  
Lx = Lambda x  
OM = Optical Mux  
OD = Optical Demux  
ROADM = Reconfigurable Optical Add Drop Mux

from Fig. 5.1/G.698.2

Figure 1: External transponder in WDM networks

## 7.1. Optical Parameters Description

The link between the external transponders through a WDM network media channels are managed at the edges, i.e. at the transmitters (Tx) and receivers (Rx) attached to the S and R reference points respectively. The set of parameters that could be managed are defined by the "application code" notation

The definitions of the optical parameters are provided below to increase the readability of the document, where the definition is

ended by (R) the parameter can be retrieve with a read, when (W) it can be provisioned by a write, (R,W) can be either read or written.

#### 7.1.1. Optical path from point Ss to Rs

The following parameters for the optical path from point S and R are defined in G.698.2 [ITU.G698.2].

##### Maximum and minimum (residual) chromatic dispersion:

These parameters define the maximum and minimum value of the optical path "end to end chromatic dispersion" (in ps/nm) that the system shall be able to tolerate. (R)

##### Minimum optical return loss at Ss:

These parameter defines minimum optical return loss (in dB) of the cable plant at the source reference point (Ss), including any connectors (R)

##### Maximum discrete reflectance between Ss and Rs:

Optical reflectance is defined to be the ratio of the reflected optical power present at a point, to the optical power incident to that point. Control of reflections is discussed extensively in ITU-T Rec. G.957 (R)

##### Maximum differential group delay:

Differential group delay (DGD) is the time difference between the fractions of a pulse that are transmitted in the two principal states of polarization of an optical signal. For distances greater than several kilometers, and assuming random (strong) polarization mode coupling, DGD in a fiber can be statistically modelled as having a Maxwellian distribution. (R)

##### Maximum polarization dependent loss:

The polarization dependent loss (PDL) is the difference (in dB) between the maximum and minimum values of the channel insertion loss (or gain) of the black link from point SS to RS due to a variation of the state of polarization (SOP) over all SOPs. (R)

##### Maximum inter-channel crosstalk:

Inter-channel crosstalk is defined as the ratio of total power in all of the disturbing channels to that in the wanted channel, where the wanted and disturbing channels are at different wavelengths. The parameter specifies the isolation of a link conforming to the "black link" approach such that under the worst-case operating conditions the inter-channel crosstalk at any reference point RS is less than the maximum inter-channel crosstalk value (R)



**Maximum interferometric crosstalk:**

This parameter places a requirement on the isolation of a link conforming to the "black link" approach such that under the worst case operating conditions the interferometric crosstalk at any reference point RS is less than the maximum interferometric crosstalk value. (R)

**Maximum optical path OSNR penalty:**

The optical path OSNR penalty is defined as the difference between the Lowest OSNR at Rs and Lowest OSNR at Ss that meets the BER requirement (R)

**Maximum ripple:**

Although is defined in G.698.2 (R).

**7.1.2. Rs and Ss Configuration**

For the Rs and Ss configuration this draft refers the draft-dharini-ccamp-dwdm-if-param-yang while for the Rs-Ss extended parameters for coherent transmission interfaces refer to draft-dharini-ccamp-dwdm-if-param-yang

**7.1.3. Table of Application Codes**

For Application Codes configuration this draft refers the draft-dharini-ccamp-dwdm-if-param-yang

**7.2. Use Cases**

The use cases are described in draft-ietf-ccamp-dwdm-if-mng-ctrl-fwk

**7.3. Optical Parameters for impairment validation in a WDM network**

The ietf-opt-parameters-wdm is an augment to the ?????. It allows the user to get and set the application Optical Parameters of a DWDM network.

```
module: ietf-opt-parameters-wdm
  augment /if:interfaces/if:interface:
    +--rw optical-transport
    |   +--rw attenuator-value?      attenuator-t
    |   +--rw offset?                decimal64
    |   +--rw channel-power-ref?     decimal64
    |   +--rw tilt-calibration?      tilt-t
    +--rw opwr-threshold-warning
    |   +--rw opwr-min?              dbm-t
    |   +--rw opwr-min-clear?       dbm-t
```

```

|   +---rw opwr-max?          dbm-t
+---rw gain-degrade-alarm
|   +---rw gain-degrade-low?   dbm-t
|   +---rw gain-degrade-high?  dbm-t
+---rw power-degrade-high-alarm
|   +---rw gain-degrade-high?   dbm-t
+---rw power-degrade-low-alarm
|   +---ro power-degrade-low?   dbm-t
+---rw noise
|   +---rw noise?    decimal64
+---rw noise-sigma
|   +---rw noise?    decimal64
+---rw chromatic-dispersion
|   +---rw noise-sigma?    decimal64
+---rw chromatic-dispersion-slope
|   +---rw chromatic-dispersion-slope?    decimal64
+---rw pmd
|   +---rw pmd?    decimal64
+---rw pdl
|   +---rw pdl?    decimal64
+---rw drop-power
|   +---rw drop-power?    decimal64
+---rw drop-power-sigma
|   +---rw noise?    decimal64
+---rw ripple
|   +---rw drop-power-sigma?    decimal64
+---ro ch-noise-figure
|   +---ro ch-noise-figure* [ch-noise-fig]
|       +---ro ch-noise-fig        ch-noise-figure-point
|       +---ro input-to-output?    decimal64
|       +---ro input-to-drop?      decimal64
|       +---ro add-to-output?      decimal64
+---rw dgd
|   +---rw dgd?    decimal64
+---ro ch-isolation
|   +---ro ch-isolation* [ch-isolat]
|       +---ro ch-isolat        ch-isolation-cross
|       +---ro ad-ch-isol?      decimal64
|       +---ro no-ad-ch-iso?    decimal64
+---rw ch-extinction
|   +---rw cer?    decimal64

```

## 8. Structure of the Yang Module

ietf-opt-parameters-wdm is a top level model for the support of this feature.

## 9. Yang Module

The ietf-opt-parameters-wdm is defined as an extension to ietf interfaces ????.

```
<CODE BEGINS> file "ietf-opt-parameters-wdm.yang"
```

```
module ietf-opt-parameters-wdm {  
  namespace "urn:ietf:params:xml:ns:yang:ietf-opt-parameters-wdm";  
  prefix iietf-opt-parameters-wdm;
```

```
  
  import ietf-interfaces {  
    prefix if;  
  }
```

```
  
  import iana-if-type {  
    prefix ianaift;  
  }
```

```
  
  organization  
    "IETF CCAMP  
    Working Group";
```

```
  contact  
    "WG Web:  <http://tools.ietf.org/wg/ccamp/>  
    WG List:  <mailto:ccamp@ietf.org>
```

```
  
    Editor:    Gabriele Galimberti  
              <mailto:ggalimbe@cisco.com>;
```

```
  description  
    "This module contains a collection of YANG definitions for  
    collecting and configuring Optical Parameters  
    in Optical Networks and calculate the circuit feasibility.
```

```
  
    Copyright (c) 2016 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).";

revision "2018-10-22" {
    description
        "Revision 1.1";
    reference
        "";
}

revision "2018-03-06" {
    description
        "Revision 1.0";
    reference
        "";
}

revision "2016-10-30" {
    description
        "Initial revision.";
    reference
        "RFC XXXX: A YANG Data Model for Optical Paramenters
        of DWDM Networks
        ";
}

typedef tilt-t {
    type decimal64 {
        fraction-digits 2;
        range "-5..5";
    }
    description "Tilt Type";
}

typedef signal-output-power-t {
    type decimal64 {
        fraction-digits 2;
        range "-10..30";
    }
    description "
        Amplifier Power provisioning ";
}

typedef active-channel-t {
    type union {
        type uint8 {
```

```
        range "0..200";
    }
}
description "
    Number of channels active on a span - and on an amplifier";
}

typedef dbm-t {
    type decimal64 {
        fraction-digits 2;
        range "-50..-30 | -10..5 | 10000000";
    }
    description "
        Amplifier Power in dBm ";
}

typedef attenuator-t {
    type decimal64 {
        fraction-digits 2;
        range "-15..-5";
    }
    description "
        Attenuation value (attenuator) applied after the Amplifier";
}

typedef ch-noise-figure-point {
    type decimal64 {
        fraction-digits 2;
        range "-15..-5";
    }
    description "
        Amplifier noise figure of point power";
}

typedef ch-isolation-cross {
    type decimal64 {
        fraction-digits 2;
        range "-15..-5";
    }
    description "
        cross channel isolation value";
}

grouping opwr-threshold-warning-grp {
    description "
        Minimum Optical Power threshold
        - this is used to rise Power alarm ";
}
```

```
leaf opwr-min {
  type dbm-t;
  units "dBm";
  default -1;
  description "Minimum Power Value";
}

leaf opwr-min-clear {
  type dbm-t;
  units "dBm";
  default -1;
  description "threshold to clear Minimum Power value Alarm";
}

leaf opwr-max {
  type dbm-t;
  units "dBm";
  default 1;
  description "
    Maximum Optical Power threshold
    - this is used to rise Power alarm ";
}
}

grouping gain-degrade-alarm-grp {
  description "
    Low Optical Power gain threshold
    - this is used to rise Power alarm ";

  leaf gain-degrade-low {
    type dbm-t;
    units "dBm";
    default -1;
    description "Low Gain Degrade Value";
  }

  leaf gain-degrade-high {
    type dbm-t;
    units "dBm";
    default 1;
    description "
      High Optical Power gain threshold
      - this is used to rise Power alarm ";
  }
}

grouping power-degrade-high-alarm-grp {
  description "
```

```
    High Optical Power gain alarm ";

    leaf gain-degrade-high {
        type dbm-t;
        units "dBm";
        default 1;
        description "Low Gain Degrade Value";
    }
}

grouping power-degrade-low-alarm-grp {
    description "
        Low Optical Power gain alarm ";

    leaf power-degrade-low {
        type dbm-t;
        units "dBm";
        default -1;
        config false;
        description "High Gain Degrade Value";
    }
}

grouping noise-grp {
    description "Noise feasibility";
    leaf noise {
        type decimal64 {
            fraction-digits 2;
        }
        units "dB";
        description "Noise feasibility - reference ITU-T G.680
            OSNR added to the signal by the OMS. The noise is intended
            per channel and is independent of the number of active
            channels in OMS";
    }
}

grouping noise-sigma-grp {
    description "Noise sigma feasibility";
    leaf noise-sigma {
        type decimal64 {
            fraction-digits 2;
        }
        units "dB";
        description "Noise Sigma feasibility - accuracy of the
            OSNR added to
```

```
        the signal by the OMS";
    }
}

grouping chromatic-dispersion-grp {
    description "Chromatic Dispersion";
    leaf chromatic-dispersion {
        type decimal64 {
            fraction-digits 2;
        }
        units "ps/nm";
        description "Chromatic Dispersion (CD) related to the OMS";
    }
}

grouping chromatic-dispersion-slope-grp {
    description "Chromatic Dispersion slope";
    leaf chromatic-dispersion-slope {
        type decimal64 {
            fraction-digits 2;
        }
        units "ps/nm^2";
        description "Chromatic Dispersion (CD) Slope related to
            the OMS";
    }
}

grouping pmd-grp {
    description "Polarization Mode Dispersion";
    leaf pmd {
        type decimal64 {
            fraction-digits 2;
        }
        units "ps";
        description "Polarization Mode Dispersion (PMD) related
            to OMS";
    }
}

grouping pdl-grp {
    description "Polarization Dependent Loss";
    leaf pdl {
        type decimal64 {
            fraction-digits 2;
        }
        units "dB";
        description "Polarization Dependent Loss (PDL) related to
            the OMS";
    }
}
```



```
    }  
  }  
  
  grouping drop-power-grp {  
    description "Drop power at DWDM if RX feasibility";  
    leaf drop-power {  
      type decimal64 {  
        fraction-digits 2;  
      }  
      units "dBm";  
      description "Drop Power value at the DWDM Transceiver RX  
        side";  
    }  
  }  
  
  grouping drop-power-sigma-grp {  
    description "Drop power sigma at DWDM if RX feasibility ";  
    leaf drop-power-sigma {  
      type decimal64 {  
        fraction-digits 2;  
      }  
      units "db";  
      description "Drop Power Sigma value at the DWDM Transceiver  
        RX side";  
    }  
  }  
  
  grouping ripple-grp {  
    description "Channel Ripple";  
    leaf ripple {  
      type decimal64 {  
        fraction-digits 2;  
      }  
      units "db";  
      description "Channel Ripple";  
    }  
  }  
  
  grouping ch-noise-figure-grp {  
    list ch-noise-figure {  
      key "ch-noise-fig";  
      description "Channel signal-spontaneous noise figure";  
  
      leaf ch-noise-fig {  
        type ch-noise-figure-point;  
        description "Channel signal-spontaneous noise  
          figure point";  
      }  
    }  
  }
```

```
    leaf input-to-output {
      type decimal64 {
        fraction-digits 2;
      }
      units "dB";
      description "from input port to output port";
    }

    leaf input-to-drop {
      type decimal64 {
        fraction-digits 2;
      }
      units "dB";
      description "from input port to drop port";
    }

    leaf add-to-output {
      type decimal64 {
        fraction-digits 2;
      }
      units "dB";
      description "from add port to output port";
    }
  }
  description "Channel signal-spontaneous noise figure";
}

grouping dgd-grp {
  description "Differential Group Delay";
  leaf dgd {
    type decimal64 {
      fraction-digits 2;
    }
    units "db";
    description "differential group delay";
  }
}

grouping ch-isolation-grp {
  list ch-isolation {
    key "ch-isolat";
    description "adjacent and not adjacent channel isolation";

    leaf ch-isolat {
      type ch-isolation-cross;
      description "channel isolation from adjacent";
    }
  }
}
```

```
    leaf ad-ch-isol {
      type decimal64 {
        fraction-digits 2;
      }
      units "dB";
      description "adjacent channel isolation";
    }

    leaf no-ad-ch-iso {
      type decimal64 {
        fraction-digits 2;
      }
      units "dB";
      description "non adjacent channel isolation";
    }
  }
  description "djacent and not adjacent channel isolation";
}

grouping ch-extinction-grp {
  description "Channel Extinsion";
  leaf cer {
    type decimal64 {
      fraction-digits 2;
    }
    units "db";
    description "channel extinction";
  }
}

grouping att-coefficient-grp {
  description "Attenuation coefficient (for a fibre segment)";
  leaf att {
    type decimal64 {
      fraction-digits 2;
    }
    units "db";
    description "Attenuation coefficient (for a fibre segment)";
  }
}

augment "/if:interfaces/if:interface" {
  when "if:type = 'ianaift:opticalTransport'" {
    description "Specific optical-transport Interface Data";
  }
  description "Specific optical-transport Interface Data";
  container optical-transport {
```

```
description "Specific optical-transport Data";

leaf attenuator-value {
  type attenuator-t;
  description "External attenuator value ";
}

leaf offset {
  type decimal64 {
    fraction-digits 2;
    range "-30..30";
  }
  description "Raman and power amplifiers offset";
}

leaf channel-power-ref {
  type decimal64 {
    fraction-digits 2;
    range "-10..15";
  }
  description "Optical power per channel";
}

leaf tilt-calibration {
  type tilt-t;
  description "Amplifier Tilt tuning";
}
}

container opwr-threshold-warning {
  description "Optical power threshold warning";
  uses opwr-threshold-warning-grp;
}

container gain-degrade-alarm {
  description "Gain degrade alarm";
  uses gain-degrade-alarm-grp;
}

container power-degrade-high-alarm {
  description "Power degrade high aparm";
  uses power-degrade-high-alarm-grp;
}

container power-degrade-low-alarm {
  description "Power degrade low alarm";
  uses power-degrade-low-alarm-grp;
}

container noise {
  description "Channel Noise feasibility";
  uses noise-grp;
}
```

```
container noise-sigma {
    description "Channel Noise sigma feasibility";
    uses noise-grp;
}
container chromatic-dispersion {
    description "Chromatic Dispersion";
    uses noise-sigma-grp;
}
container chromatic-dispersion-slope {
    description "Chromatic Dispersion slope";
    uses chromatic-dispersion-slope-grp;
}
container pmd {
    description "Polarization Mode Dispersion";
    uses pmd-grp;
}
container pdl {
    description "Polarization Dependent Loss";
    uses pdl-grp;
}
container drop-power {
    description "Drop power at DWDM if RX feasibility";
    uses drop-power-grp;
}
container drop-power-sigma {
    description "Drop power sigma at DWDM if RX feasibility";
    uses noise-grp;
}
container ripple {
    description "Channel Ripple";
    uses drop-power-sigma-grp;
}
container ch-noise-figure {
    config false;
    description "Channel signal-spontaneous noise figure";
    uses ch-noise-figure-grp;
}
container dgd {
    description "Differential Group Delay";
    uses dgd-grp;
}
container ch-isolation {
    config false;
    description "adjacent and not adjacent channel isolation";
    uses ch-isolation-grp;
}
container ch-extinction {
    description "Channel Extinsion";
```

```
        uses ch-extinction-grp;
      }
    }
  }
}

<CODE ENDS>
```

## 10. Security Considerations

The YANG module defined in this memo is designed to be accessed via the NETCONF protocol [RFC6241]. The lowest NETCONF layer is the secure transport layer and the mandatory-to-implement secure transport is SSH [RFC6242]. The NETCONF access control model [RFC6536] provides the means to restrict access for particular NETCONF users to a pre-configured subset of all available NETCONF protocol operation and content.

## 11. IANA Considerations

This document registers a URI in the IETF XML registry [RFC3688]. Following the format in [RFC3688], the following registration is requested to be made:

URI: urn:ietf:params:xml:ns:yang:ietf-interfaces:ietf-ext-xponder-wdm-if

Registrant Contact: The IESG.

XML: N/A, the requested URI is an XML namespace.

This document registers a YANG module in the YANG Module Names registry [RFC6020].

This document registers a YANG module in the YANG Module Names registry [RFC6020].

prefix: ietf-ext-xponder-wdm-if reference: RFC XXXX

## 12. Acknowledgements

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#### Appendix A. Change Log

This optional section should be removed before the internet draft is submitted to the IESG for publication as an RFC.

Note to RFC Editor: please remove this appendix before publication as an RFC.

#### Appendix B. Open Issues

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Extension to the Link Management Protocol (LMP/DWDM -rfc4209) for Dense  
Wavelength Division Multiplexing (DWDM) Optical Line Systems to manage  
the application code of optical interface parameters in DWDM application  
draft-ggalimbe-ccamp-flex-if-lmp-07

#### Abstract

This experimental memo defines extensions to LMP(rfc4209) for  
managing Optical parameters associated with Wavelength Division  
Multiplexing (WDM) adding a set of parameters related to multicarrier  
DWDM interfaces to be used in Spectrum Switched Optical Networks  
(sson).

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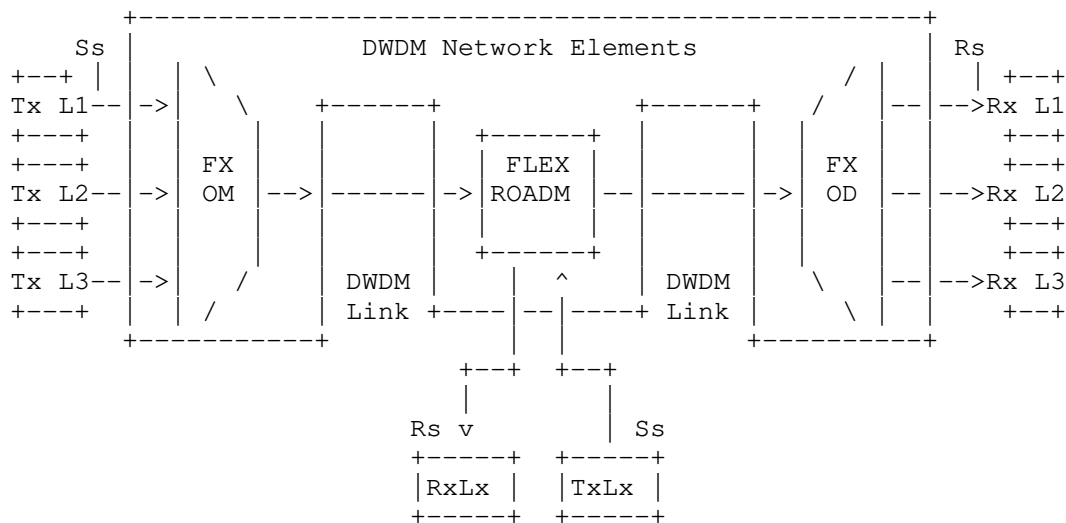
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## 1. Introduction

This experimental extension addresses the use cases described by "draft-ietf-ccamp-dwdm-if-mng-ctrl-fwk" to the Spectrum Switched Optical Network applications. LMP [RFC4902] provides link property correlation capabilities that can be used between a transceiver device and an Optical Line System (OLS) device. Link property correlation is a procedure by which, intrinsic parameters and capabilities are exchanged between two ends of a link. Link property correlation as defined in RFC4204 allows either end of the link to supervise the received signal and operate within a commonly understood parameter window. Here the term 'link' refers in particular to the attachment link between OXC and OLS (see Figure 1). The relevant novelty is the interface configuration having a multiple carrier where the client signal is spread on. The parameters are not yet fully defined by ITU-, so this document can just be seen as an experimental proposal not binding operators and vendors to comply and implement them

## 2. DWDM line system

Figure 1 shows a set of reference points (Rs and Ss), for a single-channel connection between transmitter (Tx) and receiver (Rx) devices. Here the DWDM network elements in between those devices include an Optical Multiplexer (OM) and an Optical Demultiplexer (OD). In addition it may include one or more Optical Amplifiers (OA) and one or more Optical Add-Drop Multiplexers (OADM).



Ss = Sender reference point at the DWDM network element tributary output, this can be a set of multiple transceivers carrying the same client payload.

Rs = Receiver reference point at the DWDM network element tributary input this can be a set of multiple transceivers carrying the same client payload.

FX OM = Flex-Spectrum Optical Mux

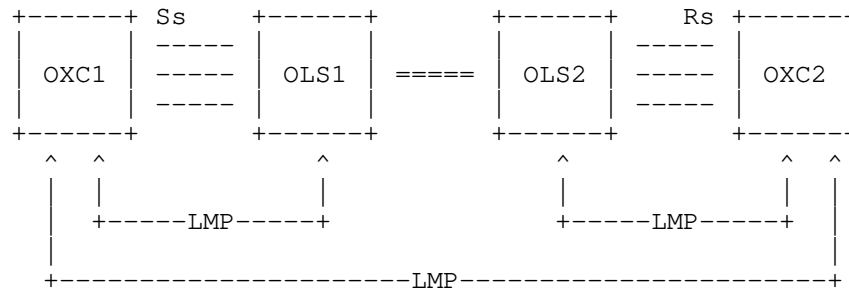
FX OD = Flex-Spectrum Optical Demux

Flex ROADM = Flex-Spectrum Optical Add Drop Mux (reconfigurable)

extending Fig. 5.1/G.698.2

Figure 1: Linear Single Channel approach

Figure 2 Extended LMP Model ( from [RFC4209] )



OXC : is an entity that contains Multiple carriers transponders  
 OLS : generic Flex-Spectrum optical system, it can be -  
       Optical Mux, Optical Demux, Optical Add  
       Drop Mux, Amplifier etc.  
 OLS to OLS: represents the Optical Multiplex section  
       <xref target="ITU.G709"/>  
 Rs/Ss : reference points in between the OXC and the OLS

Figure 2: Extended LMP Model

### 3. Use Cases

The set of parameters exchanged between OXC and OLS is to support the Spectrum Switched Optical Network in terms of Number of Sub-carriers available at the transceiver and their characteristics to provide the SSON control plane all the information suitable to calculate the path and the optical feasibility

### 4. Extensions to LMP-WDM Protocol

This document defines extensions to [RFC4209] to allow a set of characteristic parameters, to be exchanged between a router or optical switch and the optical line system to which it is attached. In particular, this document defines additional Data Link sub-objects to be carried in the LinkSummary message defined in [RFC4204] and [RFC6205]. The OXC and OLS systems may be managed by different Network management systems and hence may not know the capability and status of their peer. These messages and their usage are defined in subsequent sections of this document.

The following new messages are defined for the SSON extension  
   - Multi carrier Transceiver (sub-object Type = TBA)

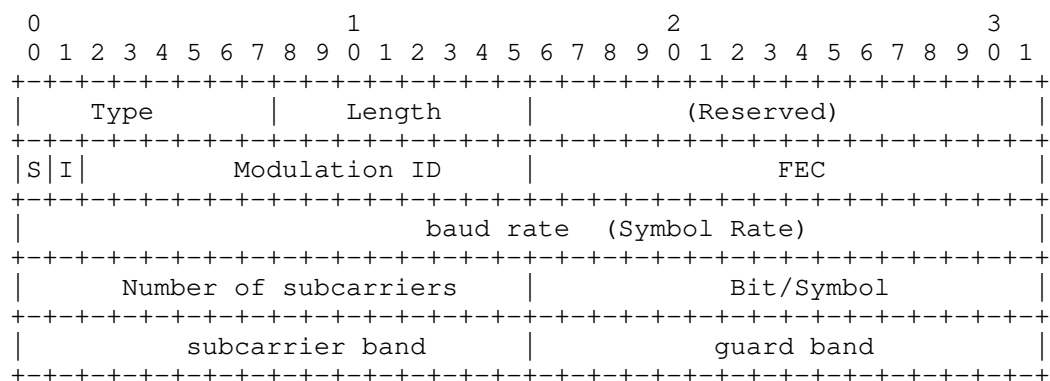
## 5. Multi carrier Transceiver

These are a set of general parameters extending the description in [G698.2] and [G.694.1]. ITU-T working groups are working to detail most of parameters and an update of the TLV may be required.

Other than the Application Identifier described in [G698.2] and draft-dharinigert-ccamp-dwdm-if-lmp the parameters to describe a multicarrier transceiver are describes as follows:

1. Modulation format: indicates the Transceiver capabilities to support a single or multiple modulation format like: BPSK, DC-DP-BSPSK, QPSK, DP-QPSK, QAM16, DP-QAM16, DC-DP-QAM16, 64QAM.
2. FEC: indicates the FEC types the transceiver can support
3. baud rate: symbols rate, basically this identify the channel symbols number per second
4. Num Carriers: number of (sub)carriers the trasceiver can support and can be "mapped" in a Mediachannel
5. Bits/symbol: number of bit per simbol (aka spectral efficiency)
6. Subcarrier band (minimum distance between subcarriers) in GHz
7. Guard band (required guard band at the side of media channel)
8. Sub-carrier TX Power: output optical power the transceiver can provide
9. Sub-carrier RX Power: Input optical power Range the transceiver can support, this is known also as Sensitivity
- 10 Max-pol-power-difference: max power difference between the polarised components
- 11 Max-pol-skew-difference: maw Skew between polarised signal and subcarriers supported by the transceiver
12. Sub-carrier OSNR robustness

Figure 3: The format of the this sub-object (Type = TBA, Length = TBA) is as follows:





```

|               sub-carrier TX power               |
+-----+-----+-----+-----+-----+-----+
|               sub-carrier RX power HIGH           |
+-----+-----+-----+-----+-----+-----+
|               sub-carrier RX power LOW            |
+-----+-----+-----+-----+-----+-----+
|               Max-pol-power-difference            |
+-----+-----+-----+-----+-----+-----+
|               Max-pol-skew-difference             |
+-----+-----+-----+-----+-----+-----+
|               sub-carrier OSNR                    |
+-----+-----+-----+-----+-----+-----+

```

- S: standardized format;
- I: input / output (1 / 0)
- Modulation Format: is the modulation type:
  - BPSK, DC DP BPSK, QPSK, DP QPSK, 8QAM, 16QAM, 64QAM, Hybrid, etc.
  - <TBD> (ITU-T reference)
  - value > 32768 (first bit is 1): custom defined values
  - Value 0 is reserved to be used if no value is defined
- FEC: the signal Forward Error Corrections type (16-bit unsigned integer), the defined values are:
  - <TBD> (ITU-T reference)
  - 32768 (first bit is 1): custom defined values
  - Value 0 is reserved to be used if no value is defined
- Baud Rate: the signal symbol rate (IEEE 32-bit float, in bauds/s)
  - Value 0 is reserved to be used if no value is defined
- Num Carriers
- Bits/symbol
- Subcarrier band (minimum distance between subcarriers)
- Guard band (required guard band at the side of media channel)
- Sub-carrier Transmit Power
- Sub-carrier Receive HIGH Power range (Sensitivity)
- Sub-carrier Receive LOW Power range (Sensitivity)
- Sub-carrier OSNR robustness
- Max-pol-power-difference
- Max-pol-skew-difference
- Sub-carrier OSNR

Figure 3: Multi carrier Transceiver

## 6. Security Considerations

LMP message security uses IPsec, as described in [RFC4204]. This document only defines new LMP objects that are carried in existing

LMP messages, similar to the LMP objects in [RFC:4209]. This document does not introduce new security considerations.

## 7. IANA Considerations

LMP <xref target="RFC4204"/> defines the following name spaces and the ways in which IANA can make assignments to these namespaces:

- LMP Message Type
  - LMP Object Class
  - LMP Object Class type (C-Type) unique within the Object Class
  - LMP Sub-object Class type (Type) unique within the Object Class
- This memo introduces the following new assignments:

LMP Sub-Object Class names:

under DATA\_LINK Class name (as defined in <xref target="RFC4204"/>)

- Multi carrier Transceiver (sub-object Type = TBA)

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Signaling extensions for Media Channel sub-carriers configuration in  
Spectrum Switched Optical Networks (SSON) in Lambda Switch Capable (LSC)  
Optical Line Systems.  
draft-ggalimbe-ccamp-flexigrid-carrier-label-06

#### Abstract

This memo defines the signaling extensions for managing Spectrum Switched Optical Network (SSON) parameters shared between the Client and the Network and inside the Network in accordance to the model described in RFC 7698. The extensions are in accordance and extending the parameters defined in ITU-T Recommendation G.694.1.[ITU.G694.1] and its extensions and G.872.[ITU.G872].

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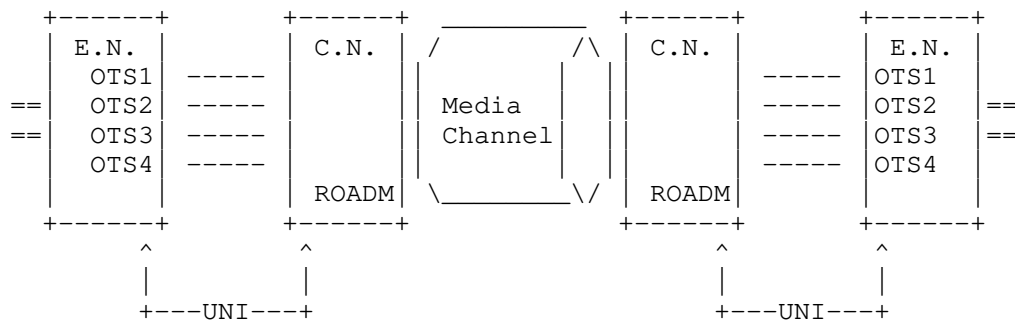
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## 1. Introduction

Generalised Multiprotocol Label Switched (GMPLS) is widely used in Wavelength Switched Optical Network (WSO) to support the optical circuits set-up through the signalling between Core Nodes and Edge Nodes. This extension addresses the use cases described by [RFC7698] Ch.3.3 and supports the information, needed in Spectrum Switched Optical Network (SSO), to signal a Media Channel and the associated carriers set request. The new set of parameters is related to the Media Channel and the carrier(s) routed with it and keep the backward compatibility with the WSO signalling. In particular this memo wants to address the use cases where the SSO LSP (the Media Channel in RFC7698) carries multiple carrier (OTSi) containing same Payload. The set of the carriers can be seen as single Logical circuit. This

memo can be considered as the extension of [RFC7792]. The contents and the parameters reflect the experimental activity on IP over SSON recently done by some vendors and research consortia.

Figure 1 shows how the multiple carrier are mapped into a Media Channel. A set of parameters must be shared on the UNI to allow the GMPLS to do the proper routing and Spectrum Assignment and decide the carrier position.



E.N. = Edge Node - UNI Client  
 C.N. = Core Node - UNI Network  
 ROADM = Lambda/Spectrum switch  
 Media Channel = the optical circuit  
 OTSi = Carriers belonging to the same Network Media Channel (or Super Channel)  
 UNI = Signalig interface

Figure 1: Multi carrier LSP

## 2. Client interface parameters

The Edge Node interface can have one or multiple carriers (OTSi). All the carrier have the same characteristics and are provisionable in terms of:

### Number of subcarriers:

This parameter indicates the number of subcarriers available for the super-channel in case the Transceiver can support multiple carrier circuits.

### Central frequency (see G.694.1 Table 1):

This parameter indicates the Central frequency value that Ss and Rs will be set to work (in THz). See the details in Section 6/



G.694.1 or based on "n" value explanation and the following "k" values definition in case of multicarrier transceivers.

Central frequency granularity:

This parameter indicates the Central frequency granularity supported by the transceiver, this value is combined with k and n value to calculate the central frequency of the carrier or sub-carriers.

Minimum channel spacing:

This is the minimum nominal difference in frequency (in GHz) between two adjacent channels (or carriers) depending on the Transceiver characteristics.

Bit rate / Baud rate of optical tributary signals:

Optical Tributary Signal bit (for NRZ signals) rate or Symbol (for Multiple bit per symbol) rate .

FEC Coding:

This parameter indicate what Forward Error Correction (FEC) code is used at Ss and Rs (R/W) (not mentioned in G.698.2). .

Wavelength Range (see G.694.1): [ITU.G694.1]

This parameter indicate minimum and maximum wavelength spectrum in a definite wavelength Band (L, C and S).

Modulation format:

This parameter indicates the list of supported Modulation Formats and the provisioned Modulation Format..

Inter carrier skew:

This parameter indicates, in case of multi-carrier transceivers the maximum skew between the sub-carriers supported by the transceiver.

Laser Output power:

This parameter provisions the Transceiver Output power, it can be either a setting and measured value.

receiver input power:

This parameter provisions the Min and MAX input power supported by the Transceiver, i.e. Receiver Sensitivity.

The above parameters are related to the Edge Node Transceiver and are used by the Core Network GMPLS in order to calculate the optical feasibility and the spectrum allocation. The parameters can be shared between the Client and the Network via LMP or provisioned to the Network by an EMS or an operator OSS.

### 3. Use Cases

The use cases are described in draft-ietf-ccamp-dwdm-if-mng-ctrl-fwk and [RFC7698]

### 4. Signalling Extensions

Some of the above parameters can be applied to RFC7792 (SENDER\_TSPEC/FLOWSPEC). The above parameters could be applied to [RFC4208] scenarios but they are valid also in case of non UNI scenarios. The [RFC6205] parameters remain valid.

#### 4.1. New LSP set-up parameters

When the E.N. wants to request to the C.N. a new circuit set-up request or the GMPLS wants to signal in the SSON network the Optical Interface characteristics the following parameters will be provided to the C.N.:

Number of available subcarriers (c):

This parameter is an integer and identifies the number of Client ports connected to the Core ports available to support the requested circuit

Total bandwidth request:

e.g. 200Gb, 400Gb, 1Tb - it is the bandwidth (payload) to be carried by the multiple carrier circuit

Policy (strict/loose):

Strict/loose referred to B/W and subcarrier number. This is to give some flexibility to the GMPLS in order to commit client request.

Subcarrier bandwidth tunability:

(optional) e.g. 34Ghz, 48GHz.

The TLV define the resource constraints for the requested Media Channel.

The format of the this sub-object is as follows:

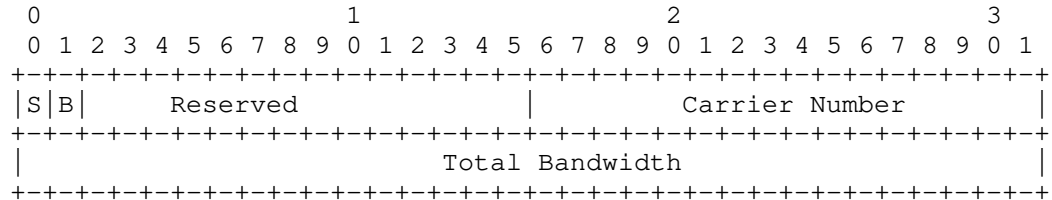


Figure 2: SSON LSP set-up request

Carrier Number: number of carrier to be allocated for the requested channel (16-bit unsigned integer)  
 If Carrier Number == 0 no constraint set on the number of carriers to be used

S strict number of subcarrier

- S = 0 the number of requested carriers is the maximum number that can be allocated (a lower value can be allocated if the requested bandwidth is satisfied)
- S = 1 the number of requested carriers is strict (must be > 0)

Total Bandwidth: the requested total bandwidth to be supported by the Media Channel (32-bit IEEE float, bytes/s)  
 If Total Bandwidth == 0: no bandwidth constraint is defined (B must be 0)

B Bandwidth constraints

- B = 0: the value is the maximum requested bandwidth (a lower value can be allocated if resources are not available)
- B = 1: the requested bandwidth is the minimum value to be allocated (a higher value can be allocated if requested by the physical constraints of the ports)

Reserved: unused bit (for future use, should be 0)

Note: bandwidth unit is defined in accordance to RFC 3471  
chap. 3.1.2 Bandwidth Encoding specification. Bandwidth higher  
than 40Gb/s values must be defined (e.g. 100Gb/s, 150Gb/s  
400Gb/s, etc.)

TLV Usage:

Head UNI-C PATH: requested traffic constraints, the Head UNI-N node  
must satisfy when reserving the optical resources and defining  
the carriers configuration

The TLV can be omitted: no traffic constraints is defined (resources  
allocated by UNI-N based on a local policy)

#### 4.2. Extension to LSP set-up reservation

Once the GMPLS has calculated the Media Channel path, the Spectrum  
Allocation, the Sub-carrier number and frequency, the modulation  
format, the FEC and the Transmit power, sends back to the E.N. the  
path set-up confirmation providing the values of the calculated  
parameters:

Media Channel:

(Grid, C.S., Identifier m and n). as indicated in RFC7699  
Section 4.1

Modulation format:

This parameter indicates the Modulation Formats to be set in the  
Transceivers.

FEC Coding:

This parameter indicate what Forward Error Correction (FEC) code  
must be used by the Transceivers (not mentioned in G.698). .

Bit rate / Baud rate of optical tributary signals:

Optical tributary signal bit (for NRZ signals) rate or Symbol (for  
Multiple bit per symbol) rate.

List of subcarriers:

This parameter indicates the subcarriers to be used for the super-  
channel in case the Transceiver can support multiple carrier  
Circuits.

Central frequency granularity (J):

This parameter indicates the Central frequency granularity  
supported by the transceiver, this value is combined with K and n  
value to calculate the central frequency on the carrier or sub-  
carriers.

Central frequency (see G.694.1 Table 1):

Grid, Identifiers, central frequency and granularity.

Laser Output power:

This parameter provisions the Transceiver Output power, it can be either a setting and measured value.

Circuit Path, RRO, etc:

All these info are defined in [RFC4208].

Path Error:

e.g. no path exist, all the path error defined in [RFC4208].

The TLV defines the carriers signal configuration.

All carriers in a Media Channel MUST have the same configuration.

The format of this sub-object (Type = TBA, Length = TBA) is as follows:

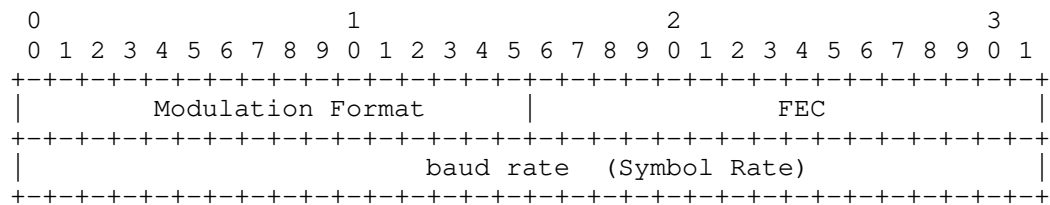


Figure 3: OCh\_General

Traffic Type

- Modulation Format: is the modulation type:
  - BPSK, DC DP BPSK, QPSK, DP QPSK, 8QAM, 16QAM, 64QAM, Hybrid, etc.
  - <TBD> (ITU-T reference)
  - value > 32768 (first bit is 1): custom defined values
  - Value 0 is reserved to be used if no value is defined
- FEC: the signal Forward Error Corrections type (16-bit unsigned integer), the defined values are:
  - <TBD> (ITU-T reference)
  - 32768 (first bit is 1): custom defined values
  - Value 0 is reserved to be used if no value is defined
- Baud Rate: the signal symbol rate (IEEE 32-bit float, in bauds/s)
  - Value 0 is reserved to be used if no value is defined

Notes:

- The PATH request from the Head UNI-C node can specify all or only a subset of the parameters (e.g. the Modulation and the baud rate as required but not the FEC) setting to 0 for the undefined parameters.  
When forwarding the PATH message, the UNI-N will set the undefined parameters based on the optical impairment calculation and the constraints given by the UNI-C
- Custom codes (values > 0x8000) interpretation is a local installation matter.

TLV Usage:

- Head UNI-C PATH: used to force specific transponder configurations
- Head UNI-N RESV: set selected configuration on head node
- Tail UNI-N PATH: set selected configuration on tail node

4.2.1. Sub-carrier list content

For Each carrier inside the Media Channel the TLV is used.

The format of this sub-object (Type = TBA, Length = TBA) is as follows:

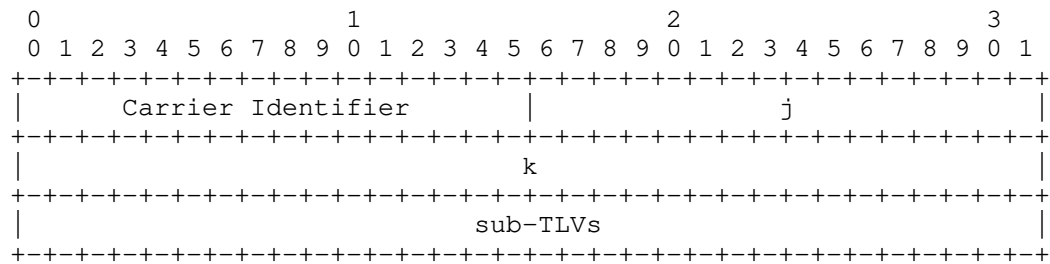
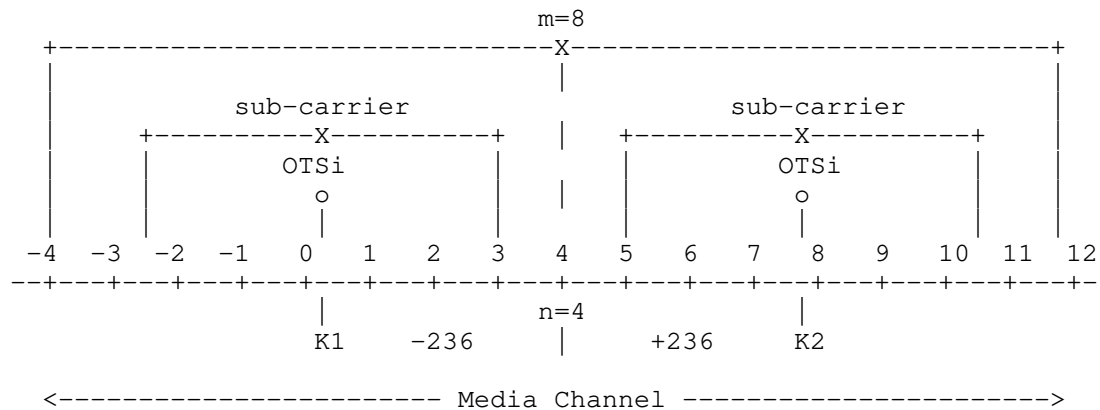


Figure 4: Sub-Carrier parameters

#### Carrier set-up:

- Carrier identifier field: sub-carrier identifier inside the mediachannel. Identifies the carrier position inside the Media Channel (16-bit unsigned integer) The Carrier Identifier is the logical circuit sub-lane position, a TLV for each value from 1 to the number of allocated carriers must be present.
- J field: granularity of the channel spacing, can be a multiple of 0.01GHz. - default value is 0.1GHz.
- K field: positive or negative integer (including 0) to multiply by J and identify the Carrier Position inside the Media Channel, offset from media Channel Central frequency
- sub-TLVs: additional information related to carriers if needed and the ports associated to the carrier.

In summary Carrier Frequency = MC-C.F. (in THz) + K \* J GHz.



#### 4.2.2. Sub-carrier sub-TLV

The defined sub-TLVs are Port Identifiers and Carrier Power

## Source Port Identifier

The format of this sub-object (Type = TBA, Length = TBD) is as follows:

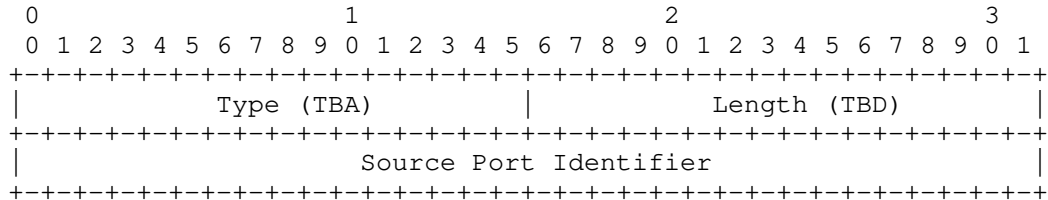


Figure 5: Source Port Identifier

Source Port Identifier: the HEAD UNI-C optical logical source end point identifier (32-bits integer, ifindex)

## TLV Usage:

- Head UNI-C PATH: used to force specific carrier ports [optional use, e.g. with external PCE scenario]
- Tail UNI-N PATH: report selected carrier head ports to tail UNI-C
- RESV: report selected configuration to HEAD UNI-C node

## Destination Port Identifier

The format of this sub-object (Type = TBA, Length = TBD) is as follows:

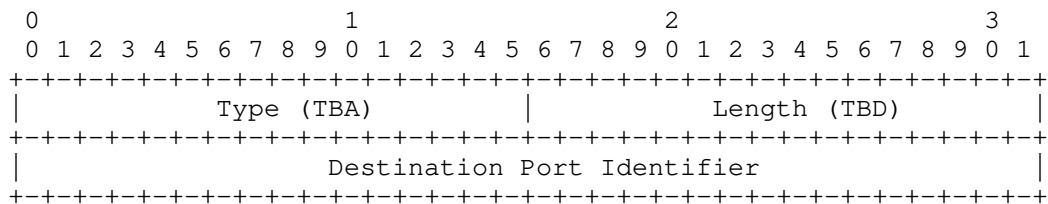


Figure 6: Destination Port Identifiers



Destination Port Identifier: the local upstream optical logical destination end point identifier (32-bits integer, ifindex)

TLV Usage:

- Head UNI-C PATH: used to force specific carrier ports [optional use, e.g. with external PCE scenario]
- Tail UNI-N PATH: set selected configuration on tail node
- RESV: report selected configuration to HEAD UNI-C node

Carrier Power

The format of this sub-object (Type = TBA, Length = TBD) is as follows:

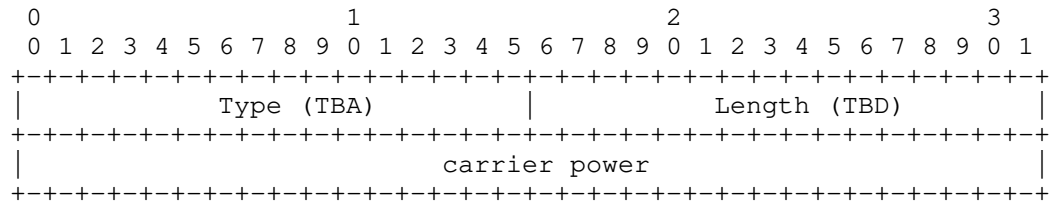


Figure 7: Carrier Power

Carrier Power: the requested carrier transmit power (32-bits IEEE Float, dBm), optionally used to notify the configured power (in UNI client side) or force the power to the to the UNI client).

TLV Usage:

- Head UNI-C PATH: used to force specific carrier frequency/ports (optional use, e.g. with external PCE scenario)
- Head UNI-N RESV: set selected configuration on head node
- Tail UNI-N PATH: set selected configuration on tail node

#### 4.3. RSVP Protocol Extensions considerations

The additional information described in the draft, is related to the Media Channel supported traffic. It could be encoded in the SENDER\_TSPEC/FLOW\_SPEC objects by extending the SSON\_SENDER\_TSPEC/SSON\_FLOW\_SPEC defined in RFC 7792 (or defining a new C-Type) with an optional TLV list or it could be encoded in a newly defined entry (new OBJECT or new LSP\_ATTRIBUTES OBJECT TLV)

This solution is consistent with other technology specific extensions (e.g. SDH), but requires the explicit handling of the extensions by all nodes.

Beside this, some of the additional information defined is local to the head/tail UNI link (e.g. the carrier/port association), while the traffic spec info should be valid end-to-end.

There can be different methods to model and signal the carriers as described in draft-lee-ccamp-optical-impairment-topology-yang. The Media Channel, Network Media Channel and labels are well modelled by the RFC7698, RFC7699 and RFC7792 reflecting the ITU-T Recommendations G.694.1 and G.698.2.

Some work is in progress in ITU-T SG15/Q12 to define Network Media Channel (group) that is capable of accommodating the optical tributary signals (OTSi) belonging to optical tributary signal group (OTSiG) (see new ITU-T Draft Recommendation G.807). Currently, no models exist (in the IETF nor ITU-T SG15) that define how the optical tributary signals are described inside the Network Media Channel Group in terms of OTSi identifier, OTSi carrier frequency and OTSi signal width.

Other the encoding proposal reported in this draft, there are several at least two other methods to describe the parameters. An option is to describe the OTSi carrier frequency relative to the anchor frequency 193.1THz based on a well-defined granularity (e.g. OTSi carrier frequency = 193100 (GHz) + K \* granularity (GHz) where K is a signed integer value). A second option is to explicitly describe the OTSi carrier frequency and the OTSi signal width in GHz with a certain accuracy.

The second option which is independent of the n, m values already defined in ITU-T Recommendation G.694.1. The OTSi carrier frequency is described in GHz with 3 fractional digits (decimal 64 fraction digits 3). The OTSi signal width is described in GHz with 3 fractional digits (decimal 64 fraction digits 3) and includes the signal roll off as well as some guard band.

The accuracy of 0.001 GHz does not impose a requirement on the optical transceiver components (optical transmitter) in terms of carrier frequency tunability precision. Today's components typically provide a tunability precision in the range of 1..1.5GHz (carrier frequency offset compared to the configured nominal carrier frequency). Future components may provide a better precision as technology evolves. If needed, a controller may retrieve the transceiver properties in terms of carrier frequency tunability precision in order to be capable of properly configuring the underlying transceiver.

NOTE FROM THE EDITORS: As this description is arbitrarily proposed by the authors to cover a lack of information in IETF and ITU-T, a

liaison request to ITU-T is needed. The authors are willing to contribute to Liaison editing and to consider any feedback and proposal from ITU-T.

## 5. Security Considerations

GMPLS message security uses IPsec, as described in xxxx. This document only defines new UNI objects that are carried in existing UNI messages, similar to the UNI objects in xxx. This document does not introduce new security considerations.

## 6. IANA Considerations

T.B.D.

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## A YANG Data Model for L1 Connectivity Service Model (L1CSM)

draft-ietf-ccamp-l1csm-yang-09

### Abstract

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

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## 1. Introduction

This document provides a YANG data model for L1VPN Connectivity Service Model (L1CSM) which can be classified as Network Service YANG module per [RFC8199]. The intent of this document is to provide a transport service model exploiting YANG data model, which can be utilized by a client network controller to initiate a service



request connectivity request as well as retrieving service states toward a transport network controller communicating with the client controller via a NETCONF [RFC8341] or a RESTCONF [RFC8040] interface.

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

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

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

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

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

### 1.1. Deployment Scenarios

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

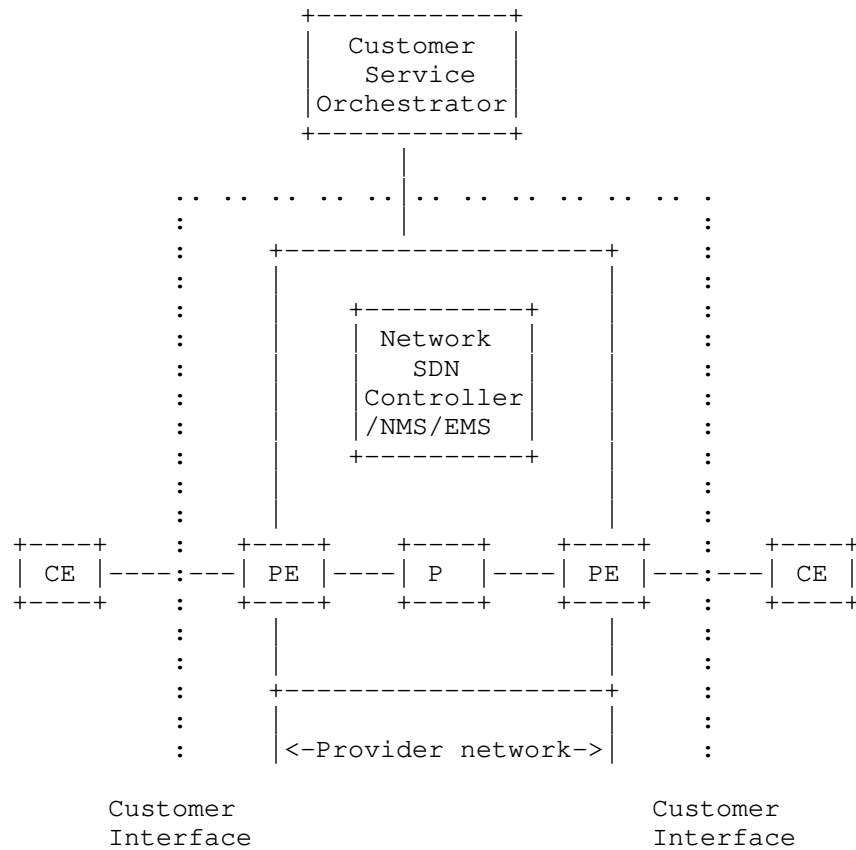


Figure 1: L1VPN SDN Controller/EMS/NMS-Based Service Model:  
External Customer

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

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

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

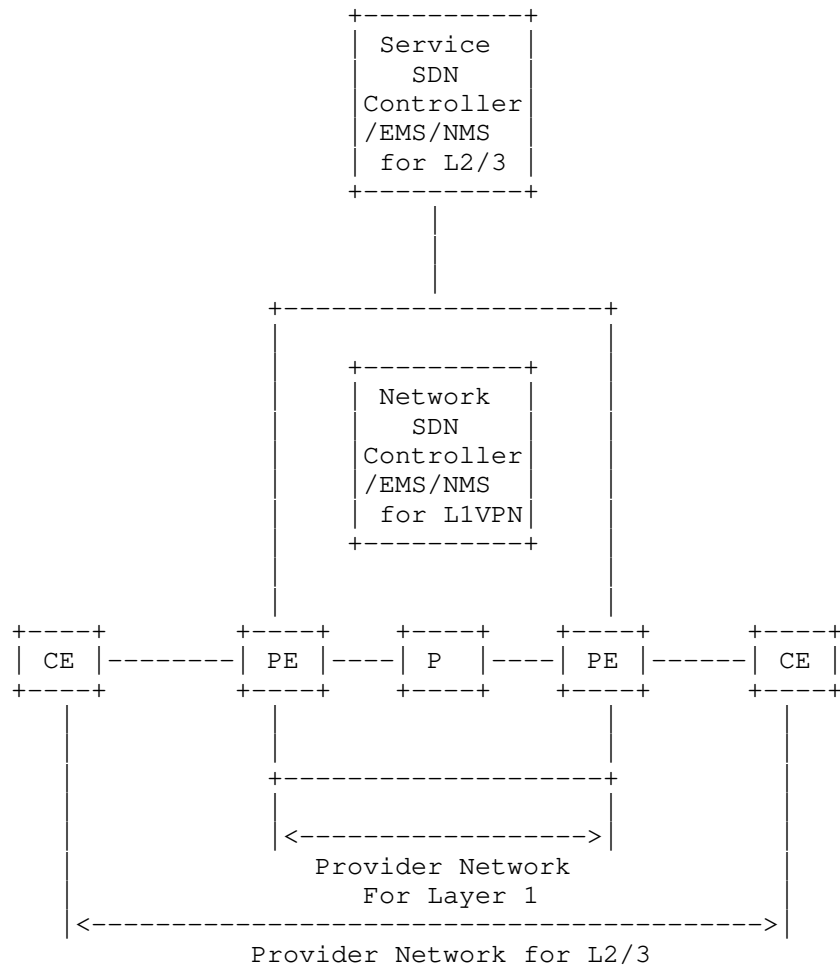


Figure 2: L1VPN SDN Controller/EMS/NMS-Based Service Model:  
Internal Customer

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

## 1.2. Terminology

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

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

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

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

- o configuration data
- o state data

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

## 1.3. Tree diagram

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

## 1.4. Prefixes in Data Node Names

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

corresponding YANG imported modules, as shown in Table 1.

Prefix	YANG module	Reference
llcsm	ietf-llcsm	[RFC XXXX]
ll-st	ietf-ll-service-types	[RFC XXXX]
yang	ietf-yang-types	[RFC6991]

Table 1: Prefixes and corresponding YANG modules

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

## 2. Definitions

L1VC Layer 1 Virtual Connection

SLS Service Level Specification

UNI User Network Interface

PE Provider Edge

CE Customer Edge

EP End Point

P Protocol

C Coding

O Optical Interface

## 3. L1SM YANG Model (Tree Structure)

```

module: ietf-llcsm
  +--rw ll-connectivity
    +--rw access
      +--rw unis
        +--rw uni* [id]
          +--rw id string
          +--rw protocol? identityref
          +--rw coding? identityref

```

```

|         +--rw optical-interface?  identityref
+--rw services
  +--rw service* [service-id]
    +--rw service-id                string
    +--rw endpoint-1
      |   +--rw id                  string
      |   +--rw uni                  -> /l1-connectivity/access/unis/uni/id
    +--rw endpoint-2
      |   +--rw id                  string
      |   +--rw uni                  -> /l1-connectivity/access/unis/uni/id
    +--rw start-time?               yang:date-and-time
    +--rw time-interval?            int32
    +--rw performance-metric*       identityref

```

#### 4. L1SM YANG Code

The YANG code is as follows:

```

<CODE BEGINS> file "ietf-l1csm@2018-09-12.yang"

module ietf-l1csm {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-l1csm";

  prefix "l1csm";
  import ietf-yang-types {
    prefix "yang";
    reference "RFC 6991 - Common YANG Data Types";
  }

  import ietf-l1-service-types {
    prefix "l1-st";
    reference "RFC XXXX - A YANG Data Model for L1 Connectivity
              Service Model (L1CSM)";
  }

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

  contact

    "Editor: G. Fioccola (giuseppe.fioccola@telecomitalia.it)
    Editor: K. Lee (kwangkoog.lee@kt.com)
    Editor: Y. Lee (leeyoung@huawei.com)
    Editor: D. Dhody (dhruv.ietf@gmail.com)
    Editor: O. G. de-Dios (oscar.gonzalezdedios@telefonica.com)
    Editor: D. Ceccarelli (daniele.ceccarelli@ericsson.com)";

```

## description

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

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

```
revision "2018-09-12" {
  description "Initial revision.";
  reference "RFC XXXX: A YANG Data Model for L1 Connectivity
    Service Model (L1CSM)";
// Note: The RFC Editor will replace XXXX with the number
// assigned to the RFC once this draft becomes an RFC.
}
```

```
grouping protocol-coding-optical-interface {
  description
    "describes <p,c,o> where p:protocol type; c:coding
    function; o:optical interface function";
  reference "MEF 63";
  leaf protocol {
    type identityref {
      base "l1-st:protocol-type";
    }
    description
      "List of physical layer L1VC clientprotocol";
  }
  leaf coding {
    type identityref {
      base "l1-st:coding-func";
    }
    description "coding function";
  }

  leaf optical-interface {
```

```
        type identityref {
          base "l1-st:optical-interface-func";
        }
        description "optical-interface-function";
      }
    }

    grouping subscriber-l1vc-sls-service-attribute {
      description
        "The value of the Subscriber L1VC SLS (Service Level
        Specification) Service Attribute";
      reference "MEF 63";

      leaf start-time {
        type yang:date-and-time;
        description "a time that represent the date and time
          for the start of the SLS";
      }

      leaf time-interval {
        type int32;
        units seconds;
        description "a time interval (e.g., 2,419,200 seconds
          which is 28 days) that is used in
          conjunction wuth time-start to specify a
          contiguous sequence of time intervals T for
          determining when performance objectives are
          met.";
      }

      leaf-list performance-metric {
        type identityref {
          base "l1-st:performance-metric";
        }
        description "list of performance metric";
      }
    }

    grouping subscriber-l1vc-endpoint-attributes {
      description
        "subscriber layer 1 connection endpoint attributes";
      reference "MEF 63";

      container endpoint-1 {
        description "One end of UNI id's - string and id";
        leaf id {
          type string;
        }
      }
    }
  }
}
```



```
        mandatory true;
        description "subscriber end point ID of one end";
    }

    leaf uni {
        type leafref {
            path "/l1-connectivity/access/unis/uni/id";
        }
        mandatory true;
        description "this is one end of subscriber L1VC end point
            ID value = UNI-1";
    }
}

container endpoint-2 {
    description "One end of UNI id's - string and id";
    leaf id {
        type string;
        mandatory true;
        description "subscriber end point ID of the other end";
    }

    leaf uni {
        type leafref {
            path "/l1-connectivity/access/unis/uni/id";
        }
        mandatory true;
        description
            "this is one other end of subscriber L1VC end point
            ID value = UNI-2";
    }
}

}

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

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

        container unis {
            description "the list of UNI's to be configured";

            list uni {
                key "id";
                description "UNI identifier";
                leaf id {
                    type string;
                    description "the UNI id of UNI Service Attributes";
                }
            }
        }
    }
}
```

```
        }
        uses protocol-coding-optical-interface;
    }
}

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

        leaf service-id {
            type string;
            mandatory true;
            description "a unique service identifier for
                subscriber L1VC.";
        }

        uses subscriber-llvc-endpoint-attributes;
        uses subscriber-llvc-sls-service-attribute;

        } //end of service list
    } //end of service container
} //service top container
}
```

<CODE ENDS>

<CODE BEGINS> file "ietf-ll-service-types@2018-09-12.yang"

```
module ietf-ll-service-types {
    namespace "urn:ietf:params:xml:ns:yang:ietf-ll-service-types";
    prefix "ll-st";

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

        Editor: G. Fioccola (giuseppe.fioccola@telecomitalia.it)
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        Editor: O. G. de-Dios (oscar.gonzalezdedios@telefonica.com)
```

Editor: D. Ceccarelli(daniele.ceccarelli@ericsson.com)";

description

"This module defines L1 service types based on MEF 63: Subscriber Layer 1 Service Attribute Technical Specification. Refer to MEF 63 for all terms and the original references used in the module. As for the protocol-type, refer also to the client-type in G.709.

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

```
revision "2018-09-12" {
  description "Initial revision.";
  reference "RFC XXXX: A Yang Data Model for L1 Connectivity
    Service Model (L1CSM)";
  // Note: The RFC Editor will replace XXXX with the number
  // assigned to the RFC once this draft becomes an RFC.
}
```

```
identity protocol-type {
description
"base identity from which client protocol type is derived.";
}
```

```
identity ETH-1GbE {
  base "protocol-type";
  description
    "Gigabit Ethernet protocol type";
  reference "MEF63 & G.709";
}
```

```
identity ETH-10GbE-WAN {
  base "protocol-type";
  description
    "10 Gigabit Ethernet-WAN protocol type";
  reference "MEF63 & G.709";
}
```

```
}

identity ETH-10GbE-LAN {
    base "protocol-type";
    description
        "10 Gigabit Ethernet-LAN protocol type";
    reference "MEF63 & G.709";
}

identity ETH-40GbE {
    base "protocol-type";
    description
        "40 Gigabit Ethernet protocol type";
    reference "MEF63 & G.709";
}

identity ETH-100GbE {
    base "protocol-type";
    description
        "100 Gigabit Ethernet protocol type";
    reference "MEF63 & G.709";
}

identity FC-100 {
    base "protocol-type";
    description
        "Fiber Channel - 100 protocol type";
    reference "MEF63 & G.709";
}

identity FC-200 {
    base "protocol-type";
    description
        "Fiber Channel - 200 protocol type";
    reference "MEF63 & G.709";
}

identity FC-400 {
    base "protocol-type";
    description
        "Fiber Channel - 400 protocol type";
    reference "MEF63 & G.709";
}

identity FC-800 {
    base "protocol-type";
    description
```

```
        "Fiber Channel - 800 protocol type";
        reference "MEF63 & G.709";
    }

    identity FC-1200 {
        base "protocol-type";
        description
            "Fiber Channel - 1200 protocol type";
        reference "MEF63 & G.709";
    }

    identity FC-1600 {
        base "protocol-type";
        description
            "Fiber Channel - 1600 protocol type";
        reference "MEF63 & G.709";
    }

    identity FC-3200 {
        base "protocol-type";
        description
            "Fiber Channel - 3200 protocol type";
        reference "MEF63 & G.709";
    }

    identity STM-1 {
        base "protocol-type";
        description
            "SDH STM-1 protocol type";
        reference "MEF63 & G.709";
    }

    identity STM-4 {
        base "protocol-type";
        description
            "SDH STM-4 protocol type";
        reference "MEF63 & G.709";
    }

    identity STM-16 {
        base "protocol-type";
        description
            "SDH STM-16 protocol type";
        reference "MEF63 & G.709";
    }

    identity STM-64 {
```

```
    base "protocol-type";
    description
        "SDH STM-64 protocol type";
    reference "MEF63 & G.709";
}

identity STM-256 {
    base "protocol-type";
    description
        "SDH STM-256 protocol type";
    reference "MEF63 & G.709";
}

identity OC-3 {
    base "protocol-type";
    description
        "SONET OC-3 protocol type";
    reference "MEF63 & G.709";
}

identity OC-12 {
    base "protocol-type";
    description
        "SONET OC-12 protocol type";
    reference "MEF63 & G.709";
}

identity OC-48 {
    base "protocol-type";
    description
        "SONET OC-48 protocol type";
    reference "MEF63 & G.709";
}

identity OC-192 {
    base "protocol-type";
    description
        "SONET OC-192 protocol type";
    reference "MEF63 & G.709";
}

identity OC-768 {
    base "protocol-type";
    description
        "SONET OC-768 protocol type";
    reference "MEF63 & G.709";
}
```

```
identity coding-func {
  description
    "base identity from which coding func is derived.";
}

identity ETH-1000X-PCS-36 {
  base "coding-func";
  description
    "PCS clause 36 coding function that corresponds to
    1000BASE-X";
  reference "MEF63 & IEEE802.3";
}

identity ETH-10GW-PCS-49-WIS-50 {
  base "coding-func";
  description
    "PCS clause 49 and WIS clause 50 coding func that
    corresponds to 10GBASE-W (WAN PHY)";
  reference "MEF63 & IEEE802.3";
}

identity ETH-10GR-PCS-49 {
  base "coding-func";
  description
    "PCS clause 49 coding function that corresponds to
    10GBASE-R (LAN PHY)";
  reference "MEF63 & IEEE802.3";
}

identity ETH-40GR-PCS-82 {
  base "coding-func";
  description
    "PCS clause 82 coding function that corresponds to
    40GBASE-R";
  reference "MEF63 & IEEE802.3";
}

identity ETH-100GR-PCS-82 {
  base "coding-func";
  description
    "PCS clause 82 coding function that corresponds to
    100GBASE-R";
  reference "MEF63 & IEEE802.3";
}

/* coding func needs to expand for Fiber Channel, SONET, SDH */

identity optical-interface-func {
```

```
description
  "base identity from which optical-interface-function is
  derived.";
}

identity SX-PMD-clause-38 {
  base "optical-interface-func";
  description
    "SX-PMD-clause-38 Optical Interface function for
    1000BASE-X PCS-36";
  reference "MEF63 & IEEE802.3";
}

identity LX-PMD-clause-38 {
  base "optical-interface-func";
  description
    "LX-PMD-clause-38 Optical Interface function for
    1000BASE-X PCS-36";
  reference "MEF63 & IEEE802.3";
}

identity LX10-PMD-clause-59 {
  base "optical-interface-func";
  description
    "LX10-PMD-clause-59 Optical Interface function for
    1000BASE-X PCS-36";
  reference "MEF63 & IEEE802.3";
}

identity BX10-PMD-clause-59 {
  base "optical-interface-func";
  description
    "BX10-PMD-clause-59 Optical Interface function for
    1000BASE-X PCS-36";
  reference "MEF63 & IEEE802.3";
}

identity LW-PMD-clause-52 {
  base "optical-interface-func";
  description
    "LW-PMD-clause-52 Optical Interface function for
    10GBASE-W PCS-49-WIS-50";
  reference "MEF63 & IEEE802.3";
}

identity EW-PMD-clause-52 {
  base "optical-interface-func";
  description
```



```
        "EW-PMD-clause-52 Optical Interface function for
        10GBASE-W PCS-49-WIS-50";
        reference "MEF63 & IEEE802.3";
    }

    identity LR-PMD-clause-52 {
        base "optical-interface-func";
        description
            "LR-PMD-clause-52 Optical Interface function for
            10GBASE-R PCS-49";
        reference "MEF63 & IEEE802.3";
    }

    identity ER-PMD-clause-52 {
        base "optical-interface-func";
        description
            "ER-PMD-clause-52 Optical Interface function for
            10GBASE-R PCS-49";
        reference "MEF63 & IEEE802.3";
    }

    identity LR4-PMD-clause-87 {
        base "optical-interface-func";
        description
            "LR4-PMD-clause-87 Optical Interface function for
            40GBASE-R PCS-82";
        reference "MEF63 & IEEE802.3";
    }

    identity ER4-PMD-clause-87 {
        base "optical-interface-func";
        description
            "ER4-PMD-clause-87 Optical Interface function for
            40GBASE-R PCS-82";
        reference "MEF63 & IEEE802.3";
    }

    identity FR-PMD-clause-89 {
        base "optical-interface-func";
        description
            "FR-PMD-clause-89 Optical Interface function for
            40GBASE-R PCS-82";
        reference "MEF63 & IEEE802.3";
    }

    identity LR4-PMD-clause-88 {
        base "optical-interface-func";
```

```
        description
            "LR4-PMD-clause-88 Optical Interface function for
            100GBASE-R PCS-82";
        reference "MEF63 & IEEE802.3";
    }

    identity ER4-PMD-clause-88 {
        base "optical-interface-func";
        description
            "ER4-PMD-clause-88 Optical Interface function for
            100GBASE-R PCS-82";
        reference "MEF63 & IEEE802.3";
    }

    /* optical interface func needs to expand for Fiber Channel,
       SONET and SDH */

    identity performance-metric {
        description "list of performance metric";
    }

    identity One-way-Delay {
        base "performance-metric";
        description "one-way-delay";
    }

    identity One-way-Errored-Second {
        base "performance-metric";
        description "one-way-errored-second";
    }

    identity One-way-Severely-Errored-Second {
        base "performance-metric";
        description "one-way-severely-errored-second";
    }

    identity One-way-Unavailable-Second {
        base "performance-metric";
        description "one-way-unavailable-second";
    }

    identity One-way-Availability {
        base "performance-metric";
        description "one-way-availability";
    }
}
```

```
}  
  
<CODE ENDS>
```

## 5. JSON Example

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

```
{  
  "l1-connectivity": {  
    "access": {  
      "unis": {  
        "uni": [  
          {  
            "id": "MTL-HQ-Node3-Slot2-Port1",  
            "protocol": "ETH-10GigE_LAN ",  
            "coding": "ETH-10GR-PCS-49 ",  
            "optical_interface": "LR-PMD-clause-52 "  
          },  
          {  
            "id": "MTL-STL-Node5-Slot4-Port3",  
            "protocol": "ETH-10GigE_LAN ",  
            "coding": "ETH-10GR-PCS-49 ",  
            "optical_interface": "ER-PMD-clause-52 "  
          }  
        ]  
      },  
    },  
    "services": {  
      "service": [  
        {  
          "service-id": "Sub-L1VC-1867-LT-MEGAMART",  
          "endpoint-1": {  
            "id": "MTL-HQ_1867-MEGAMART",  
            "uni": "MTL-HQ-Node3-Slot2-Port1"  
          }  
        },  
      ]  
    }  
  }  
}
```

```
        "endpoint-2":
          {
            "id": "MTL-STL_1867-MEGAMART",
            "uni": "MTL-STL-Node5-Slot4-Port3"
          },
        "start-time": "2018-09-13T06:06:09Z",
        "time-interval": 2419200,
        "performance-metric": "One-way-Delay "
      }
    ]
  },
}
```

## 6. Security Considerations

The 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 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 users to a preconfigured subset of all available NETCONF protocol operations and content.

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

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

unis:  
- id

Service:  
- service-id  
- endpoint-1  
- endpoint-2

- start-time
- time-interval
- performance-metric

## 7. IANA Considerations

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

```
-----  
URI: urn:ietf:params:xml:ns:yang:ietf-l1csm  
Registrant Contact: The IESG.  
XML: N/A, the requested URI is an XML namespace.  
-----
```

```
-----  
URI: urn:ietf:params:xml:ns:yang:ietf-l1-service-types  
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 [RFC6020]:

```
-----  
name:          ietf-l1csm  
namespace:     urn:ietf:params:xml:ns:yang:ietf-l1csm  
reference:     RFC XXXX (TDB)  
-----
```

```
-----  
name:          ietf-l1-service-types  
namespace:     urn:ietf:params:xml:ns:yang:ietf-l1-service-types  
reference:     RFC XXXX (TDB)  
-----
```

## 8. Acknowledgments

The authors would like to thank Tom Petch and Italo Busi for their helpful comments and valuable contributions and Robert Wilton for his YANG doctor's review that improved the model significantly.

## 9. References

### 9.1. Normative References

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### 9.2. Informative References

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A YANG Data Model for Microwave Topology  
draft-ietf-ccamp-mw-topo-yang-01

Abstract

This document defines a YANG data model to describe the topologies of microwave/millimeter.

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 BCP14 [RFC2119] [RFC8174] when, and only when, they appear in all captials, as shown here.

Status of This Memo

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## 1. Terminology and Definitions

The following acronyms are used in this document:

PNC Provisioning Network Controller

MDSC Multi Domain Service Coordinator

## 2. Introduction

This document defines a YANG data model to describe the topologies of microwave/millimeter(hereafter microwave is used to simplify the text). The microwave topology model augments the TE topology model defines in [I-D.ietf-teas-yang-te-topo].

The microwave topology model is expected to be used between a Provisioning Network Controller(PNC) and a Multi Domain Service Coordinator(MDSC) ([RFC8453]). Possible use cases of microwave topology models include:

1. The microwave link frequency could be used to understand the current frequency usage, enabling a whole view of the network topology information, and as an input for network frequency planning.
2. The microwave radio link could change its bandwidth according to the environments under the adaptive modulation mode, e.g., the bandwidth will degrade when there's a heavy rain. To get to know of current microwave link bandwidth is important for path computation and service provisioning across different technologies/networks.
3. Due to bandwidth changing feature, availability is normally used to describe the microwave radio link characteristic. [RFC8330] defines a mechanism to report bandwidth-availability information through OSPF-TE. It's also necessary to include the information in the YANG data model to optimize the path/route computation.

## 3. YANG Data Model (Tree Structure)

### 3.1. The YANG Tree

The tree format defined in [RFC8340] is used for the YANG data model tree representation.

```
module: ietf-microwave-topology
  augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
    +--rw mw-topology!
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes:
    +--rw mw-channels* [mw-channel-frequency mw-channel-id]
      +--rw mw-channel-id                               uint32
      +--rw mw-channel-frequency                         uint32
      +--rw mw-channel-separation?                       uint32
      +--ro mw-channel-nominal-bandwidth?                 uint64
      +--ro mw-channel-current-bandwidth?                 uint64
```

```

    +--rw mw-channel-availability* [availability]
    |   +--rw availability          decimal64
    |   +--ro channel-bandwidth?   uint64
    +--rw interface-root {root-radio-if}?
augment /nw:networks/nw:network/nw:node/nt:termination-point/tet:te
/tet:interface-switching-capability/tet:max-lsp-bandwidth
/tet:te-bandwidth/tet:technology:
  +--: (mw)
    +--ro mw-bandwidth?   uint64
    +--ro mw-unreserved-bandwidth uint64
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
/tet:connectivity-matrices/tet:path-constraints/tet:te-bandwidth
/tet:technology:
  +--: (mw)
    +--ro mw-bandwidth?   uint64
    +--ro mw-unreserved-bandwidth uint64
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
/tet:connectivity-matrices/tet:connectivity-matrix
/tet:path-constraints/tet:te-bandwidth/tet:technology:
  +--: (mw)
    +--ro mw-bandwidth?   uint64
    +--ro mw-unreserved-bandwidth uint64
augment /nw:networks/nw:network/nw:node/tet:te
/tet:information-source-entry/tet:connectivity-matrices
/tet:path-constraints/tet:te-bandwidth/tet:technology:
  +--: (mw)
    +--ro mw-bandwidth?   uint64
    +--ro mw-unreserved-bandwidth uint64
augment /nw:networks/nw:network/nw:node/tet:te
/tet:information-source-entry/tet:connectivity-matrices
/tet:connectivity-matrix/tet:path-constraints/tet:te-bandwidth
/tet:technology:
  +--: (mw)
    +--ro mw-bandwidth?   uint64
    +--ro mw-unreserved-bandwidth uint64
augment /nw:networks/nw:network/nw:node/tet:te
/tet:tunnel-termination-point/tet:client-layer-adaptation
/tet:switching-capability/tet:te-bandwidth/tet:technology:
  +--: (mw)
    +--ro mw-bandwidth?   uint64
    +--ro mw-unreserved-bandwidth uint64
augment /nw:networks/nw:network/nw:node/tet:te
/tet:tunnel-termination-point/tet:local-link-connectivities
/tet:path-constraints/tet:te-bandwidth/tet:technology:
  +--: (mw)
    +--ro mw-bandwidth?   uint64
    +--ro mw-unreserved-bandwidth uint64
augment /nw:networks/nw:network/nw:node/tet:te

```

```
/tet:tunnel-termination-point/tet:local-link-connectivities
/tet:local-link-connectivity/tet:path-constraints
/tet:te-bandwidth/tet:technology:
  +--: (mw)
    +--ro mw-bandwidth?   uint64
    +--ro mw-unreserved-bandwidth uint64
augment /nw:networks/nw:network/nt:link/tet:te
/tet:te-link-attributes/tet:interface-switching-capability
/tet:max-lsp-bandwidth/tet:te-bandwidth/tet:technology:
  +--: (mw)
    +--ro mw-bandwidth?   uint64
    +--ro mw-unreserved-bandwidth uint64
augment /nw:networks/nw:network/nt:link/tet:te
/tet:te-link-attributes/tet:max-link-bandwidth
/tet:te-bandwidth/tet:technology:
  +--: (mw)
    +--ro mw-bandwidth?   uint64
    +--ro mw-unreserved-bandwidth uint64
augment /nw:networks/nw:network/nt:link/tet:te
/tet:te-link-attributes/tet:max-resv-link-bandwidth
/tet:te-bandwidth/tet:technology:
  +--: (mw)
    +--ro mw-bandwidth?   uint64
    +--ro mw-unreserved-bandwidth uint64
augment /nw:networks/nw:network/nt:link/tet:te
/tet:te-link-attributes/tet:unreserved-bandwidth
/tet:te-bandwidth/tet:technology:
  +--: (mw)
    +--ro mw-bandwidth?   uint64
    +--ro mw-unreserved-bandwidth uint64
augment /nw:networks/nw:network/nt:link/tet:te
/tet:information-source-entry
/tet:interface-switching-capability/tet:max-lsp-bandwidth
/tet:te-bandwidth/tet:technology:
  +--: (mw)
    +--ro mw-bandwidth?   uint64
    +--ro mw-unreserved-bandwidth uint64
augment /nw:networks/nw:network/nt:link/tet:te
/tet:information-source-entry/tet:max-link-bandwidth
/tet:te-bandwidth/tet:technology:
  +--: (mw)
    +--ro mw-bandwidth?   uint64
    +--ro mw-unreserved-bandwidth uint64
augment /nw:networks/nw:network/nt:link/tet:te
/tet:information-source-entry/tet:max-resv-link-bandwidth
/tet:te-bandwidth/tet:technology:
  +--: (mw)
    +--ro mw-bandwidth?   uint64
```



```

      +---ro mw-unreserved-bandwidth uint64
augment /nw:networks/nw:network/nt:link/tet:te
/tet:information-source-entry/tet:unreserved-bandwidth
/tet:te-bandwidth/tet:technology:
  +--: (mw)
    +---ro mw-bandwidth?   uint64
    +---ro mw-unreserved-bandwidth uint64
augment /nw:networks/tet:te/tet:templates/tet:link-template
/tet:te-link-attributes/tet:interface-switching-capability
/tet:max-lsp-bandwidth/tet:te-bandwidth/tet:technology:
  +--: (mw)
    +---ro mw-bandwidth?   uint64
    +---ro mw-unreserved-bandwidth uint64
augment /nw:networks/tet:te/tet:templates/tet:link-template
/tet:te-link-attributes/tet:max-link-bandwidth/tet:te-bandwidth
/tet:technology:
  +--: (mw)
    +---ro mw-bandwidth?   uint64
    +---ro mw-unreserved-bandwidth uint64
augment /nw:networks/tet:te/tet:templates/tet:link-template
/tet:te-link-attributes/tet:max-resv-link-bandwidth/tet:te-bandwidth
/tet:technology:
  +--: (mw)
    +---ro mw-bandwidth?   uint64
    +---ro mw-unreserved-bandwidth uint64
augment /nw:networks/tet:te/tet:templates/tet:link-template
/tet:te-link-attributes/tet:unreserved-bandwidth/tet:te-bandwidth
/tet:technology:
  +--: (mw)
    +---ro mw-bandwidth?   uint64
    +---ro mw-unreserved-bandwidth uint64

```

### 3.2. Relationship with microwave interface YANG model

The microwave topology model is expected to be used between a PNC and a MDSC. [I-D.ietf-ccamp-mw-yang] defines an interface YANG model for microwave radio link which is used between the PNC and the physical device for device configuration. The PNC is able to convert the information received from the topology model into the interface model. For example, link in the topology model represent the connection between the Radio Link Terminations in the interface model, channels in the topology model represent the connections between Carrier Terminations in the interface model. Thus the channel frequency in the topology model is mapped to the tx-frequency of the Carrier Termination in the interface model.

If the purpose is to access more information of the microwave interface YANG model through the microwave topology model, a schema mount mechanism could be used, see the "interface-root" in the microwave topology model. [RFC8528] defines a mechanism to add the schema trees defined by a set of YANG modules onto a mount point defined in the schema tree in some YANG module. The current defined schema mount mechanism allows mounting of complete data models only. If complete mounting of the microwave interface YANG model is not necessary, a deviation model could be created to remove unneeded schema in the microwave interface model, and be mounted to the topology model.

### 3.3. Relationship with client topology model

Ethernet is the most common client signal over microwave link. The Ethernet topology is an overlay TE topology on microwave topology. When an ETH service is transported by a single microwave radio link, the ETH link is supported by the microwave link in underlay microwave topology. Appendix A.1 shows some JSON example of Ethernet link over single microwave link with one microwave channel. When an ETH service is transported over two microwave radio links, the ETH link is supported by the microwave link with two microwave channels in underlay microwave topology. Appendix A.2 shows some JSON example of Ethernet link over two microwave links.

### 3.4. Model applicability to other technology

TBA

## 4. YANG Module

```
<CODE BEGINS> file "ietf-microwave-topology@2019-02-27.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";
    }

// Note to RFC Editor: please replace YYYY with the number assigned
// to draft-ietf-teas-yang-te-topo
import ietf-te-topology {
    prefix "tet";
    reference "RFC xxxx: YANG Data Model for Traffic Engineering
              (TE) Topologies";
}

/*
*import ietf-routing-types {
*  prefix "rt-types";
* }
*/

import ietf-yang-schema-mount {
    prefix yangmnt;
    reference "RFC 8528: YANG Schema Mount";
}

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

  Editor: Min Ye
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           <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 microwave topology.
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  authors of the code. All rights reserved.
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  without modification, is permitted pursuant to, and subject to
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```

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 2019-02-27 {
  description
    "Update microwave link key.";
  reference "";
}

revision 2019-01-03 {
  description
    "Align with the TE topology YANG model.";
  reference "";
}

revision 2018-10-22 {
  description
    "change the type of serveral data nodes.";
  reference "";
}

revision 2018-06-30 {
  description
    "Updated version to add mount point to the interface model.";
  reference "";
}

revision 2018-03-05 {
  description
    "Initial version.";
  reference "";
}

feature root-radio-if{
  description
    "This feature means that root for microwave radio
    interface model is supported.";
}

/*
 * Groupings
 */
grouping mw-bandwidth {
  description "Microwave bandwidth attributes";
```

```
leaf mw-bandwidth {
    type uint64;
    units "Kbps";
    config false;
    description "Microwave nominal bandwidth. Calculation
of microwave nominal bandwidth is implementation specific.
For example, if there's only one channel in the mw-channels
list, the microwave nominal bandwidth is equal to the
channel bandwidth. If there's two channels in the mw-channels
list, depending on the configuration of the channels, the
microwave nominal bandwidth is the sum of channel
bandwidth(2+0), or just one channel bandwidth
(1+1 with protection).";
}

    leaf mw-unreserved-bandwidth {
        type uint64;
        units "Kbps";
        config false;
        description "The unreserved bandwidth of the link is
mw-bandwidth minus occupied bandwidth
on mw link";
    }
}

grouping mw-link-attributes {
    description "Microwave link attributes.";
    list mw-channels {
        key "mw-channel-frequency mw-channel-id";
        description "List of microwave channels supporting the link.";
        uses mw-channel-attributes;
    }
}

grouping mw-channel-attributes {
    description "Microwave channel attributes";

    leaf mw-channel-id {
        type string;
        description "Microwave channel identifier";
    }

    leaf mw-channel-frequency {
        type uint32;
        units "kHz";
        description "Microwave channel frequency";
    }
}
```

```
leaf mw-channel-separation {
  type uint32;
  units "kHz";
  description
    "The distance between adjacent channels
     in a radio frequency channel arrangement
     used in this link";
  reference "ETSI EN 302 217-1";
}

leaf mw-channel-nominal-bandwidth {
  type uint64;
  units "Kbps";
  config false;
  description "The nominal channel bandwidth";
}

leaf mw-channel-current-bandwidth {
  type uint64;
  units "Kbps";
  config false;
  description "The current channel bandwidth";
}

list mw-channel-availability{
  key "availability";
  description
    "List of availability and corresponding
     channel bandwidth";

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

  leaf channel-bandwidth {
    type uint64;
    units "Kbps";
    config false;
    description
      "The channel bandwidth corresponding
       to the availability level";
  }
}
```

```

        container "interface-root" {
        if-feature root-radio-if;
        description
            "Container for mount point.";
        yangmnt:mount-point "interface-root" {
            description
                "Root for microwave radio interface model.
                It could contain an interface instance.";
        }
    }
}

/*
 * Data nodes
 */
augment "/nw:networks/nw:network/nw:network-types/"
    + "tet:te-topology" {
    container mw-topology {
        presence "indicates a topology type of microwave.";
        description "Microwave topology type";
    }
    description "augment network types to include microwave network";
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
    + "tet:te-link-attributes" {
    when "../..../nw:network-types/tet:te-topology/"
        + "mwtopo:mw-topology" {
        description "This augment is only valid for microwave.";
    }
    description "Microwave link augmentation";

    uses mw-link-attributes;
}

/*
 * Augment TE bandwidth
 */

/* Augment maximum LSP bandwidth of link terminationpoint (LTP) */
augment "/nw:networks/nw:network/nw:node/nt:termination-point/"
    + "tet:te/"
    + "tet:interface-switching-capability/tet:max-lsp-bandwidth/"
    + "tet:te-bandwidth/tet:technology" {
    when "../..../nw:network-types/tet:te-topology/"
        + "mwtopo:mw-topology" {
        description "Augment microwave TE bandwidth";
    }
}

```

```

    }
    description "microwave bandwidth.";
    case mw {
        uses mw-bandwidth;
    }
}

/* Augment bandwidth path constraints of connectivity-matrices */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:path-constraints/tet:te-bandwidth/tet:technology" {
    when "../..../..../..../nw:network-types/tet:te-topology/"
        + "mwtopo:mw-topology" {
        description "Augment microwave TE bandwidth";
    }
    description "microwave bandwidth.";
    case mw {
        uses mw-bandwidth;
    }
}

/* Augment bandwidth path constraints of connectivity-matrix */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/"
    + "tet:path-constraints/tet:te-bandwidth/tet:technology" {
    when "../..../..../..../nw:network-types/tet:te-topology/"
        + "mwtopo:mw-topology" {
        description "Augment microwave TE bandwidth";
    }
    description "microwave bandwidth.";
    case mw {
        uses mw-bandwidth;
    }
}

/* Augment bandwidth path constraints of connectivity-matrices
 * information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:information-source-entry/tet:connectivity-matrices/"
    + "tet:path-constraints/tet:te-bandwidth/tet:technology" {
    when "../..../..../..../nw:network-types/tet:te-topology/"
        + "mwtopo:mw-topology" {
        description "Augment microwave TE bandwidth";
    }
    description "microwave bandwidth.";
    case mw {
        uses mw-bandwidth;
    }
}

```



```

}

/* Augment bandwidth path constraints of connectivity-matrix
 * information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/"
  + "tet:path-constraints/tet:te-bandwidth/tet:technology" {
when "../..../nw:network-types/tet:te-topology/"
  + "mwtopo:mw-topology" {
  description "Augment microwave TE bandwidth";
}
description "microwave bandwidth.";
case mw {
  uses mw-bandwidth;
}
}

/* Augment client bandwidth of tunnel termination point (TTP) */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:tunnel-termination-point/"
  + "tet:client-layer-adaptation/tet:switching-capability/"
  + "tet:te-bandwidth/tet:technology" {
when "../..../nw:network-types/tet:te-topology/"
  + "mwtopo:mw-topology" {
  description "Augment microwave TE bandwidth";
}
description "microwave bandwidth.";
case mw {
  uses mw-bandwidth;
}
}

/* Augment bandwidth path constraints of local-link-connectivities */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:tunnel-termination-point/"
  + "tet:local-link-connectivities/tet:path-constraints/"
  + "tet:te-bandwidth/tet:technology" {
when "../..../nw:network-types/tet:te-topology/"
  + "mwtopo:mw-topology" {
  description "Augment microwave TE bandwidth";
}
description "microwave bandwidth.";
case mw {
  uses mw-bandwidth;
}
}

```

```
/* Augment bandwidth path constraints of
*local-link-connectivity (LLC) */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:tunnel-termination-point/"
  + "tet:local-link-connectivities/"
  + "tet:local-link-connectivity/tet:path-constraints/"
  + "tet:te-bandwidth/tet:technology" {
  when "../..../nw:network-types/tet:te-topology/"
    + "mwtopo:mw-topology" {
    description "Augment microwave TE bandwidth";
  }
  description "microwave bandwidth.";
  case mw {
    uses mw-bandwidth;
  }
}

/* Augment maximum LSP bandwidth of TE link */
augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:te-link-attributes/"
  + "tet:interface-switching-capability/tet:max-lsp-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
  when "../..../nw:network-types/tet:te-topology/"
    + "mwtopo:mw-topology" {
    description "Augment microwave TE bandwidth";
  }
  description "microwave bandwidth.";
  case mw {
    uses mw-bandwidth;
  }
}

/* Augment maximum bandwidth of TE link */
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 "Augment microwave TE bandwidth";
  }
  description "microwave bandwidth.";
  case mw {
    uses mw-bandwidth;
  }
}

/* Augment maximum reservable bandwidth of TE link */
```

```

augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:te-link-attributes/"
  + "tet:max-resv-link-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
when "../..../nw:network-types/tet:te-topology/"
  + "mwtopo:mw-topology" {
  description "Augment microwave TE bandwidth";
}
description "microwave bandwidth.";
case mw {
  uses mw-bandwidth;
}
}

/* Augment unreserved bandwidth of TE Link */
augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:te-link-attributes/"
  + "tet:unreserved-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
when "../..../nw:network-types/tet:te-topology/"
  + "mwtopo:mw-topology" {
  description "Augment microwave TE bandwidth";
}
description "microwave bandwidth.";
case mw {
  uses mw-bandwidth;
}
}

/* Augment maximum LSP bandwidth of TE link information-source */
augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:information-source-entry/"
  + "tet:interface-switching-capability/"
  + "tet:max-lsp-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
when "../..../nw:network-types/tet:te-topology/"
  + "mwtopo:mw-topology" {
  description "Augment microwave TE bandwidth";
}
description "microwave bandwidth.";
case mw {
  uses mw-bandwidth;
}
}

/* Augment maximum bandwidth of TE link information-source */
augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:information-source-entry/"
  + "tet:max-link-bandwidth/"

```

```
    + "tet:te-bandwidth/tet:technology" {
when "../..../..../nw:network-types/tet:te-topology/"
  + "mwtopo:mw-topology" {
    description "Augment microwave TE bandwidth";
  }
  description "microwave bandwidth.";
  case mw {
    uses mw-bandwidth;
  }
}

/* Augment maximum reservable bandwidth of TE link
* information-source */
augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:information-source-entry/"
  + "tet:max-resv-link-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
when "../..../..../nw:network-types/tet:te-topology/"
  + "mwtopo:mw-topology" {
    description "Augment microwave TE bandwidth";
  }
  description "microwave bandwidth.";
  case mw {
    uses mw-bandwidth;
  }
}

/* Augment unreserved bandwidth of TE link information-source */
augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:information-source-entry/"
  + "tet:unreserved-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
when "../..../..../nw:network-types/tet:te-topology/"
  + "mwtopo:mw-topology" {
    description "Augment microwave TE bandwidth";
  }
  description "microwave bandwidth.";
  case mw {
    uses mw-bandwidth;
  }
}

/* Augment maximum LSP bandwidth of TE link template */
augment "/nw:networks/tet:te/tet:templates/"
  + "tet:link-template/tet:te-link-attributes/"
  + "tet:interface-switching-capability/"
  + "tet:max-lsp-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
```

```
    description "microwave bandwidth.";
    case mw {
        uses mw-bandwidth;
    }
}

/* Augment maximum bandwidth of TE link template */
augment "/nw:networks/tet:te/tet:templates/"
    + "tet:link-template/tet:te-link-attributes/"
    + "tet:max-link-bandwidth/"
    + "tet:te-bandwidth/tet:technology" {
    description "microwave bandwidth.";
    case mw {
        uses mw-bandwidth;
    }
}

/* Augment maximum reservable bandwidth of TE link template */
augment "/nw:networks/tet:te/tet:templates/"
    + "tet:link-template/tet:te-link-attributes/"
    + "tet:max-resv-link-bandwidth/"
    + "tet:te-bandwidth/tet:technology" {
    description "microwave bandwidth.";
    case mw {
        uses mw-bandwidth;
    }
}

/* Augment unreserved bandwidth of TE link template */
augment "/nw:networks/tet:te/tet:templates/"
    + "tet:link-template/tet:te-link-attributes/"
    + "tet:unreserved-bandwidth/"
    + "tet:te-bandwidth/tet:technology" {
    description "microwave bandwidth.";
    case mw {
        uses mw-bandwidth;
    }
}
}
<CODE ENDS>
```

## 5. Security Considerations

The YANG module specified in this document defines a schema for data that is designed to be accessed via network management protocols such as NETCONF [RFC6241] or RESTCONF [RFC8040][RFC8040]. The lowest

NETCONF layer is the secure transport layer, and the mandatory-to-implement secure transport is Secure Shell (SSH) [RFC6242]. The lowest RESTCONF layer is HTTPS, and the mandatory-to-implement secure transport is TLS [RFC8446].

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

There are a number of data nodes defined in this YANG module that are writable/creatable/deletable (i.e., config true, which is the default). These data nodes may be considered sensitive or vulnerable in some network environments. Write operations (e.g., edit-config) to these data nodes without proper protection can have a negative effect on network operations. These are the subtrees and data nodes and their sensitivity/vulnerability:

TBD.(list subtrees and data nodes and state why they are sensitive)

Some of the readable data nodes in this YANG module may be considered sensitive or vulnerable in some network environments. It is thus important to control read access (e.g., via get, get-config, or notification) to these data nodes. These are the subtrees and data nodes and their sensitivity/vulnerability:

TBD.(list subtrees and data nodes and state why they are sensitive)

## 6. IANA Considerations

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

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

IANA has recorded a YANG module name in the "YANG Module Names" registry [RFC6020] as follows:

Name: ietf-microwave-topology  
Namespace: urn:ietf:params:xml:ns:yang:ietf-microwave-topology  
Prefix: mwtopo  
Reference: RFC xxxx

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## Appendix A. Appendix A Examples of microwave topology

### A.1. Appendix A.1 A topology with single microwave radio link

Microwave is a transport technology which can be used to transport client services, such as ETH. When an ETH service is transported by a single microwave radio link, the topology could be shown as the Figure 3. Note that the figure just shows an example, there might be other possibilities to demonstrate the topology.



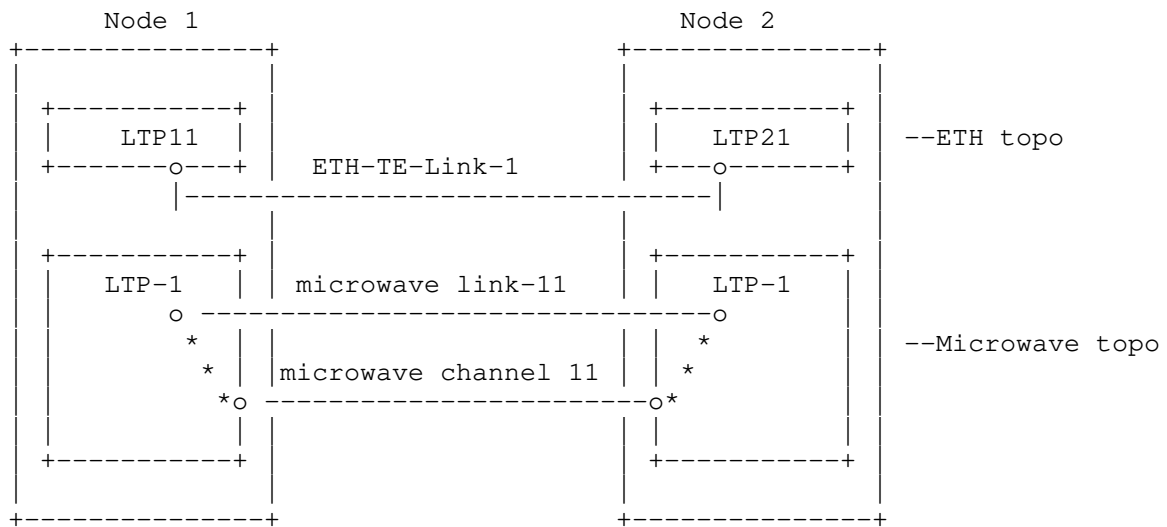


Figure 3: ETH transported on a single microwave radio link

In the above ETH topology, the ETH-TE-link is encoded in JSON as below:

```
...
"ietf-network-topology:link": [
  {
    "link-id": "N1,LTP11,N2,LTP21",
    "source": {
      "source-node": "N1",
      "source-tp": "LTP11"
    }
    "destination": {
      "dest-node": "N2",
      "dest-tp": "LTP21"
    }
    "supporting-link": {
      "network-ref": "mw-topo",
      "link-ref": "mw-link-11"
    }
  }
]
```

Note that the example above just shows the particular ETH link, not the full ETH topology.

In the microwave topology, the microwave link is encoded in JSON as below:

```

...
"ietf-network-topology:link": [
  {
    "link-id": "N1,LTP-1,N2,LTP-1",
    "source": {
      "source-node": "N1",
      "source-tp": "LTP-1"
    }
    "destination": {
      "dest-node": "N2",
      "dest-tp": "LTP-1"
    }
  }
]

"ietf-te-topology:link/te/te-link-attributes": [
  {
    "mw-channels":{
      "ietf-microwave-topology:mw-channel-id": "1",
      "ietf-microwave-topology:mw-channel-frequency": 10728000,
      "ietf-microwave-topology:mw-channel-separation": "28000",
      "ietf-microwave-topology:mw-channel-nominal-bandwidth":
        "1000",
      "ietf-microwave-topology:mw-channel-current-bandwidth":
        "1000",
      "ietf-microwave-topology:mw-channel-availability":{
        "availability":"99.99",
        "channel-bandwidth": "1000"
      }
    }
  }
]

"ietf-te-topology:node/te/interface-switching-capability
/max-lsp-bandwidth/te-bandwidth/technology":{
  "mw-bandwidth":"1000"
}

```

#### A.2. Appendix A.2 A topology with microwave radio links bundling

When a ETH service is transported over two microwave radio links (2+0 configuration), the topologies could be shown as in Figure 4. Note that the figure just shows one example, there might be other possibilities to demonstrate the topology.

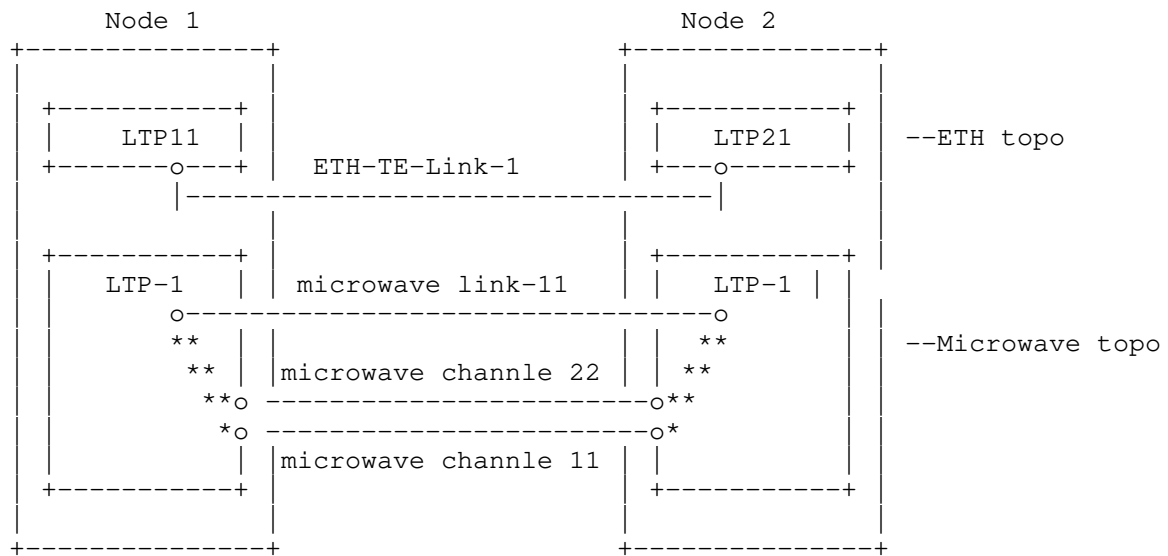


Figure 4: ETH transported on two microwave radio links

In the ETH topology, the ETH-TE-link is encoded in JSON as below:

```
...
"ietf-network-topology:link": [
  {
    "link-id": "N1,LTP11,N2,LTP21",
    "source": {
      "source-node": "N1",
      "source-tp": "LTP11"
    }
    "destination": {
      "dest-node": "N2",
      "dest-tp": "LTP21"
    }
    "supporting-link": {
      "network-ref": "mw-topo",
      "link-ref": "mw-link-11"
    }
  }
]
```

Note that the example above just shows the specific ETH link, not the full ETH topology.

In the microwave topology, the microwave link is encoded in JSON as below:

```
...

"ietf-network-topology:link": [
  {
    "link-id": "N1,LTP-1,N2,LTP-1",
    "source": {
      "source-node": "N1",
      "source-tp": "LTP-1"
    }
    "destination": {
      "dest-node": "N2",
      "dest-tp": "LTP-1"
    }
  }
]

"ietf-te-topology:link/te/te-link-attributes": [
  {
    "mw-channels":
    {
      "ietf-microwave-topology:mw-channel-id": "1",
      "ietf-microwave-topology:mw-channel-frequency": 10728000,
      "ietf-microwave-topology:mw-channel-separation": "28000",
      "ietf-microwave-topology:mw-channel-nominal-bandwidth":
      "1000",
      "ietf-microwave-topology:mw-channel-current-bandwidth":
      "1000",
      "ietf-microwave-topology:mw-channel-availability":{
        "availability":"99.99",
        "channel-bandwidth": "1000"
      }
    }

    {
      "ietf-microwave-topology:mw-channel-id": "2",
      "ietf-microwave-topology:mw-channel-frequency": 10756000,
      "ietf-microwave-topology:mw-channel-separation": "28000",
      "ietf-microwave-topology:mw-channel-nominal-bandwidth":
      "1000",
      "ietf-microwave-topology:mw-channel-current-bandwidth":
      "1000",
      "ietf-microwave-topology:mw-channel-availability":{
        "availability":"99.99",
        "channel-bandwidth": "1000"
      }
    }
  }
]
```

```
        }  
      }  
    ]  
  
    "ietf-te-topology:node/te/interface-switching-capability  
      /max-lsp-bandwidth/te-bandwidth/technology":{  
      "mw-bandwidth":"2000"  
    }  
  }
```

Note that the example above just shows the microwave component links, it doesn't show the full microwave topology.

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## Abstract

Transport network domains, including Optical Transport Network (OTN) and Wavelength Division Multiplexing (WDM) networks, are typically deployed based on a single vendor or technology platforms. They are often managed using proprietary interfaces to dedicated Element Management Systems (EMS), Network Management Systems (NMS) and increasingly Software Defined Network (SDN) controllers.

A well-defined open interface to each domain management system or controller is required for network operators to facilitate control automation and orchestrate end-to-end services across multi-domain networks. These functions may be enabled using standardized data models (e.g. YANG), and appropriate protocol (e.g., RESTCONF).

This document analyses the applicability of the YANG models being defined by the IETF (Traffic Engineering Architecture and Signaling (TEAS) and Common Control and Measurement Plane (CCAMP) WGs in particular) to support OTN single and multi-domain scenarios.

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## 1. Introduction

Transport of packet services are critical for a wide-range of applications and services, including data center and LAN interconnects, Internet service backhauling mobile backhaul and enterprise Carrier Ethernet services. These services are typically setup using stovepipe NMS and EMS platforms, often requiring propriety management platforms and legacy management interfaces. A clear goal of operators is to automate the setup of transport services across multiple transport technology domains.

A common open interface (API) to each domain controller and or management system is pre-requisite for network operators to control multi-vendor and multi-domain networks and also enable service provisioning coordination/automation. This can be achieved by using standardized YANG models, used together with an appropriate protocol (e.g., RESTCONF [RFC8040]).

This document analyses the applicability of the YANG models being defined by IETF (Traffic Engineering Architecture and Signaling (TEAS) and Common Control and Measurement Plane (CCAMP) WGs in particular) to support Optical Transport Networks (OTN) single and multi-domain scenarios.

### 1.1. The scope of this document

This document assumes a reference architecture, including interfaces, based on the Abstraction and Control of Traffic-Engineered Networks (ACTN), defined in [RFC8453].

The focus of this document is on the MPI (interface between the Multi Domain Service Coordinator (MDSC) and a Physical Network Controller (PNC), controlling a transport network domain).

It is worth noting that the same MPI analyzed in this document could be used between hierarchical MDSC controllers, as shown in Figure 4 of [RFC8453].

Detailed analysis of the CMI (interface between the Customer Network Controller (CNC) and the MDSC) as well as of the interface between service and network orchestrators are outside the scope of this document. However, some considerations and assumptions about the information are described when needed.

The relationship between the current IETF YANG models and the type of ACTN interfaces can be found in [ACTN-YANG]. Therefore, it considers the TE Topology YANG model defined in [TE-TOPO], with the OTN Topology augmentation defined in [OTN-TOPO] and the TE Tunnel YANG model defined in [TE-TUNNEL], with the OTN Tunnel augmentation defined in [OTN-TUNNEL]. It also considers the Ethernet Client Topology augmentation defined in [CLIENT-TOPO] as well as the Client Signal YANG models defined in [CLIENT-SIGNAL] for both Transparent and Ethernet clients.

The ONF Technical Recommendations for Functional Requirements for the transport API in [ONF TR-527] and the ONF transport API multi-domain examples in [ONF GitHub] have been considered as input for defining the reference scenarios analyzed in this document.

## 1.2. Assumptions

This document is making the following assumptions:

1. The MDSC can request, at the MPI, a PNC to setup a Transit Tunnel Segment using the TE Tunnel YANG model: in this case, since the endpoints of the E2E Tunnel are outside the domain controlled by that PNC, the MDSC would not specify any source or destination TE Tunnel Termination Point (TTP), i.e., it would leave empty the source, destination, src-tp-id and dst-tp-id attributes of the TE tunnel instance, and it would use the explicit-route-object (ERO) or route-object-include-exclude list to specify the ingress and egress links for each path of the Transit Tunnel Segment.
2. Each PNC provides to the MDSC, at the MPI, the list of available timeslots on the inter-domain links using the TE Topology YANG model and OTN Topology augmentation. The TE Topology YANG model in [TE-TOPO] is being updated to report the label set information.

See section 1.7 of [TE-TUTORIAL] for more details.

This document has made the following assumptions:

1. The topology information for the Ethernet Client access links is modelled using the YANG model defined in [CLIENT-TOPO];
2. The topology information for the OTN and Transparent Client access links is modelled using the YANG model defined in [OTN-TOPO];
3. The mapping information for Ethernet and Transparent Client signals are modelled using the YANG model defined in [CLIENT-SIGNAL].

Finally, the Network Elements (NEs) described in the scenarios used in the document are using ODU switching. It is assumed that the ODU links are pre-configured and using mechanisms such as WDM wavelength, which are outside the scope of this document.

## 2. Terminology

**Domain:** A domain as defined by [RFC4655] is "any collection of network elements within a common sphere of address management or path computation responsibility". Specifically, within this document we mean a part of an operator's network that is under common management (i.e., under shared operational management using the same instances of a tool and the same policies). Network elements will often be grouped into domains based on technology types, vendor profiles, and geographic proximity.

**E-LINE:** Ethernet Line

**EPL:** Ethernet Private Line

**EVPL:** Ethernet Virtual Private Line

**OTN:** Optical Transport Network

**Service:** A service in the context of this document can be considered as some form of connectivity between customer sites across the network operator's network [RFC8309].

Service Model: As described in [RFC8309] it describes a service and the parameters of the service in a portable way that can be used uniformly and independent of the equipment and operating environment.

UNI: User Network Interface

MDSC: Multi-Domain Service Coordinator

CNC: Customer Network Controller

PNC: Provisioning Network Controller

### 3. Conventions used in this document

#### 3.1. Topology and traffic flow processing

The traffic flow between different nodes is specified as an ordered list of nodes, separated with commas, indicating within the brackets the processing within each node:

<node> [<processing>]{, <node> [<processing>]}

The order represents the order of traffic flow being forwarded through the network.

The processing can be just switching at a given layer "[switching]" or also having an adaptation of a client layer into a server layer "[client -> server]" or [client -> (server)], depending on whether the node is switching in the client or in the server layer.

For example, the following traffic flow:

R1 [(PKT) -> ODU2], S3 [(ODU2)], S5 [(ODU2)], S6 [(ODU2)],  
R3 [ODU2 -> (PKT)]

Node R1 is switching at the packet (PKT) layer and mapping packets into an ODU2 before transmission to node S3. Nodes S3, S5 and S6 are switching at the ODU2 layer: S3 sends the ODU2 traffic to S5 which then sends it to S6 which finally sends to R3. Node R3 terminates the ODU2 from S6 before switching at the packet (PKT) layer.

The paths of working and protection transport entities are specified as an ordered list of nodes, separated with commas:

```
<node> {, <node>}
```

The order represents the order of traffic flow being forwarded through the network in the forward direction. In the case of bidirectional paths, the forward and backward directions are selected arbitrarily, but the convention is consistent between working/protection path pairs, as well as across multiple domains.

### 3.2. JSON code

This document provides some detailed JSON code examples to describe how the YANG models being developed by the IETF (TEAS and CCAMP WG in particular) may be used. The scenario examples are provided using JSON to facilitate readability.

Different objects need to have an identifier. The convention used to create mnemonic identifiers is to use the object name (e.g., S3 for node S3), followed by its type (e.g., NODE), separated by an "-", followed by "-ID". For example, the mnemonic identifier for node S3 would be S3-NODE-ID.

The JSON language does not support the insertion of comments that have been instead found to be useful when writing the examples. This document will insert comments into the JSON code as JSON name/value pair with the JSON name string starting with the "//" characters. For example, when describing the example of a TE Topology instance representing the ODU Abstract Topology exposed by the Transport PNC, the following comment has been added to the JSON code:

```
"// comment": "ODU Abstract Topology @ MPI",
```

The JSON code examples provided in this document have been validated against the YANG models following the validation process described in Appendix A, which would not consider the comments.

In order to have successful validation of the examples, some numbering scheme has been defined to assign identifiers to the different entities which would pass the syntax checks. In that case, to simplify the reading, another JSON name/value pair formatted as a comment and using the mnemonic identifiers is also provided. For example, the identifier of node S3 (S3-NODE-ID) has been assumed to

be "10.0.0.3" and would be shown in the JSON code example using the two JSON name/value pair:

```
"// te-node-id": "S3-NODE-ID",  
"te-node-id": "10.0.0.3",
```

The first JSON name/value pair will be automatically removed in the first step of the validation process while the second JSON name/value pair will be validated against the YANG model definitions.

#### 4. Scenarios Description

##### 4.1. Reference Network

The physical topology of the reference network is shown in Figure 1. It represents an OTN network composed of three transport network domains which provide transport connectivity services to an IP customer network through eight access links:

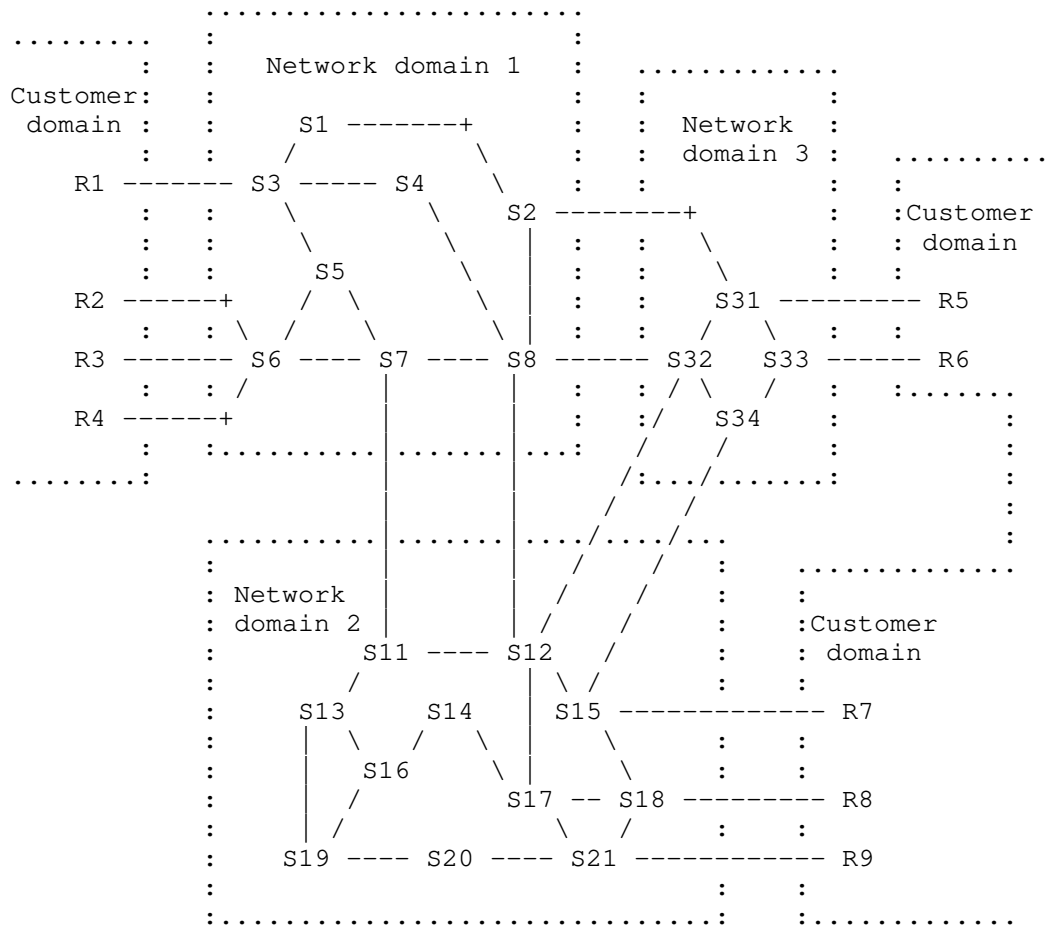


Figure 1 - Reference network

This document assumes that all the transport network switching nodes  $S_i$  are capable of switching in the electrical domain (ODU switching) and that all the  $S_i$ - $S_j$  OTN links within the transport network (intra-domain or inter-domain) are 100G links while the access  $R_i$ - $S_j$  links are 10G links.

It is also assumed that, within the transport network, the physical/optical interconnections supporting the  $S_i$ - $S_j$  OTN links (up to the OTU4 trail), are pre-configured using mechanisms which are



outside the scope of this document and are not exposed at the MPIs to the MDSC.

Different technologies can be used on the access links (e.g., Ethernet, STM-N and OTU). Section 4.3 provides more details about the different assumptions on the access links for different services types and section 4.4 describes the control of access links which can support different technology configuration (e.g., STM-64, 10GE or OTU2) depending on the type of service being configured (multi-function access links).

The transport domain control architecture, shown in Figure 2, follows the ACTN architecture and framework document [RFC8453], and functional components:

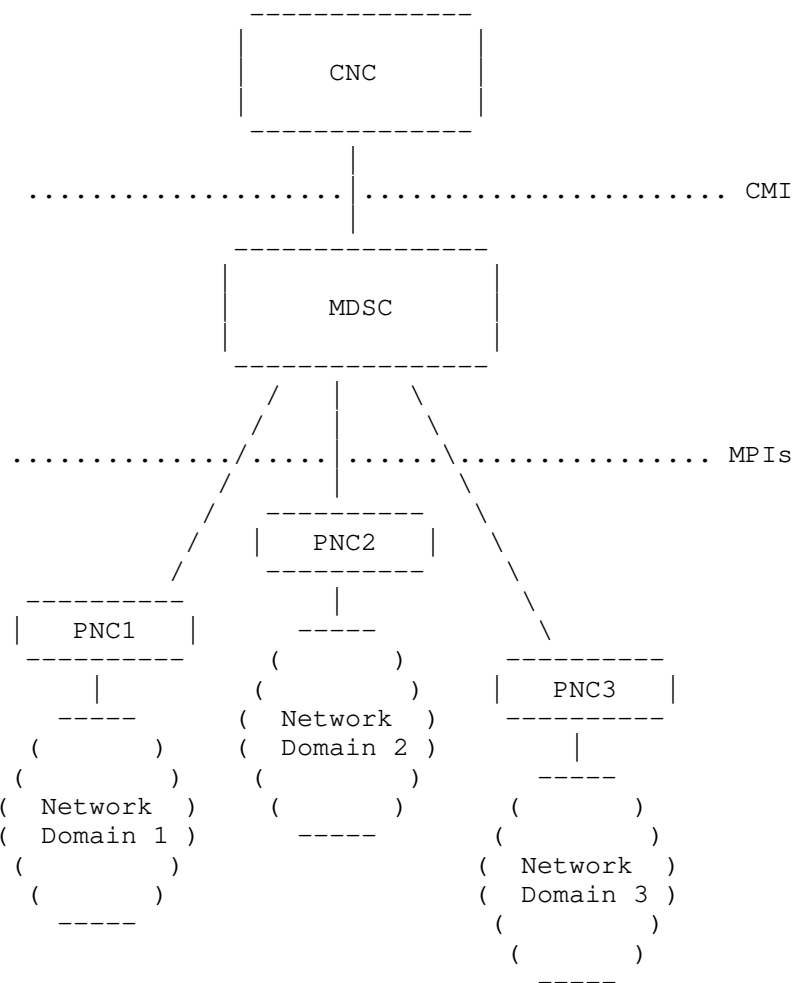


Figure 2 - Controlling Hierarchies

The ACTN framework facilitates the detachment of the network and service control from the underlying technology. It helps the customer define the network as desired by business needs. Therefore, care must be taken to keep a minimal level of dependency on the CMI (or no dependency at all) with respect to the network domain technologies. The MPI instead requires some specialization according to the domain technology.

The control interfaces within the scope of this document are the three MPIs shown in Figure 2.

It is worth noting that the split of functionality at the MPI in the ACTN architecture between the MDSC and the PNCs is equivalent/analogous to the split of functionality which is assumed for the ONF T-API interface when used between a multi-domain controller and domain controllers, as described in the ONF T-API multi-domain use cases [ONF TR-527], as well as at the MEF PRESTO interface between the Service Orchestration Functionality (SOF) and the Infrastructure Control and Management (ICM) in the MEF LSO Architecture [MEF 55].

This document does not make any assumption about the control architecture of the customer IP network: in line with [RFC8453], the CNC is just a functional component within the customer control architecture which is capable of requesting, at the CMI, transport connectivity between IP routers, when needed.

The CNC can request transport connectivity services between IP routers which can be attached to different transport domains (e.g., between R1 and R8 in Figure 1) or to the same transport domain (e.g., between R1 and R3 in Figure 1). Since the CNC is not aware of the transport network controlling hierarchy, the mechanisms used by the CNC to request, at the CMI, transport connectivity services are independent on whether the service request is single-domain or multi-domain.

It is assumed that the CMI allows the CNC to provide all the information that is required by the MDSC to understand the connectivity service request and to decide the network configurations to be requested, at the MPIs, to its underlying PNCs to support the requested connectivity service.

When a single-domain service is requested by the CNC at the CMI (e.g., between R1 and R3 in Figure 1), the MDSC can follow the same procedures, described above for the multi-domain service, and decide the network configuration to request only at the MPI of the PNC controlling that domain (e.g., MPI1 of PNC1 in Figure 2).

#### 4.2. Topology Abstractions

Abstraction provides a selective method for representing connectivity information within a domain. There are multiple methods

to abstract a network topology. This document assumes the abstraction method defined in [RFC7926]:

"Abstraction is the process of applying the policy to the available TE information within a domain, to produce selective information that represents the potential ability to connect across the domain. Thus, abstraction does not necessarily offer all possible connectivity options, but presents a general view of potential connectivity according to the policies that determine how the domain's administrator wants to allow the domain resources to be used."

[RFC8453] Provides the context of topology abstraction in the ACTN architecture and discusses a few alternatives for the abstraction methods for both packet and optical networks. This is an important consideration since the choice of the abstraction method impacts protocol design and the information it carries. According to [RFC8453], there are three types of topology:

- o White topology: This is a case where the PNC provides the actual network topology to the MDSC without any hiding or filtering. In this case, the MDSC has the full knowledge of the underlying network topology;
- o Black topology: The entire domain network is abstracted as a single virtual node with the access/egress links without disclosing any node internal connectivity information;
- o Grey topology: This abstraction level is between black topology and white topology from a granularity point of view. This is an abstraction of TE tunnels for all pairs of border nodes. We may further differentiate from a perspective of how to abstract internal TE resources between the pairs of border nodes:
  - Grey topology type A: border nodes with TE links between them in a full mesh fashion;
  - Grey topology type B: border nodes with some internal abstracted nodes and abstracted links.

Each PNC should provide the MDSC with a network topology abstractions hiding the internal details of the physical domain network topology controlled by the PNC and this abstraction is independent of the abstractions provided by other PNCs. Therefore it

is possible that different PNCs provide different types of topology abstractions and each MPI operates on the abstract topology regardless of, and independently from, the type of abstraction provided by the PNC.

To analyze how the MDSC can operate on abstract topologies independently from the topology abstraction provided by each PNC and, therefore, that different PNCs can provide different topology abstractions, that the following examples are assumed:

- o PNC1 and PNC2 provide black topology abstractions which expose at MPI1, and MPI2 respectively, a single virtual node (representing the whole network domain 1, and domain 2 respectively).
- o PNC3 provides a white topology abstraction which exposes at MPI3 all the physical nodes and links within network domain 3.

The MDSC should be capable of stitching together the abstracted topologies provided by each PNC to build its own view of the multi-domain network topology. The process may require suitable oversight, including administrative configuration and trust models, a method of how to achieve this is out of scope for this document.

The MDSC can also provide topology abstraction of its own view of the multi-domain network topology at its CMIs depending on the customers' needs: it can provide different types of topology abstractions at different CMIs. Analyzing the topology abstractions provided by the MDSC to its CMIs is outside the scope of this document.

#### 4.3. Service Configuration

In the following scenarios, it is assumed that the CNC is capable of requesting service connectivity from the MDSC to support IP routers connectivity.

The type of services could depend on the type of physical links (e.g. OTN link, ETH link or SDH link) between the routers and transport network.

The control of different adaptations inside IP routers,  $R_i$  (PKT  $\rightarrow$  foo) and  $R_j$  (foo  $\rightarrow$  PKT), are assumed to be performed by means that are not under the control of, and not visible to, the MDSC nor to

the PNCs. Therefore, these mechanisms are outside the scope of this document.

#### 4.3.1. ODU Transit

The physical links interconnecting the IP routers and the transport network can be 10G OTN links.

In this case, it is assumed that the physical/optical interconnections below the ODU layer (up to the OTU2 trail) are pre-configured using mechanisms which are outside the scope of this document and not exposed at the MPIS between the PNCs and the MDSC.

For simplicity of the description, it is also assumed that these interfaces are not channelized (i.e., they can only support one ODU2).

To setup a 10Gb IP link between R1 and R8, an ODU2 end-to-end connection needs to be created, passing through transport nodes S3, S1, S2, S31, S33, S34, S15 and S18 which belong to different PNC domains (multi-domain service request):

```
R1 [(PKT) -> ODU2], S3 [(ODU2)], S1 [(ODU2)], S2 [(ODU2)],  
S31 [(ODU2)], S33 [(ODU2)], S34 [(ODU2)],  
S15 [(ODU2)], S18 [(ODU2)], R8 [ODU2 -> (PKT)]
```

The MDSC understands that it needs to establish an ODU2 transit service between the access links on S3 and S18, which belong to different PNC domains (multi-domain service request). It also decides the network configurations to request, at the MPIS, to its underlying PNCs, to coordinate the setup of a multi-domain ODU2 segment connection between the access links on S3 and S18.

To setup of a 10Gb IP link between R1 and R3, an ODU2 end-to-end connection needs to be created, passing through transport nodes S3, S5 and S6 which belong to the same PNC domain (single-domain service request):

```
R1 [(PKT) -> ODU2], S3 [(ODU2)], S5 [(ODU2)], S6 [(ODU2)],  
R3 [ODU2 -> (PKT)]
```

As described in section 4.1, the mechanisms used by the CNC at the CMI are independent on whether the service request is single-domain service or multi-domain.

The MDSC can understand that it needs to setup an ODU2 transit service between the access links on S3 and S6, which belong to the same PNC domain (single-domain service request) and it decides the proper network configuration to request PNC1.

#### 4.3.2. EPL over ODU

The physical links interconnecting the IP routers and the transport network can be 10G Ethernet physical links (10GE).

In this case, it is assumed that the Ethernet physical interfaces (up to the MAC layer) are pre-configured using mechanisms which are outside the scope of this document and not exposed at the MPis between the PNCs and the MDSC.

To setup a 10Gb IP link between R1 and R8, an EPL service needs to be created, supported by an ODU2 end-to-end connection, between transport nodes S3 and S18, passing through transport nodes S1, S2, S31, S33, S34 and S15, which belong to different PNC domains (multi-domain service request):

```
R1 [(PKT) -> ETH], S3 [ETH -> (ODU2)], S1 [(ODU2)],  
S2 [(ODU2)], S31 [(ODU2)], S33 [(ODU2)], S34 [(ODU2)],  
S15 [(ODU2)], S18 [(ODU2) -> ETH], R8 [ETH -> (PKT)]
```

The MDSC understands that it needs to setup an EPL service between the access links on S3 and S18, which belong to different PNC domains (multi-domain service request). It also decides the network configurations to request, at the MPis, to its underlying PNCs, to coordinate the setup of an end-to-end ODU2 connection between the nodes S3 and S8, including the configuration of the adaptation functions inside these edge nodes, such as S3 [ETH -> (ODU2)] and S18 [(ODU2) -> ETH].

To setup a 10Gb IP link between R1 and R2, an EPL service needs to be created, supported by an ODU2 end-to-end connection between transport nodes S3 and S6, passing through the transport node S5, which belong to the same PNC domain (single-domain service request):

```
R1 [(PKT) -> ETH], S3 [ETH -> (PKT)] S5 [(ODU2)],  
S6 [(ODU2) -> ETH], R2 [ETH -> (PKT)]
```

As described in section 4.1, the mechanisms used by the CNC at the CMI are independent on whether the service request is single-domain service or multi-domain.

Based on the assumption above, in this case, the MDSC can understand that it needs to setup an EPL service between the access links on S3 and S6, which belong to the same PNC domain (single-domain service request) and it decides the proper network configuration to request PNC1.

#### 4.3.3. Other OTN Clients Services

[ITU-T G.709] defines mappings of different Transparent Client layers into ODU. Most of them are used to provide Private Line services over an OTN transport network supporting a variety of types of physical access links (e.g., Ethernet, SDH STM-N, Fibre Channel, InfiniBand, etc.) interconnecting the IP routers and the transport network.

In order to setup a 10Gb IP link between R1 and R8 using, with for example SDH physical links between the IP routers and the transport network, an STM-64 Private Line service needs to be created, supported by an ODU2 end-to-end connection, between transport nodes S3 and S18, passing through transport nodes S1, S2, S31, S33, S34 and S15, which belong to different PNC domains (multi-domain service request):

```
R1 [(PKT) -> STM-64], S3 [STM-64 -> (ODU2)], S1 [(ODU2)],  
S2 [(ODU2)], S31 [(ODU2)], S33 [(ODU2)], S34[(ODU2)],  
S15 [(ODU2)], S18 [(ODU2) -> STM-64], R8 [STM-64 -> (PKT)]
```

As already described (section 4.1) CNC provides the essential information to permit the MDSC to understand which type of service is needed, in this case, an STM-64 Private Line service between the access links on S3 and S8, and it also decides the network configurations, including the configuration of the adaptation functions inside these edge nodes, such as S3 [STM-64 -> (ODU2)] and S18 [(ODU2) -> STM-64].

To setup a 10Gb IP link between R1 and R3), an STM-64 Private Line service needs to be created between R1 and R3 (single-domain service request):



```
R1 [(PKT) -> STM-64], S3[STM-64 -> (ODU2)], S5 [(ODU2)],  
S6 [(ODU2) -> STM-64], R3[STM-64 -> (PKT)]
```

As described in section 4.1, the mechanisms used by the CNC at the CMI are independent on whether the service request is single-domain service or multi-domain.

Based on the assumption above, in this case, the MDSC can understand that it needs to setup an STM-64 Private Line service between the access links on S3 and S6, which belong to the same PNC domain (single-domain service request) and it decides the proper network configuration to request PNC1.

#### 4.3.4. EVPL over ODU

When the physical links interconnecting the IP routers and the transport network are Ethernet physical links, it is also possible that different Ethernet services (e.g., EVPL) can share the same physical access link using different VLANs.

As described in section 4.3.2, it is assumed that the Ethernet physical interfaces (up to the MAC layer) are pre-configured.

To setup two 1Gb IP links between R1 to R2 and between R1 and R8, two EVPL services need to be created, supported by two ODU0 end-to-end connections:

```
R1 [(PKT) -> VLAN], S3 [VLAN -> (ODU0)], S5 [(ODU0)],  
S6 [(ODU0) -> VLAN], R2 [VLAN -> (PKT)]
```

```
R1 [(PKT) -> VLAN], S3[VLAN -> (ODU0)], S1 [(ODU0)],  
S2 [(ODU0)], S31 [(ODU0)], S33 [(ODU0)], S34 [(ODU0)],  
S15 [(ODU0)], S18 [(ODU0) -> VLAN], R8[VLAN -> (PKT)]
```

It is worth noting that the first EVPL service is required between access links which belong to the same PNC domain (single-domain service request) while the second EVPL service is required between access links which belong to different PNC domains (multi-domain service request).

Since the two EVPL services are sharing the same Ethernet physical link between R1 and S3, different VLAN IDs are associated with different EVPL services: for example, VLAN IDs 10 and 20 respectively.

Based on the assumptions described in section 4.3.2, the CNC requests at the CMI the MDSC to setup these EVPL services and the MDSC understands the network configurations to request to the underlying PNCs, as described in section 4.3.2.

#### 4.4. Multi-function Access Links

Some physical links interconnecting the IP routers and the transport network can be configured in different modes, e.g., as OTU2 trail or STM-64 or 10GE physical links.

This configuration can be done a-priori by means which are outside the scope of this document. In this case, these links will appear at the MPI as links supporting only one mode (depending on the a-priori configuration) and will be controlled at the MPI as discussed in section 4.3: for example, a 10G multi-function access link can be pre-configured as an OTU2 trail (section 4.3.1), a 10GE physical link (section 4.3.2) or an STM-64 physical link (section 4.3.3).

It is also possible not to configure these links a-priori and let the MDSC (or, in case of a single-domain service request, the PNC) decide how to configure these links, based on the service configuration.

For example, if the physical link between R1 and S3 is a multi-functional access link while the physical links between R4 and S6 and between R8 and S18 are STM-64 and 10GE physical links respectively, it is possible to configure either an STM-64 Private Line service between R1 and R4 or an EPL service between R1 and R8.

The traffic flow between R1 and R4 can be summarized as:

```
R1 [(PKT) -> STM-64], S3 [STM-64 -> (ODU2)], S5 [(ODU2)],  
S6 [(ODU2) -> STM-64], R4 [STM-64 -> (PKT)]
```

The traffic flow between R1 and R8 can be summarized as:

```
R1 [(PKT) -> ETH], S3 [ETH -> (ODU2)], S1 [(ODU2)],  
S2 [(ODU2)], S31 [(ODU2)], S33 [(ODU2)], S34 [(ODU2)],  
S15 [(ODU2)], S18 [(ODU2) -> ETH], R8 [ETH -> (PKT)]
```

The CNC is capable to request at the CMI the setup either an STM-64 Private Line service, between R1 and R4, or an EPL service, between R1 and R8.

The MDSC, based on the service being request, decides the network configurations to request, at the MPis, to its underlying PNCs, to coordinate the setup of an end-to-end ODU2 connection, either between nodes S3 and S6, or between nodes S3 and S18, including the configuration of the adaptation functions on these edge nodes, and in particular whether the multi-function access link between R1 and S3 should operate as an STM-64 or as a 10GE physical link.

#### 4.5. Protection and Restoration Configuration

Protection switching provides a pre-allocated survivability mechanism, typically provided via linear protection methods and would be configured to operate as 1+1 unidirectional (the most common OTN protection method), 1+1 bidirectional or 1:n bidirectional. This ensures fast and simple service survivability.

Restoration methods would provide the capability to reroute and restore connectivity traffic around network faults, without the network penalty imposed with dedicated 1+1 protection schemes.

This section describes only services which are protected with linear protection. The description of services using dynamic restoration is outside the scope of this document.

The MDSC needs to be capable of deciding the network configuration to request different PNCs to coordinate the protection switching configuration to support protected connectivity services described in section 4.3.

Since in these service examples, switching within the transport network domain is performed only in the OTN ODU layer. It may also be assumed that protection switching within the transport network domain is provided at the OTN ODU layer.

##### 4.5.1. Linear Protection (end-to-end)

In order to protect the connectivity services described in section 4.3 from failures within the OTN multi-domain transport network, the MDSC can decide to request its underlying PNCs to configure ODU2 linear protection between the access nodes (e.g., nodes S3 and S18 for the services setup between R1 and R8).

It is assumed that the OTN linear protection is configured to with 1+1 unidirectional protection switching type, as defined in [ITU-T G.808.1] and [ITU-T G.873.1], as well as in [RFC4427].

In these scenarios, a working transport entity and a protection transport entity, as defined in [ITU-T G.808.1], (or a working LSP and a protection LSP, as defined in [RFC4427]) should be configured in the data plane.

Two cases can be considered:

- o In one case, the working and protection transport entities pass through the same PNC domains:

Working transport entity: S3, S1, S2,  
S31, S33, S34,  
S15, S18

Protection transport entity: S3, S4, S8,  
S32,  
S12, S17, S18

- o In another case, the working and protection transport entities can pass through different PNC domains:

Working transport entity: S3, S5, S7,  
S11, S12, S17, S18

Protection transport entity: S3, S1, S2,  
S31, S33, S34,  
S15, S18

The PNCs should be capable to report to the MDSC which is the active transport entity, as defined in [ITU-T G.808.1], in the data plane.

Given the fast dynamic of protection switching operations in the data plane (50ms recovery time), this reporting is not expected to be in real-time.

It is also worth noting that with unidirectional protection switching, e.g., 1+1 unidirectional protection switching, the active transport entity may be different in the two directions.

#### 4.5.2. Segmented Protection

To protect the connectivity services defined in section 4.3 from failures within the OTN multi-domain transport network, the MDSC can decide to request its underlying PNCs to configure ODU2 linear protection between the edge nodes of each domain.

For example, MDSC can request PNC1 to configure linear protection between its edge nodes S3 and S2:

Working transport entity: S3, S1, S2

Protection transport entity: S3, S4, S8, S2

MDSC can also request PNC2 to configure linear protection between its edge nodes S15 and S18:

Working transport entity: S15, S18

Protection transport entity: S15, S12, S17, S18

MDSC can also request PNC3 to configure linear protection between its edge nodes S31 and S34:

Working transport entity: S31, S33, S34

Protection transport entity: S31, S32, S34

#### 4.6. Notification

To realize the topology update, service update and restoration function, following notification type should be supported:

1. Object create
2. Object delete
3. Object state change
4. Alarm

There are three types of topology abstraction type defined in section 4.2, the notification should also be abstracted. The PNC and MDSC should coordinate together to determine the notification

policy, such as when an intra-domain alarm occurred, the PNC may not report the alarm but the service state change notification to the MDSC.

#### 4.7. Path Computation with Constraint

It is possible to define constraints to be taken into account during path computation procedures (e.g., IRO/XRO).

For example, the CNC can request, at the CMI, an ODU transit service, as described in section 4.3.1, between R1 and R8 with the constraint to pass through the link from S2 to S31 (IRO), such that a qualified path could be:

```
R1 [(PKT) -> ODU2], S3 [(ODU2)], S1 [(ODU2)], S2 [(ODU2)],  
S31 [(ODU2)], S33 [(ODU2)], S34 [(ODU2)],  
S15 [(ODU2)], S18 [(ODU2)], R8 [ODU2 -> (PKT)]
```

If the CNC instead requested to pass through the link from S8 to S12, then the above path would not be qualified, while the following would be:

```
R1 [(PKT) -> ODU2], S3[(ODU2)], S1 [(ODU2)], S2[(ODU2)],  
S8 [(ODU2)], S12[(ODU2)], S15 [(ODU2)], S18[(ODU2)], R8 [ODU2 ->  
(PKT)]
```

The mechanisms used by the CNC to provide path constraints at the CMI are outside the scope of this document. It is assumed that the MDSC can understand these constraints and take them into account in its path computation procedures (which would decide at least which domains and inter-domain links) and in the path constraints to provide to its underlying PNCs, to be taken into account in the path computation procedures implemented by the PNCs (with a more detailed view of topology).

#### 5. YANG Model Analysis

This section analyses how the IETF YANG models can be used at the MPIs, between the MDSC and the PNCs, to support the scenarios described in section 4.

The YANG models described in [ACTN-YANG] are assumed to be used at the MPI.

Section 5.1 describes the different topology abstractions provided to the MDSC by each PNC via its own MPI.

Section 5.2 describes how the MDSC can request different PNCs, via their own MPIs, the network configuration needed to setup the different services described in section 4.3.

Section 5.3 describes how the protection scenarios can be deployed, including end-to-end protection and segment protection, for both intra-domain and inter-domain scenario.

#### 5.1. YANG Models for Topology Abstraction

Each PNC reports its respective OTN abstract topology to the MDSC, as described in section 4.2, using the Topology YANG models, defined in [RFC8345], with the TE Topology YANG augmentations, provided in [TE-TOPO], and the OTN technology-specific YANG augmentations, defined in [OTN-TOPO].

The [OTN-TOPO] model allows reporting within the OTN abstract topology also the access links which are capable of supporting the transparent client layers, defined in section 4.3.3 and in [CLIENT-SIGNAL]. These links can also be multi-function access links that can be configured as a transparent client physical links (e.g., STM-64 physical link) as an OTUk trail.

In order to support the EPL and EVPL services, described in sections 4.3.2 and 4.3.4, the access links, which are capable to be configured as Ethernet physical links, are reported by each PNC within its respective Ethernet abstract topology, using the Topology YANG models, defined in [RFC8345], with the TE Topology YANG augmentations, defined in [TE-TOPO], and the Ethernet client technology-specific YANG augmentations, defined in [CLIENT-TOPO]. These links can also be multi-function access links that can be configured as an Ethernet physical link or as an OTUk trail and/or as transparent client physical links (e.g., STM-64 physical link). In this case, these physical access links are represented in both the OTN and Ethernet abstract topologies.

It is worth noting that in the network scenarios analyzed in this document (where switching is performed only in the ODU layer), the Ethernet abstract topologies reported by the PNCs describes only the Ethernet client access links: no Ethernet TE switching capabilities are reported in these Ethernet abstract topologies.

## 5.1.1.1. Domain 1 Black Topology Abstraction

PNC1 provides the required black topology abstraction, as described in section 4.2. It exposes at MPI1 to the MDSC, two TE Topology instances with only one TE node each.

The first TE Topology instance reports the domain 1 OTN abstract topology view (MPI1 OTN Topology), using the OTN technology-specific augmentations [OTN-TOPO], with only one abstract TE node (i.e., AN1) and only inter-domain and access abstract TE links (which represent the inter-domain physical links and the access physical links which can support ODU and/or transparent client layers), as shown in Figure 3 below.

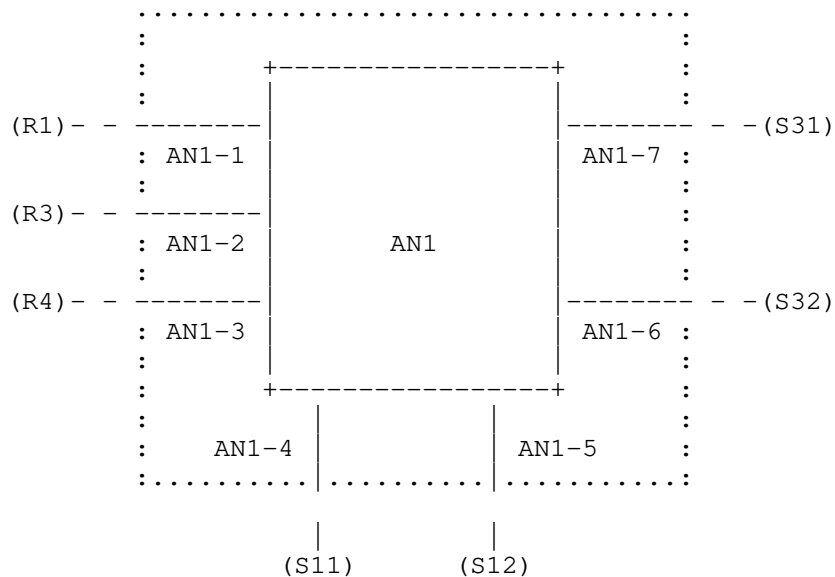


Figure 3 - OTN Abstract Topology exposed at MPI1 (MPI1 OTN Topology)

The second TE Topology instance reports the domain 1 Ethernet abstract topology view (MPI1 ETH Topology), using the Ethernet technology-specific augmentations [CLIENT-TOPO], with only one abstract TE node (i.e., AN1) and only access abstract TE links (which represent the access physical links which can support Ethernet client layers), as shown in Figure 4 below.



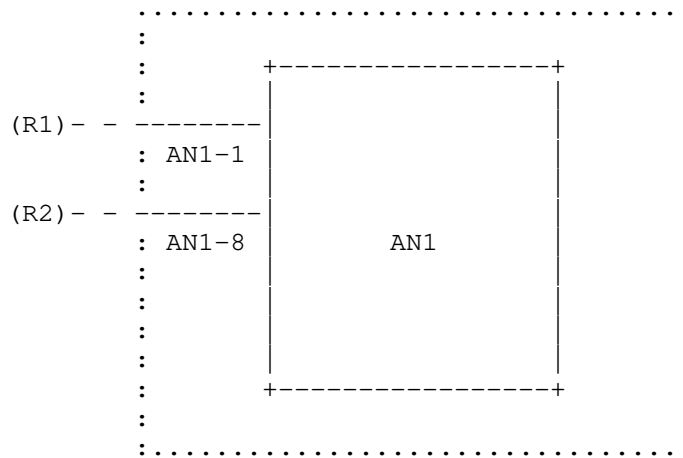


Figure 4 - ETH Abstract Topology exposed at MPI1 (MPI1 ETH Topology)

As described in section 4.1, it is assumed that the OTU4 trails on the inter-domain physical links (e.g., the link between S2 and S31) are pre-configured and exposed as external TE Links, within the MPI1 OTN topology (e.g., the external TE Link terminating on AN1-7 TE Link Termination Point (LTP) abstracting the OTU4 trail between S2 and S31).

In order to analyze the service scenarios of sections 4.3 and 4.4:

- o the access link between S3 and R1 is assumed to be a multi-function access link, which can be configured as an OTU2 trail or as an STM-64 or a 10GE physical link;
- o the access link between S6 and R2 is assumed to be pre-configured as a 10GE physical link, up to the MAC layer;
- o the access link between S6 and R3 is assumed to be a multi-function access link which can be configured as an OTU2 trail or as an STM-64 physical link;
- o the access link connected to router R4 is assumed to be pre-configured as an STM-64 physical link.

Therefore PNC1 exports at MPI1 the following external TE Links, within the MPI1 OTN topology:

- o two abstract TE Links, terminating on LTP AN1-1 and AN1-2 respectively, abstracting the physical access link between S3 and R1 and the access link between S6 and R3 respectively, reporting that they can support STM-64 client signals as well as ODU2 connections;
- o one abstract TE Link, terminating on LTP AN1-3, abstracting the physical access link between S6 and R4, reporting that it can support STM-64 client signals but no ODU2 connections.

The information about the 10GE access link between S6 and R2 as well as the fact that the access link between S3 and R1 can also be configured as a 10GE link cannot be exposed by PNC1 within the MPI1 OTN topology.

Therefore, PNC1 exports at MPI1, within the MPI1 ETH topology, two abstract TE Links, terminating on LTP AN1-1 and AN1-8 respectively, abstracting the physical access link between S3 and R1 and the access link between S6 and R2 respectively, reporting that they can support Ethernet client signal with port-based and VLAN-based classifications. The PNC1 native topology would represent the physical network topology of the domain controlled by the PNC, as shown in Figure 5.

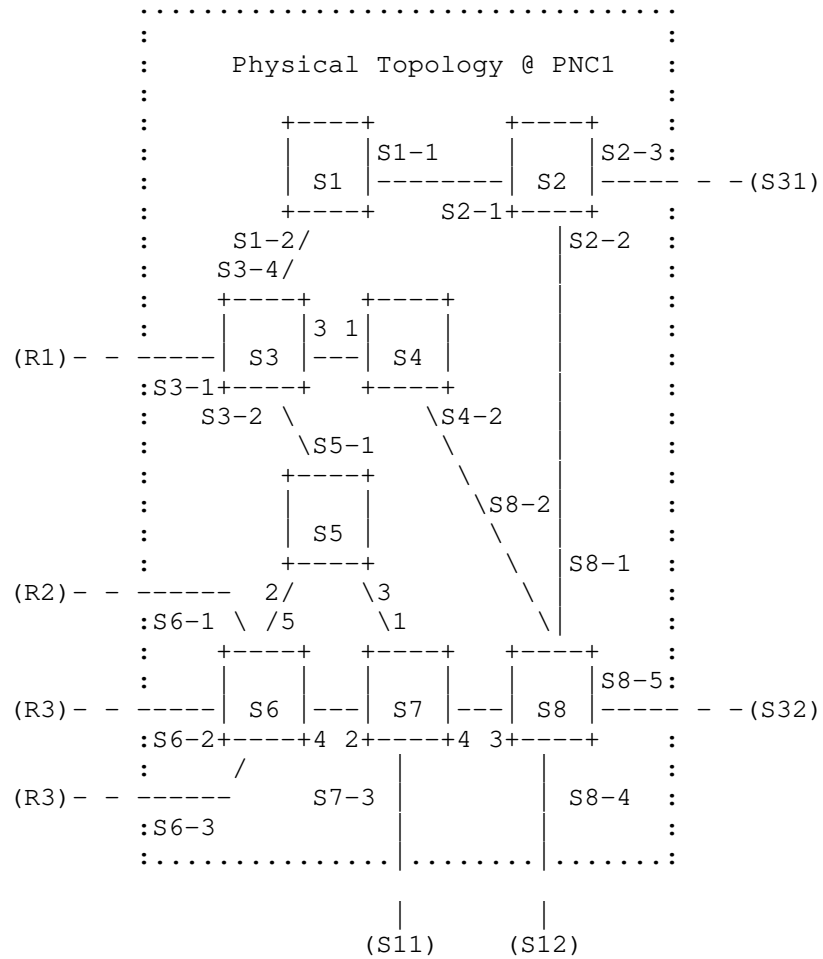


Figure 5 - Physical Topology controlled by PNC1

The PNC1 native topology is not exposed and therefore it under PNC responsibility to abstract the whole domain physical topology as a single TE node and to maintain a mapping between the LTPs exposed at MPI abstract topologies and the associated physical interfaces controlled by the PNC:

Physical Interface (Figure 5)	OTN Topology LTP (Figure 3)	ETH Topology LTP (Figure 4)
S2-3	AN1-7	
S3-1	AN1-1	AN1-1
S6-1		AN1-8
S6-2	AN1-2	
S6-3	AN1-3	
S7-3	AN1-4	
S8-4	AN1-5	
S8-5	AN1-6	

Appendix B.1.1 provides the detailed JSON code example ("mpil-otn-topology.json") describing how the MPI1 ODU Topology is reported by the PNC1, using the [RFC8345], [TE-TOPO] and [OTN-TOPO] YANG models, at MPI1.

It is worth noting that this JSON code example does not provide all the attributes defined in the relevant YANG models, including:

- o YANG attributes which are outside the scope of this document are not shown;
- o The attributes describing the set of label values that are available at the inter-domain links (label-restriction container) are also not shown to simplify the JSON code example;
- o The comments describing the rationale for not including some attributes in this JSON code example even if in the scope of this document are identified with the prefix "// \_\_COMMENT" and included only in the first object instance (e.g., in the Access Link from the AN1-1 description or in the AN1-1 LTP description).

#### 5.1.2. Domain 2 Black Topology Abstraction

PNC2 provides the required black topology abstraction, as described in section 4.2, to expose to the MDSC, at MPI2, two TE Topology instances with only one TE node each:

- o the first instance reports the domain 2 OTN abstract topology view (MPI2 OTN Topology), with only one abstract node (i.e., AN2) and only inter-domain and access abstract TE links (which represent the inter-domain physical links and the access physical links which can support ODU and/or transparent client layers);

- o the instance reports the domain 2 Ethernet abstract topology view (MPI2 ETH Topology), with only one abstract TE node (i.e., AN2) and only access abstract TE links (which represent the access physical links which can support Ethernet client layers).

#### 5.1.3. Domain 3 White Topology Abstraction

PNC3 provides the required white topology abstraction, as described in section 4.2, to expose to the MDSC, at MPI3, two TE Topology instances with multiple TE nodes, one for each physical node:

- o the first instance reports the domain 3 OTN topology view (MPI3 OTN Topology), with four TE nodes, which represent the four physical nodes (i.e. S31, S32, S33 and S34), and abstract TE links, which represent the inter-domain and internal physical links;
- o the second instance reports the domain 3 Ethernet abstract topology view (MPI3 ETH Topology), with only two TE nodes, which represent the two edge physical nodes (i.e., S31 and S33) and only the two access TE links which represent the access physical links.

#### 5.1.4. Multi-domain Topology Merging

As assumed at the beginning of this section, MDSC does not have any knowledge of the topologies of each domain until each PNC reports its own abstract topologies, so the MDSC needs to merge together these abstract topologies, provided by different PNCs, to build its own topology view of the multi-domain network (MDSC multi-domain native topology), as described in section 4.3 of [TE-TOPO].

Given the topologies reported from multiple PNCs, the MDSC need to merge them into its multi-domain native topology. The topology of each domain may be in an abstracted shape (refer to section 5.2 of [RFC8453] for a different level of abstraction), while the inter-domain link information must be complete and fully configured by the MDSC.

The inter-domain link information is reported to the MDSC by the two PNCs, controlling the two ends of the inter-domain link.

The MDSC needs to understand how to merge together these inter-domain links.

One possibility is to use the plug-id information, defined in [TE-TOPO]: two inter-domain TE links, within two different MPI abstract topologies, terminating on two LTPs reporting the same plug-id value can be merged as a single intra-domain link, within any MDSC native topology.

The value of the reported plug-id information can be either assigned by a central network authority, and configured within the two PNC domains. Alternatively, it may be discovered using an automatic discovery mechanisms (e.g., LMP-based, as defined in [RFC6898]).

In case the plug-id values are assigned by a central authority, it is under the central authority responsibility to assign unique values.

In case the plug-id values are automatically discovered, the information discovered by the automatic discovery mechanisms needs to be encoded as a bit string within the plug-id value. This encoding is implementation specific, but the encoding rules need to be consistent across all the PNCs.

In case of co-existence within the same network of multiple sources for the plug-id (e.g., central authority and automatic discovery or even different automatic discovery mechanisms), it is needed that the plug-id namespace is partitioned to avoid that different sources assign the same plug-id value to different inter-domain links. Also, the encoding of the plug-id namespace within the plug-id value is implementation specific and will need to be consistent across all the PNCs.

This document assumes that the plug-id is assigned by a central authority, with the first octet set to 0x00 to represent the central authority namespace. The configuration method used, within each PNC domain, are outside the scope of this document.

Based on the plug-id values, the MDSC can merge together the abstract topologies exposed by the underlying PNCs, as described in sections 5.1.1, 5.1.2 and 5.1.3 above, into its multi-domain native TE topology as shown in Figure 6.

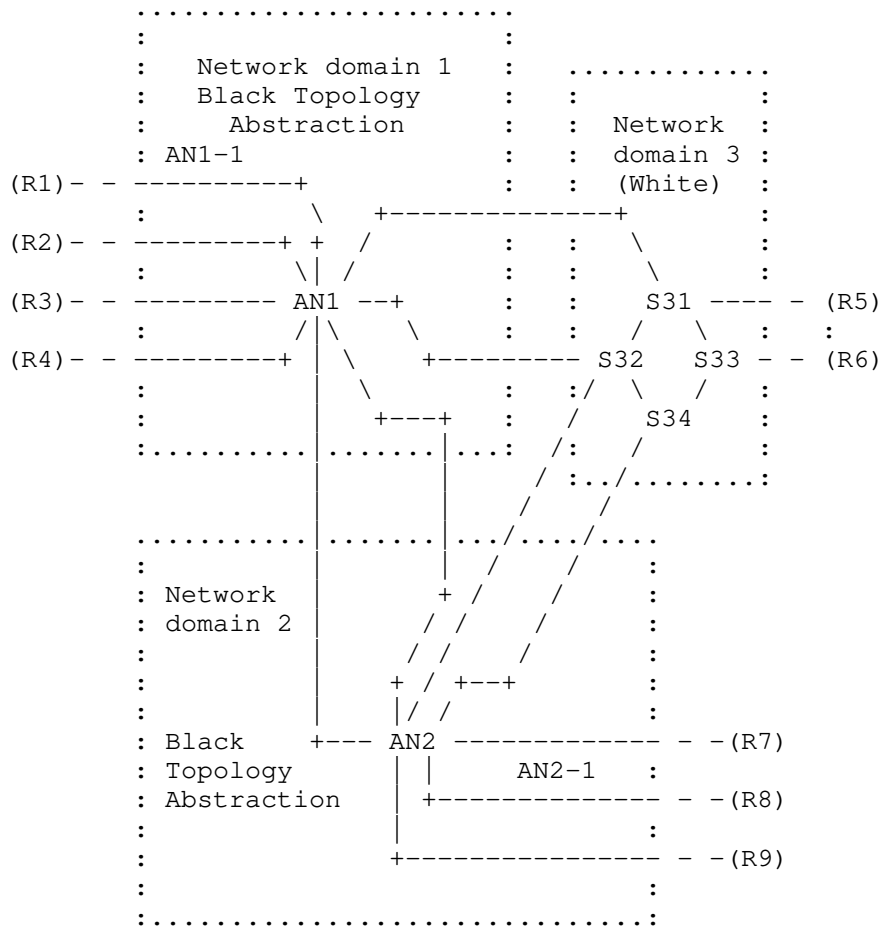


Figure 6 - Multi-domain Abstract Topology controlled by an MDSC

## 5.2. YANG Models for Service Configuration

The service configuration procedure is assumed to be initiated (step 1 in Figure 7) at the CMI from CNC to MDSC. Analysis of the CMI models is (e.g., L1CSM, L2SM, VN) is outside the scope of this document.

As described in section 4.3, it is assumed that the CMI YANG models provide all the information that allows the MDSC to understand that it needs to coordinate the setup of a multi-domain ODU data plane connection (which can be either an end-to-end connection or a segment connection) and, when needed, also the configuration of the adaptation functions in the edge nodes belonging to different domains.

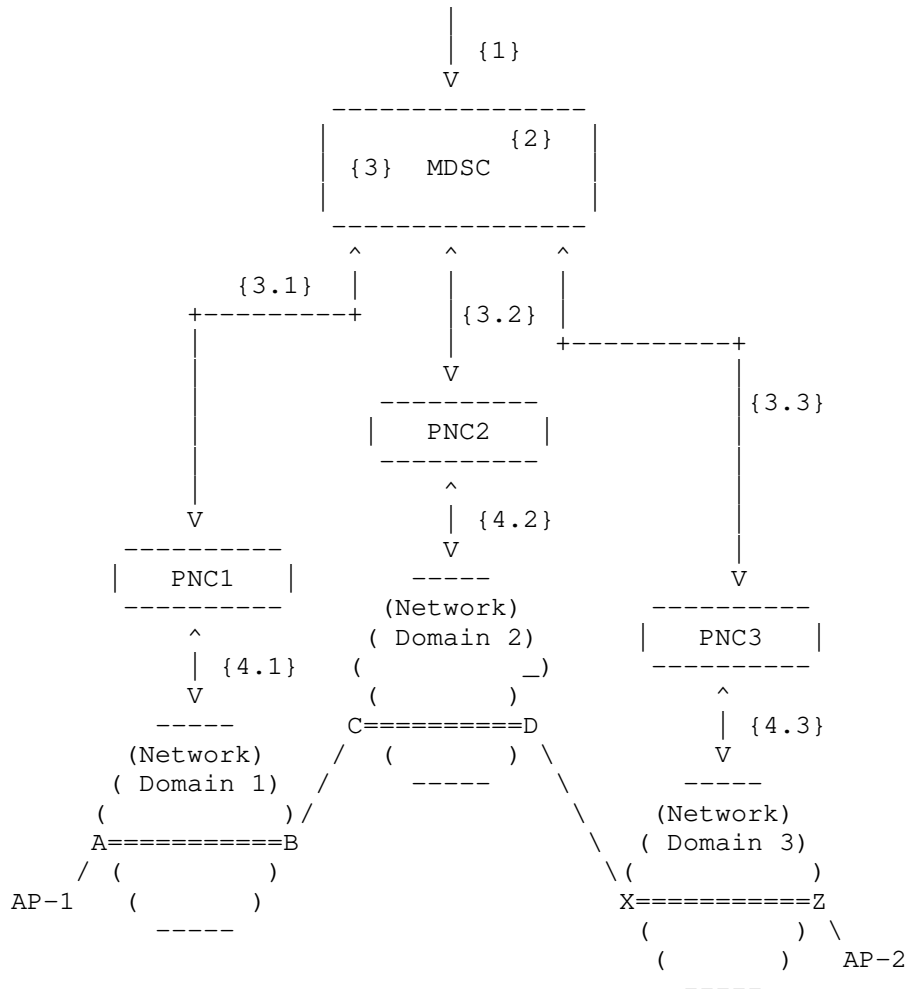


Figure 7 - Multi-domain Service Setup



As an example, the objective in this section is to configure a transport service between R1 and R8, such as one of the services described in section 4.3. The inter-domain path is assumed to be R1 <-> S3 <-> S1 <-> S2 <-> S31 <-> S33 <-> S34 <-> S15 <-> S18 <-> R8 (see the physical topology in Figure 1).

According to the different client signal types, different adaptations can be required to be configured at the edge nodes (i.e., S3 and S18).

After receiving such request, MDSC determines the domain sequence, i.e., domain 1 <-> domain 3 <-> domain 2, with corresponding PNCs and the inter-domain links (step 2 in Figure 7).

As described in [PATH-COMPUTE], the domain sequence can be determined by running the MDSC own path computation on the MDSC native topology, defined in section 5.1.4, if and only if the MDSC has enough topology information. Otherwise, the MDSC can send path computation requests to the different PNCs (steps 2.1, 2.2 and 2.3 in Figure 7) and use this information to determine the optimal path on its internal topology and therefore the domain sequence.

The MDSC will then decompose the tunnel request into a few tunnel segments via tunnel models (both technology agnostic TE tunnel model and OTN tunnel model), and request different PNCs to setup each intra-domain tunnel segment (steps 3, 3.1, 3.2 and 3.3 in Figure 7).

The MDSC will take care of the configuration of both the intra-domain tunnel segment and inter-domain tunnel via corresponding MPI (via TE tunnel model and OTN tunnel model) through all the PNCs controlling the domains selected during path computation. More specifically, for the inter-domain tunnel hand-off, taking into account that the inter-domain links are all OTN links, the list of timeslots and the TPN value assigned to that ODUk connection at the inter-domain link needs to be configured by the MDSC.

In any case, the access link configuration is done only on the PNCs that control the access links (e.g., PNC-1 and PNC-3) and not on the PNCs of transit domain(s) (e.g., PNC-2). An access link will be configured by MDSC after the OTN tunnel is set up.

Access configuration will vary and will be dependent on each type of service. Further discussion and examples are provided in the following sub-sections.

### 5.2.1. ODU Transit Service

In this scenario, described in section 4.3.1, the physical access links are configured as 10G OTN links and, as described in section 5.1, reported by each PNC as TE Links within the OTN abstract topologies they expose to the MDSC.

To setup this IP link, between R1 and R8, the CNC requests, at the CMI, the MDSC to setup an ODU transit service.

From its native topology, shown in Figure 6, the MDSC understands, by means which are outside the scope of this document, that R1 is attached to the access link terminating on AN1-1 LTP in the MPI1 OTN Abstract Topology (Figure 3), exposed by PNC1, and that R8 is attached to the access link terminating on AN2-1 LTP in the MPI2 Abstract Topology, exposed by PNC2.

MDSC then performs multi-domain path computation (step 2 in Figure 7) and requests PNC1, PNC2 and PNC3, at MPI1, MPI2 and MPI3 respectively, to setup ODU2 (Transit Segment) Tunnels within the OTN Abstract Topologies they expose (MPI1 OTN Abstract Topology, MPI2 OTN Abstract Topology and MPI3 OTN Abstract Topology, respectively).

MDSC requests, at MPI1, PNC1 to setup an ODU2 (Transit Segment) Tunnel with one primary path between AN-1 and AN1-7 LTPs, within the MPI1 OTN Abstract Topology (Figure 4), using the TE Tunnel YANG model, defined in [TE-TUNNEL], with the OTN technology-specific augmentations, defined in [OTN-TUNNEL]:

- o Source and Destination TTPs are not specified (since it is a Transit Tunnel)
- o Ingress and egress points are indicated in the route-object-include-exclude list of the explicit-route-objects of the primary path:
  - o The first element references the access link terminating on AN1-1 LTP
  - o The last two element reference respectively the inter-domain link terminating on AN1-7 LTP and the data plane resources (i.e., the list of timeslots and the TPN) used by the ODU2 connection over that link.

The configuration of the timeslots used by the ODU2 connection on the internal links within a PNC domain (i.e., on the internal links within domain1) is outside the scope of this document since it is a matter of the PNC domain internal implementation.

However, the configuration of the timeslots used by the ODU2 connection at the transport network domain boundaries (e.g., on the inter-domain links) needs to take into account the timeslots available on physical nodes belonging to different PNC domains (e.g., on node S2 within PNC1 domain and on node S31 within PNC3 domain).

The MDSC, when coordinating the setup of a multi-domain ODU connection, also configures the data plane resources (i.e., the list of timeslots and the TPN) to be used on the inter-domain links. The MDSC can know the timeslots which are available on the physical OTN nodes terminating the inter-domain links (e.g., S2 and S31) from the OTN Topology information exposed, at the MPIs, by the PNCs controlling the OTN physical nodes (e.g., PNC1 and PNC3 controlling the physical nodes S2 and S31 respectively).

Appendix B.2.1 provides the detailed JSON code ("mpil-odu2-service-config.json") describing how the setup of this ODU2 (Transit Segment) Tunnel can be requested by the MDSC, using the [TE-TUNNEL] and [OTN-TUNNEL] YANG models at MPI1.

PNC1 knows, as described in the mapping table in Section 5.1.1, that AN-1 and AN1-7 LTPs within the MPI1 OTN Abstract Topology it exposes at MPI1 correspond to the S3-1 and S2-3 LTPs, respectively, within its native topology. Therefore it performs path computation, for an ODU2 connection between these LTPs within its native topology, and sets up the ODU2 cross-connections within the physical nodes S3, S1 and S2, as shown in section 4.3.1.

Since the R1-S3 access link is a multi-function access link, PNC1 also configures the OTU2 trail before setting up the ODU2 cross-connection in node S3.

As part of the OUD2 cross-connection configuration in node S2, PNC1 configures the data plane resources (i.e., the list of timeslots and the TPN), to be used by this ODU2 connection on the S2-S31 inter-domain link, as requested by the MDSC.

Following similar requests from MDSC to setup ODU2 (Transit Segment) Tunnels within the OTN Abstract Topologies they expose, PNC2 then sets up ODU2 cross-connections on nodes S31 and S33 while PNC3 sets up ODU2 cross-connections on nodes S15 and S18, as shown in section 4.3.1. PNC2 also configures the OTU2 trail on the S18-R8 multi-function access link.

#### 5.2.1.1. Single Domain Example

To setup an ODU2 end-to-end connection, supporting an IP link, between R1 and R3, the CNC requests, at the CMI, the MDSC to setup an ODU transit service.

Following the procedures described in section 5.2.1, MDSC requests only PCN1 to setup the ODU2 (Transit Segment) Tunnel between the access links terminating on AN-1 and AN1-2 LTPs within the MPI1 Abstract Topology and PNC1 sets up ODU2 cross-connections on nodes S3, S5 and S6, as shown in section 4.3.1. PNC1 also configures the OTU2 trails on the R1-S3 and R3-S6 multi-function access links.

#### 5.2.2. EPL over ODU Service

In this scenario, described in section 4.3.2, the access links are configured as 10GE Links and, as described in section 5.1, reported by each PNC as TE Links within the ETH abstract topologies they expose to the MDSC.

To setup this IP link, between R1 and R8, the CNC requests, at the CMI, the MDSC to setup an EPL service.

From its native topology, shown in Figure 6, the MDSC understands, by means which are outside the scope of this document, that R1 is attached to the access link terminating on AN1-1 LTP in the MPI1 ETH Abstract Topology, exposed by PNC1, and that R8 is attached to the access link terminating on AN2-1 LTP in the MPI2 ETH Abstract Topology, exposed by PNC2.

The MDSC also understands that it needs to coordinate the setup of a multi-domain ODU2 Tunnel between the TTPs, abstracting nodes S3 and S18 within the OTN Abstract Topologies exposed by PNC1 and PNC2, respectively.

MDSC then performs multi-domain path computation (step 2 in Figure 7) and then requests:

- o PNC1, at MPI1, to setup an ODU2 (Head Segment) Tunnel within the MPI1 OTN Abstract Topology;
- o PNC1, at MPI1, to steer the Ethernet client traffic from/to AN1-1 LTP, within the MPI1 ETH Abstract Topology, through that ODU2 (Head Segment) Tunnel;
- o PNC3, at MPI3, to setup an ODU2 (Transit Segment) Tunnel within the MPI3 OTN Abstract Topology;
- o PNC2, at MPI2, to setup ODU2 (Tail Segment) Tunnel within the MPI2 OTN Abstract Topology;
- o PNC2, at MPI2, to steer the Ethernet client traffic to/from AN2-1 LTP, within the MPI2 ETH Abstract Topology, through that ODU2 (Tail Segment) Tunnel.

MDSC requests, at MPI1, PNC1 to setup an ODU2 (Head Segment) Tunnel with one primary path between the source TTP and AN1-7 LTP, within the MPI1 OTN Abstract Topology (Figure 4), using the TE Tunnel YANG model, defined in [TE-TUNNEL], with the OTN technology-specific augmentations, defined in [OTN-TUNNEL]:

- o Only the Source TTP is specified (since it is a Head Segment Tunnel): therefore the Destination TTP is not specified
- o The egress point is indicated in the route-object-include-exclude list of the explicit-route-objects of the primary path:
  - o The last two element reference respectively the inter-domain link terminating on AN1-7 LTP and the data plane resources (i.e., the list of timeslots and the TPN) used by the ODU2 connection over that link.

Appendix B.2.2 provides the detailed JSON code ("mpil-odu2-tunnel-config.json") describing how the setup of this ODU2 (Head Segment) Tunnel can be requested by the MDSC, using the [TE-TUNNEL] and [OTN-TUNNEL] YANG models at MPI1.

MDSC requests, at MPI1, PNC1 to steer the Ethernet client traffic from/to AN1-2 LTP, within the MPI1 ETH Abstract Topology (Figure 4), through the MPI1 ODU2 (Head Segment) Tunnel, using the Ethernet Client YANG model, defined in [CLIENT-SIGNAL].

Appendix B.2.3 provides the detailed JSON code ("mpil-epl-service-config.json") describing how the setup of this EPL service using the ODU2 Tunnel can be requested by the MDSC, using the [CLIENT-SIGNAL] YANG model at MPI1.

PNC1 knows, as described in the table in section 5.1.1, that the tunnel source TTP and AN1-7 LTP, within the MPI1 OTN Abstract Topology it exposes at MPI1, correspond to node S3 and S2-3 LTP, respectively, within its native topology. Therefore it performs path computation, for an ODU2 connection between node S3 and S2-3 LTP within its native topology, and sets up the ODU2 cross-connections within the physical nodes S3, S1 and S2, as shown in section 4.3.2.

As part of the ODU2 cross-connection configuration in node S2, PNC1 configures the data plane resources (i.e., the list of timeslots and the TPN), to be used by this ODU2 connection on the S2-S31 inter-domain link, as requested by the MDSC.

After the configuration of the ODU2 cross-connection in node S3, PNC1 also configures the [ETH -> (ODU)] and [(ODU2) -> ETH] adaptation functions, within node S3, as shown in section 4.3.2.

Since the R1-S3 access link is a multi-function access link, PNC1 also configures the 10GE link before this step.

Following similar requests from MDSC to setup ODU2 (Segment) Tunnels within the OTN Abstract Topologies they expose as well as the steering of the Ethernet client traffic, PNC3 then sets up ODU2 cross-connections on nodes S31 and S33 while PNC2 sets up ODU2 cross-connections on nodes S15 and S18 as well as the [ETH -> (ODU2)] and [(ODU2) -> ETH] adaptation functions in node S18, as shown in section 4.3.2. PNC2 also configures the 10GE link on the S18-R8 multi-function access link.

#### 5.2.2.1. Single Domain Example

To setup this IP link, between R1 and R2, the CNC requests, at the CMI, the MDSC to setup an EPL service.

Following the procedures described in section 5.2.2, the MDSC requests PCN1 to:

- o setup an ODU2 (end-to-end) Tunnel between the TTPs, abstracting nodes S3 and S6 within MPI1 OTN Abstract Topology exposed by PNC1 at MPI1;
- o steer the Ethernet client traffic between the AN1-1 and AN1-8 LTPs, exposed by PNC1 within MPI1 ETH Abstract Topology, through that ODU2 (end-to-end) Tunnel.

Then PNC1 sets up ODU2 cross-connections on nodes S3, S5 and S6 as well as the [ETH -> (ODU)] and [(ODU2) -> ETH] adaptation functions in nodes S3 and S6, as shown in section 4.3.2. PNC1 also configures the 10GE link on the R1-S3 multi-function access link (the R2-S6 access link has been pre-configured as a 10GE link).

### 5.2.3. Other OTN Client Services

In this scenario, described in section 4.3.3, the access links are configured as STM-64 links and, as described in section 5.1, reported by each PNC as TE Links within the OTN Abstract Topologies they expose to the MDSC.

The CNC requests, at the CMI, MDSC to setup an STM-64 Private Line service between R1 and R8.

Following similar procedures as described in section 5.2.2, MDSC understands that:

- o R1 is attached to the access link terminating on AN1-1 LTP in the MPI1 OTN Abstract Topology, exposed by PNC1, and that R8 is attached to the access link terminating on AN2-1 LTP in the MPI2 OTN Abstract Topology, exposed by PNC2;
- o it needs to coordinate the setup of a multi-domain ODU2 Tunnel between the TTPs, abstracting nodes S3 and S18 within the OTN Abstract Topologies exposed by PNC1 and PNC2, respectively.

The MDSC then performs multi-domain path computation (step 2 in Figure 7) and then requests:

- o PNC1, at MPI1, to setup an ODU2 (Head Segment) Tunnel within the MPI1 OTN Abstract Topology;

- o PNC1, at MPI1, to steer the STM-64 transparent client traffic from/to AN1-1 LTP, within the MPI1 OTN Abstract Topology, through that ODU2 (Head Segment) Tunnel;
- o PNC3, at MPI3, to setup an ODU2 (Transit Segment) Tunnel within the MPI3 OTN Abstract Topology;
- o PNC2, at MPI2, to setup ODU2 (Tail Segment) Tunnel within the MPI2 OTN Abstract Topology;
- o PNC2, at MPI2, to steer the STM-64 transparent client traffic to/from AN2-1 LTP, within the MPI2 ETH Abstract Topology, through that ODU2 (Tail Segment) Tunnel.

PNC1, PNC2 and PNC3 then sets up the ODU2 cross-connections within the physical nodes S3, S1, S2, S31, S33, S15 and S18 as well as the [STM-64 -> (ODU)] and [(ODU2) -> STM-64] adaptation functions in nodes S3 and S18, as shown in section 4.3.3. PNC1 and PNC2 also configure the STM-64 links on the R1-S3 and R8-S18 multi-function access links, respectively.

#### 5.2.3.1. Single Domain Example

To setup this IP link, between R1 and R3, the CNC requests, at the CMI, the MDSC to setup an STM-64 Private Line service.

The MDSC and PNC1 follows similar procedures as described in section 5.2.2.1 to set up ODU2 cross-connections on nodes S3, S5 and S6 as well as the [STM-64 -> (ODU)] and [(ODU2) -> STM-64] adaptation functions in nodes S3 and S6, as shown in section 4.3.3. PNC1 also configures the STM-64 links on the R1-S3 and R3-S6 multi-function access links.

#### 5.2.4. EVPL over ODU Service

In this scenario, described in section 4.3.4, the access links are configured as 10GE links, as described in section 5.2.2 above.

The CNC requests, at the CMI, the MDSC to setup two EVPL services: one between R1 and R2, and another between R1 and R8.

Following similar procedures as described in section 5.2.2 and 5.2.2.1, MDSC understands that:



- o R1 and R2 are attached to the access links terminating respectively on AN1-1 and AN1-8 LTPs in the MPI1 ETH Abstract Topology, exposed by PNC1, and that R8 is attached to the access link terminating on AN2-1 LTP in the MPI2 ETH Abstract Topology, exposed by PNC2;
- o to setup the first (single-domain) EVPL service, between R1 and R2, it needs to coordinate the setup of a single-domain ODU0 Tunnel between the TTPs, abstracting nodes S3 and S6 within the OTN Abstract Topology exposed by PNC1;
- o to setup the second (multi-domain) EPVL service, between R1 and R8, it needs to coordinate the setup of a multi-domain ODU0 Tunnel between the TTPs, abstracting nodes S3 and S18 within the OTN Abstract Topologies exposed by PNC1 and PNC2, respectively.

To setup the first (single-domain) EVPL service between R1 and R2, the MDSC and PNC1 follows similar procedures as described in section 5.2.2.1 to set up ODU0 cross-connections on nodes S3, S5 and S6 as well as the [VLAN -> (ODU0)] and [(ODU0) -> VLAN] adaptation functions, in nodes S3 and S6, as shown in section 4.3.4. PNC1 also configures the 10GE link on the R1-S3 multi-function access link.

As part of the [VLAN -> (ODU0)] and [(ODU0) -> VLAN] adaptation functions configurations in nodes S2 and S6, PNC1 configures also the classification rules required to associated only the Ethernet client traffic received with VLAN ID 10 on the R1-S3 and R2-S6 access links with this EVPL service. The MDSC provides this information to PNC1 using the [CLIENT-SIGNAL] model.

To setup the second (multi-domain) EVPL service between R1 and R8, the MDSC, PNC1, PNC2 and PNC3 follows similar procedures as described in section 5.2.2 to setup the ODU0 cross-connections within the physical nodes S3, S1, S2, S31, S33, S15 and S18 as well as the [VLAN -> (ODU0)] and [(ODU0) -> VLAN] adaptation functions in nodes S3 and S18, as shown in section 4.3.4. PNC2 also configures the 10GE link on the R8-S18 multi-function access link (the R1-S3 10GE link has been already configured when the first EVPL service has been setup).

As part of the [VLAN -> (ODU0)] and [(ODU0) -> VLAN] adaptation functions configurations in nodes S3 and S18, PNC1 and, respectively, PNC2 configure also the classification rules required to associated only the Ethernet client traffic received with VLAN ID

20 on the R1-S3 and R8-S18 access links with this EVPL service. The MDSC provides this information to PNC1 and PNC2 using the [CLIENT-SIGNAL] model.

### 5.3. YANG Models for Protection Configuration

#### 5.3.1. Linear Protection (end-to-end)

To be discussed in future versions of this document.

### 5.4. Notifications

Further detailed analysis is outside the scope of this document

### 5.5. Path Computation with Constraints

The path computation constraints that can be supported at the MPI using the IETF YANG models defined in [TE-TUNNEL] and [PATH-COMPUTE].

When there is a technology specific network (e.g., OTN), the corresponding technology (e.g., OTN) model should also be used to specify the tunnel information on MPI, with the constraint included in TE Tunnel model.

Further detailed analysis is outside the scope of this document

## 6. Security Considerations

This document analyses the applicability of the YANG models being defined by the IETF to support OTN single and multi-domain scenarios.

Inherently OTN networks ensure privacy and security via hard partitioning of traffic onto dedicated circuits. The separation of network traffic makes it difficult to intercept data transferred between nodes over OTN-channelized links.

In OTN the (General Communication Channel) GCC is used for OAM functions such as performance monitoring, fault detection, and signaling. The GCC control channel should be secured using a suitable mechanism.

There are no additional or new security considerations introduced by this document.

## 7. IANA Considerations

This document requires no IANA actions.

## 8. References

### 8.1. Normative References

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## Appendix A. Validating a JSON fragment against a YANG Model

The objective is to have a tool that allows validating whether a piece of JSON code embedded in an Internet-Draft is compliant with a YANG model without using a client/server.

## A.1. Manipulation of JSON fragments

This section describes the various ways JSON fragments are used in the I-D processing and how to manage them.

Let's call "folded-JSON" the JSON embedded in the I-D: it fits the 72 chars width and it is acceptable for it to be invalid JSON.

We then define "unfolded-JSON" a valid JSON fragment having the same contents of the "folded-JSON" without folding, i.e. limits on the text width. The folding/unfolding operation may be done according to [RFC-FOLD]. The "unfolded-JSON" can be edited by the authors using JSON editors with the advantages of syntax validation and pretty-printing.

Both the "folded" and the "unfolded" JSON fragments can include comments having descriptive fields and directives we'll describe later to facilitate the reader and enable some automatic processing.

The presence of comments in the "unfolded-JSON" fragment makes it an invalid JSON encoding of YANG data. Therefore we call "naked JSON" the JSON where the comments have been stripped out: not only it is valid JSON but it is a valid JSON encoding of YANG data.

The following schema resumes these definitions:

	unfold_it -->	stripper -->	
	Folded-JSON	Unfolded-JSON	Naked JSON
	<-- fold_it	<-- author edits	
<=72-chars?	MUST	MAY	MAY
valid JSON?	MAY	MUST	MUST
JSON-encoding	MAY	MAY	MUST

of YANG data

Our validation toolchain has been designed to take a JSON in any of the three formats and validate it automatically against a set of relevant YANG modules using available open-source tools. It can be found at: <https://github.com/GianmarcoBruno/json-yang/>

#### A.2. Comments in JSON fragments

We found useful to introduce two kinds of comments, both defined as key-value pairs where the key starts with "//":

- free-form descriptive comments, e.g. "// COMMENT" : "refine this" to describe properties of JSON fragments.

- machine-usable directives e.g. "// \_\_REFERENCES\_\_DRAFTS\_\_" : { "ietf-routing-types@2017-12-04": "rfc8294", } which can be used to automatically download from the network the relevant I-Ds or RFCs and extract from them the YANG models of interest. This is particularly useful to keep consistency when the drafting work is rapidly evolving.

#### A.3. Validation of JSON fragments: DSDL-based approach

The idea is to generate a JSON driver file (JTOX) from YANG, then use it to translate JSON to XML and validate it against the DSDL schemas, as shown in Figure 8.

Useful link: <https://github.com/mbj4668/pyang/wiki/XmlJson>

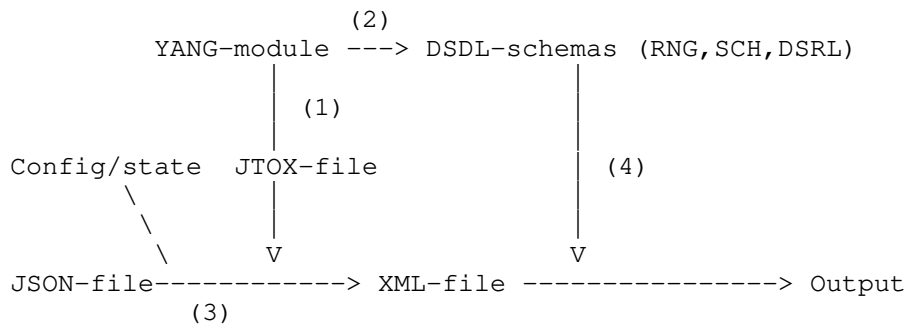


Figure 8 - DSDL-based approach for JSON code validation



In order to allow the use of comments following the convention defined in section 3, without impacting the validation process, these comments will be automatically removed from the JSON-file that will be validate.

#### A.4. Validation of JSON fragments: why not using a XSD-based approach

This approach has been analyzed and discarded because no longer supported by pyang.

The idea is to convert YANG to XSD, JSON to XML and validate it against the XSD, as shown in Figure 9:

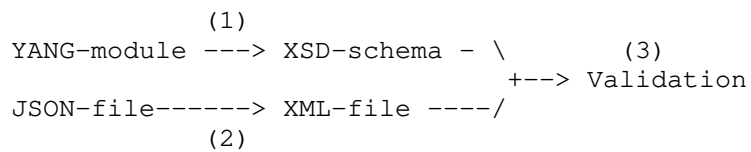


Figure 9 - XSD-based approach for JSON code validation

The pyang support for the XSD output format was deprecated in 1.5 and removed in 1.7.1. However pyang 1.7.1 is necessary to work with YANG 1.1 so the process shown in Figure 9 will stop just at step (1).

## Appendix B. Detailed JSON Examples

The JSON code examples provided in this appendix have been validated using the tools in Appendix A and folded using the tool in [RFC-FOLD].

### B.1. JSON Examples for Topology Abstractions

#### B.1.1. JSON Code: mpil-otn-topology.json

This is the JSON code reporting the OTN Topology @ MPI:

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

```
{
  "// __TITLE__": "ODU Black Topology @ MPI1",
  "// __LAST_UPDATE__": "October 18, 2018",
  "// __MISSING_ATTRIBUTES__": true,
  "// __REFERENCE_DRAFTS__": {
    "ietf-routing-types@2017-12-04": "rfc8294",
    "ietf-otn-types@2017-10-30": "draft-ietf-ccamp-otn-tunnel-model-\
01",
    "ietf-network@2018-02-26": "rfc8345",
    "ietf-network-topology@2018-02-26": "rfc8345",
    "ietf-te-types@2018-06-12": "draft-ietf-teas-yang-te-15",
    "ietf-te-topology@2018-06-15": "draft-ietf-teas-yang-te-topo-18",
    "ietf-otn-topology@2017-10-30": "draft-ietf-ccamp-otn-topo-yang-\
02"
  },
  "// __RESTCONF_OPERATION__": {
    "operation": "GET",
    "url": "http://{{PNC1-ADDR}}/restconf/data/ietf-network:networks"
  },
  "ietf-network:networks": {
    "network": [
      {
        "network-id": "providerId/201/clientId/300/topologyId/otn-bl\
ack-topology",
        "network-types": {
          "ietf-te-topology:te-topology": {
            "ietf-otn-topology:otn-topology": {}
          }
        },
        "ietf-te-topology:provider-id": 201,
        "ietf-te-topology:client-id": 300,
        "ietf-te-topology:te-topology-id": "otn-black-topology",
        "// ietf-te-topology:te": "presence container requires: prov\
ider, client and te-topology-id",
        "ietf-te-topology:te": {
          "name": "OTN Black Topology @ MPI1"
        },
        "// ietf-network:node": "Access LTPs to be reviewed in a fut\
ure update",
        "ietf-network:node": [
          {
            "// __NODE__:__DESCRIPTION__": {
```

```

    "name": "AN1",
    "identifier": "10.0.0.1",
    "type": "Abstract Node",
    "physical node(s)": "whole network domain 1"
  },
  "node-id": "10.0.0.1",
  "ietf-te-topology:te-node-id": "10.0.0.1",
  "ietf-te-topology:te": {
    "te-node-attributes": {
      "name": "AN11",
      "admin-status": "up",
      "// __DISCUSS__ is-abstract": "To be discussed with \
\TE Topology authors",
      "// __DISCUSS__ underlay-topology": "To be discussed\
\ with TE Topology authors"
    },
    "oper-status": "up",
    "// __DISCUSS__ tunnel-termination-point": []
  },
  "ietf-network-topology:termination-point": [
    {
      "// __DESCRIPTION__:__LTP__": {
        "name": "AN1-1 LTP",
        "link type(s)": "OTU-2",
        "physical node": "S3",
        "unnumberd/ifIndex": 1,
        "port type": "tributary port",
        "connected to": "R1"
      },
      "tp-id": "1",
      "ietf-te-topology:te-tp-id": 1,
      "ietf-te-topology:te": {
        "name": "AN1-1 LTP",
        "admin-status": "up",
        "// __DISCUSS__ interface-switching-capability": "\
\See Link attributes (teNodeId/10.0.0.1/teLinkId/1)",
        "// __DISCUSS__ inter-domain-plug-id": "Access Lin\
\k",
        "// __COMMENT__ inter-layer-lock-id": "Empty: OTN \
\Links are pre-configured",
        "oper-status": "up",
        "// __DISCUSS__ ietf-otn-topology:supported-payload\
\ types": "List of ODU clients?",
        "// __DISCUSS__ ietf-otn-topology:client-facing": \

```

```

\true
    }
  },
  {
    "// __DESCRIPTION__:__LTP__": {
      "name": "AN1-2 LTP",
      "link type(s)": "OTU-4",
      "physical node": "S2",
      "unnumberd/ifIndex": 1,
      "port type": "inter-domain port",
      "connected to": "S31"
    },
    "tp-id": "2",
    "ietf-te-topology:te-tp-id": 2,
    "ietf-te-topology:te": {
      "name": "AN1-2 LTP",
      "admin-status": "up",
      "// __DISCUSS__ interface-switching-capability": "\
\See Link attributes (teNodeId/10.0.0.1/teLinkId/2)",
      "// __DISCUSS__ inter-domain-plug-id": "Inter-doma\
\in Link",
      "oper-status": "up",
      "// __DISCUSS__ ietf-otn-topology:supported-payload\
\d-types": "Empty? (inter-domain OTN link)",
      "// __DEFAULT__ ietf-otn-topology:client-facing": \
\false
    }
  },
  {
    "// __DESCRIPTION__:__LTP__": {
      "name": "AN1-3 LTP",
      "link type(s)": "OTU-2",
      "physical node": "S6",
      "unnumberd/ifIndex": 1,
      "port type": "tributary port",
      "connected to": "R2"
    },
    "tp-id": "3",
    "ietf-te-topology:te-tp-id": 3,
    "ietf-te-topology:te": {
      "name": "AN1-3 LTP",
      "admin-status": "up",
      "// __DISCUSS__ interface-switching-capability": "\
\See Link attributes (teNodeId/10.0.0.1/teLinkId/3)",

```

```

        "/// __DISCUSS__ inter-domain-plug-id": "Access Lin\
\k",
        "oper-status": "up",
        "/// __DISCUSS__ ietf-otn-topology:supported-payloa\
\d-types": "List of ODU clients?",
        "/// __DISCUSS__ ietf-otn-topology:client-facing": \
\true
    }
},
{
    "/// __DESCRIPTION__:__LTP__": {
        "name": "AN1-4 LTP",
        "link type(s)": "OTU-4",
        "physical node": "S8",
        "unnumberd/ifIndex": 1,
        "port type": "inter-domain port",
        "connected to": "S32"
    },
    "tp-id": "4",
    "ietf-te-topology:te-tp-id": 4,
    "ietf-te-topology:te": {
        "name": "AN1-4 LTP",
        "admin-status": "up",
        "/// __DISCUSS__ interface-switching-capability": "\
\See Link attributes (teNodeId/10.0.0.1/teLinkId/4)",
        "/// __DISCUSS__ inter-domain-plug-id": "Inter-doma\
\in Link",
        "oper-status": "up",
        "/// __DISCUSS__ ietf-otn-topology:supported-payloa\
\d-types": "Empty? (inter-domain OTN link)",
        "/// __DEFAULT__ ietf-otn-topology:client-facing": \
\false
    }
},
{
    "/// __DESCRIPTION__:__LTP__": {
        "name": "AN1-5 LTP",
        "link type(s)": "OTU-4",
        "physical node": "S8",
        "unnumberd/ifIndex": 5,
        "port type": "inter-domain port",
        "connected to": "S12"
    },
    "tp-id": "5",

```

```

        "ietf-te-topology:te-tp-id": 5,
        "ietf-te-topology:te": {
            "name": "AN1-5 LTP",
            "admin-status": "up",
            "// __DISCUSS__ interface-switching-capability": "\
See Link attributes (teNodeId/10.0.0.1/teLinkId/5)",
            "// __DISCUSS__ inter-domain-plug-id": "Inter-doma\
in Link",
            "oper-status": "up",
            "// __DISCUSS__ ietf-otn-topology:supported-payload\
d-types": "Empty? (inter-domain OTN link)",
            "// __DEFAULT__ ietf-otn-topology:client-facing": \
false
        }
    },
    {
        "// __DESCRIPTION__:__LTP__": {
            "name": "AN1-6 LTP",
            "link type(s)": "OTU-4",
            "physical node": "S7",
            "unnumberd/idxIndex": 4,
            "port type": "inter-domain port",
            "connected to": "S11"
        },
        "tp-id": "6",
        "ietf-te-topology:te-tp-id": 6,
        "ietf-te-topology:te": {
            "name": "AN1-6 LTP",
            "admin-status": "up",
            "// __DISCUSS__ interface-switching-capability": "\
See Link attributes (teNodeId/10.0.0.1/teLinkId/6)",
            "// __DISCUSS__ inter-domain-plug-id": "Inter-doma\
in Link",
            "oper-status": "up",
            "// __DISCUSS__ ietf-otn-topology:supported-payload\
d-types": "Empty? (inter-domain OTN link)",
            "// __DEFAULT__ ietf-otn-topology:client-facing": \
false
        }
    },
    {
        "// __DESCRIPTION__:__LTP__": {
            "name": "AN1-7 LTP",
            "link type(s)": "OTU-2",

```

```

        "physical node": "S6",
        "unnumbered/ifIndex": 2,
        "port type": "tributary port",
        "connected to": "R3"
    },
    "tp-id": "7",
    "ietf-te-topology:te-tp-id": 7,
    "ietf-te-topology:te": {
        "name": "AN1-7 LTP",
        "admin-status": "up",
        "// __DISCUSS__ interface-switching-capability": "\
See Link attributes (teNodeId/10.0.0.1/teLinkId/7)",
        "// __DISCUSS__ inter-domain-plug-id": "Access Lin\
k",
        "oper-status": "up",
        "// __DISCUSS__ ietf-otn-topology:supported-payloa\
d-types": "List of ODU clients?",
        "// __DISCUSS__ ietf-otn-topology:client-facing": \
true
    }
}
]
],
    "// ietf-network-topology:link": "Access links to be reviewe\
d in a future update",
    "ietf-network-topology:link": [
        {
            "// __DESCRIPTION__:__LINK__": {
                "name": "Access Link from AN1-1",
                "type": "access link",
                "physical link": "Link from S3-1 to R1"
            },
            "link-id": "teNodeId/10.0.0.1/teLinkId/1",
            "ietf-te-topology:te": {
                "te-link-attributes": {
                    "name": "Access Link from AN1-1",
                    "// __DISCUSS__ access-type": "Can we assume point-t\
o-point as the default value?",
                    "access-type": "point-to-point",
                    "// __COMMENT__ external-domain": "Empty: the plug-i\
d is used instead of this container",
                    "// __DISCUSS__ is-abstract": "To be discussed with \
TE Topology authors",

```



```

        "// __DISCUSS__ underlay": "To be discussed with TE \
\Topology authors",
        "admin-status": "up",
        "interface-switching-capability": [
            {
                "switching-capability": "ietf-te-types:switching\
\otn",
                "encoding": "ietf-te-types:lsp-encoding-oduk",
                "max-lsp-bandwidth": [
                    {
                        "priority": 0,
                        "// __DISCUSS__ te-bandwidth": "ODU2"
                    }
                ]
            }
        ],
        "// __COMMENT__ label-restrictions": "Not described \
\in this JSON example",
        "// __DISCUSS__ link-protection-type": "Can we assum\
\e unprotected as the default value?",
        "link-protection-type": "unprotected",
        "max-link-bandwidth": {
            "// __DISCUSS__ te-bandwidth": "1xODU2"
        },
        "max-resv-link-bandwidth": {
            "// __DISCUSS__ te-bandwidth": "1xODU2"
        },
        "unreserved-bandwidth": [
            {
                "priority": 0,
                "// __DISCUSS__ te-bandwidth": "1xODU2"
            }
        ],
        "oper-status": "up",
        "// __EMPTY__ is-transitional": "It is not a transitio\
\nal link",
        "// __DISCUSS__ underlay ": "To be discussed with TE T\
\opology authors"
    },
    "source": {
        "source-node": "10.0.0.1",
        "source-tp": 1
    },
},

```

```

    "/// __EMPTY__ destination": "access link"
  },
  {
    "/// __DESCRIPTION__:__LINK__": {
      "name": "Inter-domain Link from AN1-2",
      "type": "inter-domain link",
      "physical link": "Link from S2-1 to S31"
    },
    "link-id": "teNodeId/10.0.0.1/teLinkId/2",
    "ietf-te-topology:te": {
      "te-link-attributes": {
        "name": "Inter-domain Link from AN1-2",
        "/// __DISCUSS__ access-type": "Can we assume point-to-
\o-point as the default value?",
        "access-type": "point-to-point",
        "/// __DISCUSS__ is-abstract": "To be discussed with \
\TE Topology authors",
        "/// __DISCUSS__ underlay": "To be discussed with TE \
\Topology authors",
        "admin-status": "up",
        "interface-switching-capability": [
          {
            "switching-capability": "ietf-te-types:switching\
\otn",
            "encoding": "ietf-te-types:lsp-encoding-oduk",
            "max-lsp-bandwidth": [
              {
                "priority": 0,
                "/// __DISCUSS__ te-bandwidth": "ODU4"
              }
            ],
            "/// __DISCUSS__ label-restrictions": "To be adde\
\d?"
          }
        ],
        "/// __DISCUSS__ link-protection-type": "Can we assum\
\e unprotected as the default value?",
        "link-protection-type": "unprotected",
        "max-link-bandwidth": {
          "/// __DISCUSS__ te-bandwidth": "1xODU4, ..."
        },
        "max-resv-link-bandwidth": {
          "/// __DISCUSS__ te-bandwidth": "1xODU4, ..."
        }
      }
    }
  }

```

```

        "unreserved-bandwidth": [
            {
                "priority": 0,
                "// __DISCUSS__ te-bandwidth": "1xODU4, ..."
            }
        ],
        "oper-status": "up",
        "// __EMPTY__ is-transitional": "It is not a transitio\
\nal link",
        "// __DISCUSS__ underlay": "To be discussed with TE T\
\nology authors",
        {
            "source": {
                "source-node": "10.0.0.1",
                "source-tp": 2
            },
            "// __EMPTY__ destination": "inter-domain link"
        },
        {
            "// __DESCRIPTION__:__LINK__": {
                "name": "Access Link from AN1-3",
                "type": "access link",
                "physical link": "Link from S6-1 to R2"
            },
            "link-id": "teNodeId/10.0.0.1/teLinkId/3",
            "ietf-te-topology:te": {
                "te-link-attributes": {
                    "name": "Access Link from AN1-3",
                    "// __DISCUSS__ access-type": "Can we assume point-t\
\no-point as the default value?",
                    "access-type": "point-to-point",
                    "// __DISCUSS__ is-abstract": "To be discussed with \
\nTE Topology authors",
                    "// __DISCUSS__ underlay": "To be discussed with TE \
\nTopology authors",
                    "admin-status": "up",
                    "interface-switching-capability": [
                        {
                            "switching-capability": "ietf-te-types:switching\
\n-otn",
                            "encoding": "ietf-te-types:lsp-encoding-oduk",
                            "max-lsp-bandwidth": [
                                {

```

```

        "priority": 0,
        "// __DISCUSS__ te-bandwidth": "ODU2"
    }
],
    "// __DISCUSS__ label-restrictions": "To be adde\
\d?"
    }
],
    "// __DISCUSS__ link-protection-type": "Can we assum\
e unprotected as the default value?",
    "link-protection-type": "unprotected",
    "max-link-bandwidth": {
        "// __DISCUSS__ te-bandwidth": "1xODU2"
    },
    "unreserved-bandwidth": [
        {
            "priority": 0,
            "// __DISCUSS__ te-bandwidth": "1xODU2"
        }
    ],
    "max-resv-link-bandwidth": {
        "// __DISCUSS__ te-bandwidth": "1xODU2"
    }
},
    "oper-status": "up",
    "// __EMPTY__ is-transitional": "It is not a transitio\
nal link",
    "// __DISCUSS__ underlay ": "To be discussed with TE T\
opology authors"
},
    "source": {
        "source-node": "10.0.0.1",
        "source-tp": 3
    },
    "// __EMPTY__ destination": "access link"
},
{
    "// __DESCRIPTION__:__LINK__": {
        "name": "Inter-domain Link from AN1-4",
        "type": "inter-domain link",
        "physical link": "Link from S8-1 to S32"
    },
    "link-id": "teNodeId/10.0.0.1/teLinkId/4",
    "ietf-te-topology:te": {

```

```

      "te-link-attributes": {
        "name": "Inter-domain Link from AN1-4",
        "// __DISCUSS__ access-type": "Can we assume point-t\
\o-point as the default value?",
        "access-type": "point-to-point",
        "// __DISCUSS__ is-abstract": "To be discussed with \
\TE Topology authors",
        "// __DISCUSS__ underlay": "To be discussed with TE \
\Topology authors",
        "admin-status": "up",
        "interface-switching-capability": [
          {
            "switching-capability": "ietf-te-types:switching\
\otn",
            "encoding": "ietf-te-types:lsp-encoding-oduk",
            "max-lsp-bandwidth": [
              {
                "priority": 0,
                "// __DISCUSS__ te-bandwidth": "ODU4"
              }
            ],
            "// __DISCUSS__ label-restrictions": "To be adde\
\d?"
          }
        ],
        "// __DISCUSS__ link-protection-type": "Can we assum\
\e unprotected as the default value?",
        "link-protection-type": "unprotected",
        "max-link-bandwidth": {
          "// __DISCUSS__ te-bandwidth": "1xODU4, ..."
        },
        "unreserved-bandwidth": [
          {
            "priority": 0,
            "// __DISCUSS__ te-bandwidth": "1xODU4, ..."
          }
        ],
        "max-resv-link-bandwidth": {
          "// __DISCUSS__ te-bandwidth": "1xODU4, ..."
        }
      },
      "oper-status": "up",
      "// __EMPTY__ is-transitional": "It is not a transitio\
\nal link",

```

```

        "// __DISCUSS__ underlay ": "To be discussed with TE T\
\opology authors"
    },
    "source": {
        "source-node": "10.0.0.1",
        "source-tp": 4
    },
    "// __EMPTY__ destination": "inter-domain link"
},
{
    "// __DESCRIPTION__:__LINK__": {
        "name": "Inter-domain Link from AN1-5",
        "type": "inter-domain link",
        "physical link": "Link from S8-5 to S12"
    },
    "link-id": "teNodeId/10.0.0.1/teLinkId/5",
    "ietf-te-topology:te": {
        "te-link-attributes": {
            "name": "Inter-domain Link from AN1-5",
            "// __DISCUSS__ access-type": "Can we assume point-t\
\o-point as the default value?",
            "access-type": "point-to-point",
            "// __DISCUSS__ is-abstract": "To be discussed with \
\TE Topology authors",
            "// __DISCUSS__ underlay": "To be discussed with TE \
\Topology authors",
            "admin-status": "up",
            "interface-switching-capability": [
                {
                    "switching-capability": "ietf-te-types:switching\
\otn",
                    "encoding": "ietf-te-types:lsp-encoding-oduk",
                    "max-lsp-bandwidth": [
                        {
                            "priority": 0,
                            "// __DISCUSS__ te-bandwidth": "ODU4"
                        }
                    ],
                    "// __DISCUSS__ label-restrictions": "To be adde\
\d?"
                }
            ],
            "// __DISCUSS__ link-protection-type": "Can we assum\
\e unprotected as the default value?",

```

```

    "link-protection-type": "unprotected",
    "max-link-bandwidth": {
      "/// __DISCUSS__ te-bandwidth": "1xODU4, ..."
    },
    "max-resv-link-bandwidth": {
      "/// __DISCUSS__ te-bandwidth": "1xODU4, ..."
    },
    "unreserved-bandwidth": [
      {
        "priority": 0,
        "/// __DISCUSS__ te-bandwidth": "1xODU4, ..."
      }
    ]
  },
  "oper-status": "up",
  "/// __EMPTY__ is-transitional": "It is not a transitio\
\nal link",
  "/// __DISCUSS__ underlay ": "To be discussed with TE T\
\nology authors"
},
"source": {
  "source-node": "10.0.0.1",
  "source-tp": 5
},
"/// __EMPTY__ destination": "inter-domain link"
},
{
  "/// __DESCRIPTION__:__LINK__": {
    "name": "Inter-domain Link from AN1-6",
    "type": "inter-domain link",
    "physical link": "Link from S7-4 to S11"
  },
  "link-id": "teNodeId/10.0.0.1/teLinkId/6",
  "ietf-te-topology:te": {
    "te-link-attributes": {
      "name": "Inter-domain Link from AN1-6",
      "/// __DISCUSS__ access-type": "Can we assume point-t\
\no-point as the default value?",
      "access-type": "point-to-point",
      "/// __DISCUSS__ is-abstract": "To be discussed with \
\nTE Topology authors",
      "/// __DISCUSS__ underlay": "To be discussed with TE \
\nTopology authors",
      "admin-status": "up",

```

```

        "interface-switching-capability": [
            {
                "switching-capability": "ietf-te-types:switching\
\ -otn",
                "encoding": "ietf-te-types:lsp-encoding-oduk",
                "max-lsp-bandwidth": [
                    {
                        "priority": 0,
                        "// __DISCUSS__ te-bandwidth": "ODU4"
                    }
                ],
                "// __DISCUSS__ label-restrictions": "To be adde\
\d?"
            }
        ],
        "// __DISCUSS__ link-protection-type": "Can we assum\
\ e unprotected as the default value?",
        "link-protection-type": "unprotected",
        "max-link-bandwidth": {
            "// __DISCUSS__ te-bandwidth": "1xODU4, ..."
        },
        "max-resv-link-bandwidth": {
            "// __DISCUSS__ te-bandwidth": "1xODU4, ..."
        },
        "unreserved-bandwidth": [
            {
                "priority": 0,
                "// __DISCUSS__ te-bandwidth": "1xODU4, ..."
            }
        ]
    },
    "oper-status": "up",
    "// __EMPTY__ is-transitional": "It is not a transitio\
\ nal link",
    "// __DISCUSS__ underlay ": "To be discussed with TE T\
\ opology authors"
},
"source": {
    "source-node": "10.0.0.1",
    "source-tp": 6
},
"// __EMPTY__ destination": "inter-domain link"
},
{

```



```

    "// __DESCRIPTION__:__LINK__": {
      "name": "Access Link from AN1-7",
      "type": "access link",
      "physical link": "Link from S6-2 to R3"
    },
    "link-id": "teNodeId/10.0.0.1teLinkId/7",
    "ietf-te-topology:te": {
      "te-link-attributes": {
        "name": "Access Link from AN1-7",
        "// __DISCUSS__ access-type": "Can we assume point-to-
\o-point as the default value?",
        "access-type": "point-to-point",
        "// __DISCUSS__ is-abstract": "To be discussed with \
\TE Topology authors",
        "// __DISCUSS__ underlay": "To be discussed with TE \
\Topology authors",
        "admin-status": "up",
        "interface-switching-capability": [
          {
            "switching-capability": "ietf-te-types:switching\
\otn",
            "encoding": "ietf-te-types:lsp-encoding-oduk",
            "max-lsp-bandwidth": [
              {
                "priority": 0,
                "// __DISCUSS__ te-bandwidth": "ODU2"
              }
            ],
            "// __DISCUSS__ label-restrictions": "To be adde\
\d?"
          }
        ],
        "// __DISCUSS__ link-protection-type": "Can we assum\
\e unprotected as the default value?",
        "link-protection-type": "unprotected",
        "max-link-bandwidth": {
          "// __DISCUSS__ te-bandwidth": "1xODU2"
        },
        "max-resv-link-bandwidth": {
          "// __DISCUSS__ te-bandwidth": "1xODU2"
        },
        "unreserved-bandwidth": [
          {
            "priority": 0,

```

```

        "/// __DISCUSS__ te-bandwidth": "1xODU2"
      }
    ],
    },
    "oper-status": "up",
    "/// __EMPTY__ is-transitional": "It is not a transitio\
\nal link",
    "/// __DISCUSS__ underlay ": "To be discussed with TE T\
\nopology authors"
  },
  "source": {
    "source-node": "10.0.0.1",
    "source-tp": 7
  },
  "/// __EMPTY__ destination": "access link"
}
]
}
]
}
}

```

## B.2. JSON Examples for Service Configuration

### B.2.1. JSON Code: mpil-odu2-service-config.json

This is the JSON code reporting the ODU2 transit service configuration @ MPI:

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

```
{
  "// __TITLE__": "ODU2 Service Configuration @ MPI1",
  "// __LAST_UPDATE__": "October 22, 2018",
  "// __MISSING_ATTRIBUTES__": true,
  "// __REFERENCE_DRAFTS__": {
    "ietf-routing-types@2017-12-04": "rfc8294",
    "ietf-otn-types@2018-06-07": "draft-ietf-ccamp-otn-tunnel-model-\
\02",
    "ietf-te-types@2018-07-01": "draft-ietf-teas-yang-te-16",
    "ietf-te@2018-07-01": "draft-ietf-teas-yang-te-16",
    "ietf-otn-tunnel@2018-06-07": "draft-ietf-ccamp-otn-tunnel-model\
\02"
  },
  "// __RESTCONF_OPERATION__": {
    "operation": "PUT",
    "url": "http://{PNC1-ADDR}/restconf/data/ietf-te:te"
  },
  "ietf-te:te": {
    "tunnels": {
      "tunnel": [
        {
          "name": "mpil-odu2-service",
          "// identifier": "ODU2-SERVICE-TUNNEL-ID @ MPI1",
          "identifier": 1,
          "description": "ODU2 Service implemented by ODU2 OTN Tunne\
\01 Segment @ MPI1",
          "// encoding and switching-type": "ODU",
          "encoding": "ietf-te-types:lsp-encoding-oduk ",
          "switching-type": "ietf-te-types:switching-otn",
          "// source": "None: transit tunnel segment",
          "// destination": "None: transit tunnel segment",
          "// src-tp-id": "None: transit tunnel segment",
          "// dst-tp-id": "None: transit tunnel segment",
          "// ietf-otn-tunnel:src-client-signal": "None: ODU transit\
\0 tunnel segment",
          "// ietf-otn-tunnel:dst-client-signal": "None: ODU transit\
\0 tunnel segment",
          "bidirectional": true,
          "// protection": "No protection",
          "// __ DEFAULT __ protection": {
            "// __ DEFAULT __ enable": false
          },

```

```

    "// restoration": "No restoration",
    "// __ DEFAULT __ restoration": {
        "// __ DEFAULT __ enable": false
    },
    "// te-topology-identifier": "ODU Black Topology @ MPI1",
    "te-topology-identifier": {
        "provider-id": 201,
        "client-id": 300,
        "topology-id": "otn-black-topology"
    },
    "te-bandwidth": {
        "ietf-otn-tunnel:odu-type": "ietf-otn-types:prot-ODU2"
    },
    "// hierarchical-link": "None: transit tunnel segment",
    "p2p-primary-paths": {
        "p2p-primary-path": [
            {
                "name": "mpil-odu2-service-primary-path",
                "path-scope": "ietf-te-types:path-scope-segment",
                "// te-bandwidth": "None: only the tunnel bandwidth \
needs to be specified in transport applications",
                "explicit-route-objects": {
                    "route-object-include-exclude": [
                        {
                            "// comment": "Tunnel hand-off OTU2 ingress in\
terface (S3-1)",
                            "index": 1,
                            "explicit-route-usage": "ietf-te-types:route-i\
nclude-ero",
                            "num-unnum-hop": {
                                "// node-id": "AN1 Node",
                                "node-id": "10.0.0.1",
                                "// link-tp-id": "AN1-1 LTP",
                                "link-tp-id": 1,
                                "hop-type": "STRICT",
                                "direction": "INCOMING"
                            }
                        }
                    ],
                    {
                        "// comment": "Tunnel hand-off ODU2 ingress la\
bel (ODU2 over OTU2) at S3-1",
                        "index": 2,
                        "explicit-route-usage": "ietf-te-types:route-i\
nclude-ero",

```

```

        "label-hop": {
            "te-label": {
                "// __ DISCUSS __ odu-label": "How are HO-\
\ODU (ODUk over OTUk) label represented?",
                "// __ DISCUSS __ direction": "Check with \
\TE Tunnel authors",
                "direction": "FORWARD "
            }
        },
        {
            "// comment": "Tunnel hand-off OTU4 egress int\
\erface (S2-1)",
            "index": 3,
            "explicit-route-usage": "ietf-te-types:route-i\
\nclude-ero",
            "num-unnum-hop": {
                "// node-id": "AN1 Node",
                "node-id": "10.0.0.1",
                "// link-tp-id": "AN1-2 LTP",
                "link-tp-id": 1,
                "hop-type": "STRICT",
                "direction": "OUTGOING"
            }
        },
        {
            "// comment": "Tunnel hand-off ODU2 egress lab\
\el (ODU2 over OTU4) at S2-1",
            "index": 4,
            "explicit-route-usage": "ietf-te-types:route-i\
\nclude-ero",
            "label-hop": {
                "te-label": {
                    "ietf-otn-tunnel:tpn": 1,
                    "ietf-otn-tunnel:tsg": "ietf-otn-types:tsg\
\n1.25G",
                    "ietf-otn-tunnel:ts-list": "1-8",
                    "// __ DISCUSS __ direction": "Check with \
\TE Tunnel authors",
                    "direction": "FORWARD "
                }
            }
        }
    ]

```

```
    }  
  }  
]  
}  
]  
}  
}
```

B.2.2. JSON Code: `mpil-odu2-tunnel-config.json`

The JSON code for this use case will be added in a future version of this document

An incomplete version is located on GitHub at:

<https://github.com/danielkinguk/transport-nbi>

B.2.3. JSON Code: `mpil-epl-service-config.json`

The JSON code for this use case will be added in a future version of this document

An incomplete version is located on GitHub at:

<https://github.com/danielkinguk/transport-nbi>

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## A Yang Data Model for WSON Tunnel

draft-ietf-ccamp-wson-tunnel-model-03

### Abstract

This document provides a YANG data model for WSON TE tunnel.

### Status of this Memo

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Lee, et al.

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[Page 1]

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## 1. Introduction

This document provides a YANG data model for WSON tunnel model. The YANG model described in this document is a WSON technology-specific Yang Tunnel 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].

This document augments the generic TE tunnel model [TE-Tunnel].

### 1.1. Terminology

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:

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

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

- o configuration data
- o state data

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

### 1.2. Tree diagram

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

### 1.3. Prefixes in Data Node Names

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

Prefix	YANG module	Reference
layer0-types	ietf-layer0-types	[WSON-TOPO]
wson-tunnel	ietf-wson-tunnel	[RFCXXXX]
tepc	ietf-te-path-computation	[TE-PC]
te	ietf-te	[TE-Tunnel]

otn-types	ietf-otn-types	[OTN-TOPO]	
+-----+	+-----+	+-----+	+-----+

Table 1: Prefixes and corresponding YANG modules

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

## 2. YANG Model (Tree Structure)

```

module: ietf-wson-tunnel
  augment /te:te/te:tunnels/te:tunnel:
    +-rw src-client-signal?  identityref
    +-rw dst-client-signal?  identityref
    +-rw fec-type?           identityref
    +-rw termination-type?   identityref
    +-rw bit-stuffing?       boolean
  augment /te:te/te:globals/te:named-path-constraints/te:named-path-
constraint/te:te-bandwidth/te:technology:
    +--:(wson)
      +-rw bandwidth-type?  identityref
  augment /te:te/te:tunnels/te:tunnel/te:te-bandwidth/te:technology:
    +--:(wson)
      +-rw bandwidth-type?  identityref
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:te-bandwidth/te:technology:
    +--:(wson)
      +-rw bandwidth-type?  identityref
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-primary-reverse-path/te:te-bandwidth/te:technology:
    +--:(wson)
      +-rw bandwidth-type?  identityref
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:te-bandwidth/te:technology:
    +--:(wson)
      +-rw bandwidth-type?  identityref
  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:
    +--:(wson)
      +-rw (grid-type)?

```

```

    +-:(dwdm)
    |   +-rw (single-or-super-channel)?
    |       +-:(single)
    |       |   +-rw dwdm-n?                int16
    |       +-:(super)
    |           +-rw subcarrier-dwdm-n*    int16
    +-:(cwdm)
    |   +-rw cwdm-n?                int16
    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:
    +-:(wson)
    |   +-rw (grid-type)?
    |       +-:(dwdm)
    |       |   +-rw (single-or-super-channel)?
    |       |       +-:(single)
    |       |       |   +-rw dwdm-n?                int16
    |       |       +-:(super)
    |       |           +-rw subcarrier-dwdm-n*    int16
    |       +-:(cwdm)
    |           +-rw cwdm-n?                int16
    augment /te:te/te:globals/te:named-path-constraints/te:named-path-
    constraint/te:path-in-segment/te:label-restrictions/te:label-restriction:
    +-rw grid-type?    identityref
    +-rw priority?    uint8
    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:
    +-:(wson)
    |   +-rw (grid-type)?
    |       +-:(dwdm)
    |       |   +-rw dwdm-n?    int16
    |       +-:(cwdm)
    |           +-rw cwdm-n?    int16
    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:
    +-:(wson)
    |   +-rw (grid-type)?
    |       +-:(dwdm)
    |       |   +-rw dwdm-n?    int16
    |       +-:(cwdm)
    |           +-rw cwdm-n?    int16
    augment /te:te/te:globals/te:named-path-constraints/te:named-path-
    constraint/te:path-out-segment/te:label-restrictions/te:label-restriction:

```

```

    +-rw grid-type?    identityref
    +-rw priority?     uint8
    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:
    +-(wson)
        +-rw (grid-type)?
            +-(dwdm)
                | +-rw dwdm-n?    int16
            +-(cwdm)
                +-rw cwdm-n?    int16
    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:
    +-(wson)
        +-rw (grid-type)?
            +-(dwdm)
                | +-rw dwdm-n?    int16
            +-(cwdm)
                +-rw cwdm-n?    int16
    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:
    +-(wson)
        +-rw (grid-type)?
            +-(dwdm)
                | +-rw (single-or-super-channel)?
                    +-(single)
                        | +-rw dwdm-n?                int16
                    +-(super)
                        +-rw subcarrier-dwdm-n*    int16
            +-(cwdm)
                +-rw cwdm-n?                int16
    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:
    +-(wson)
        +-rw (grid-type)?
            +-(dwdm)
                | +-rw (single-or-super-channel)?
                    +-(single)
                        | +-rw dwdm-n?                int16
                    +-(super)

```

```

        |           +-rw subcarrier-dwdm-n*    int16
        +-:(cwdm)
            +-rw cwdm-n?                        int16
    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:
        +-:(wson)
            +-rw (grid-type)?
            +-:(dwdm)
                +-rw (single-or-super-channel)?
                +-:(single)
                |   +-rw dwdm-n?                int16
                +-:(super)
                |   +-rw subcarrier-dwdm-n*    int16
            +-:(cwdm)
                +-rw cwdm-n?                    int16
    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:
        +-:(wson)
            +-rw (grid-type)?
            +-:(dwdm)
                +-rw (single-or-super-channel)?
                +-:(single)
                |   +-rw dwdm-n?                int16
                +-:(super)
                |   +-rw subcarrier-dwdm-n*    int16
            +-:(cwdm)
                +-rw cwdm-n?                    int16
    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:
        +-rw grid-type?    identityref
        +-rw priority?     uint8
    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:
        +-:(wson)
            +-rw (grid-type)?
            +-:(dwdm)
                |   +-rw dwdm-n?    int16
            +-:(cwdm)
                +-rw cwdm-n?    int16
    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:

```



```

+-:(wson)
  +-rw (grid-type)?
    +-:(dwdm)
      | +-rw dwdm-n?    int16
    +-:(cwdm)
      +-rw cwdm-n?    int16
  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:
    +-rw grid-type?    identityref
    +-rw priority?     uint8
  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:
    +-:(wson)
      +-rw (grid-type)?
        +-:(dwdm)
          | +-rw dwdm-n?    int16
        +-:(cwdm)
          +-rw cwdm-n?    int16
      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:
        +-:(wson)
          +-rw (grid-type)?
            +-:(dwdm)
              | +-rw dwdm-n?    int16
            +-:(cwdm)
              +-rw cwdm-n?    int16
          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:
            +-:(wson)
              +-ro (grid-type)?
                +-:(dwdm)
                  +-ro (single-or-super-channel)?
                    +-:(single)
                      | +-ro dwdm-n?                int16
                    +-:(super)
                      +-ro subcarrier-dwdm-n*      int16
                +-:(cwdm)
                  +-ro cwdm-n?                int16
              augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
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:

```

```

+-:(wson)
  +-ro (grid-type)?
  +-:(dwdm)
    +-ro (single-or-super-channel)?
    +-:(single)
      | +-ro dwdm-n? int16
    +-:(super)
      +-ro subcarrier-dwdm-n* int16
  +-:(cwdm)
    +-ro cwdm-n? int16
  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:
  +-:(wson)
    +-ro (grid-type)?
    +-:(dwdm)
      +-ro (single-or-super-channel)?
      +-:(single)
        | +-ro dwdm-n? int16
      +-:(super)
        +-ro subcarrier-dwdm-n* int16
    +-:(cwdm)
      +-ro cwdm-n? int16
    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:
  +-:(wson)
    +-rw (grid-type)?
    +-:(dwdm)
      +-rw (single-or-super-channel)?
      +-:(single)
        | +-rw dwdm-n? int16
      +-:(super)
        +-rw subcarrier-dwdm-n* int16
    +-:(cwdm)
      +-rw cwdm-n? int16
    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:
  +-:(wson)
    +-rw (grid-type)?

```

```

    +-:(dwdm)
    |   +-rw (single-or-super-channel)?
    |       +-:(single)
    |       |   +-rw dwdm-n?                int16
    |       +-:(super)
    |           +-rw subcarrier-dwdm-n*    int16
    +-:(cwdm)
    |   +-rw cwdm-n?                        int16
    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:
    +-:(wson)
    |   +-rw (grid-type)?
    |       +-:(dwdm)
    |       |   +-rw (single-or-super-channel)?
    |       |       +-:(single)
    |       |       |   +-rw dwdm-n?                int16
    |       |       +-:(super)
    |       |           +-rw subcarrier-dwdm-n*    int16
    |       +-:(cwdm)
    |           +-rw cwdm-n?                        int16
    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:
    +-:(wson)
    |   +-rw (grid-type)?
    |       +-:(dwdm)
    |       |   +-rw (single-or-super-channel)?
    |       |       +-:(single)
    |       |       |   +-rw dwdm-n?                int16
    |       |       +-:(super)
    |       |           +-rw subcarrier-dwdm-n*    int16
    |       +-:(cwdm)
    |           +-rw cwdm-n?                        int16
    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:
    |   +-rw grid-type?    identityref
    |   +-rw priority?     uint8
    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:
    +-:(wson)
    |   +-rw (grid-type)?

```

```

    +-:(dwdm)
    | +-rw dwdm-n?    int16
    +-:(cwdm)
    +-rw cwdm-n?    int16
    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:
    +-:(wson)
    +-rw (grid-type)?
    +-:(dwdm)
    | +-rw dwdm-n?    int16
    +-:(cwdm)
    +-rw cwdm-n?    int16
    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:
    +-rw grid-type?    identityref
    +-rw priority?    uint8
    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:
    +-:(wson)
    +-rw (grid-type)?
    +-:(dwdm)
    | +-rw dwdm-n?    int16
    +-:(cwdm)
    +-rw cwdm-n?    int16
    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:
    +-:(wson)
    +-rw (grid-type)?
    +-:(dwdm)
    | +-rw dwdm-n?    int16
    +-:(cwdm)
    +-rw cwdm-n?    int16
    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:
    +-:(wson)
    +-ro (grid-type)?
    +-:(dwdm)
    | +-ro (single-or-super-channel)?
    | +-:(single)

```

```

        |         | +-ro dwdm-n?                int16
        |         +-:(super)
        |         +-ro subcarrier-dwdm-n*      int16
    +-:(cwdm)
        +-ro cwdm-n?                int16
    augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
    path/te:p2p-primary-reverse-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:
    +-:(wson)
        +-ro (grid-type)?
        +-:(dwdm)
            +-ro (single-or-super-channel)?
            +-:(single)
            | +-ro dwdm-n?                int16
            +-:(super)
            | +-ro subcarrier-dwdm-n*      int16
        +-:(cwdm)
            +-ro cwdm-n?                int16
    augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
    path/te:p2p-primary-reverse-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:
    +-:(wson)
        +-ro (grid-type)?
        +-:(dwdm)
            +-ro (single-or-super-channel)?
            +-:(single)
            | +-ro dwdm-n?                int16
            +-:(super)
            | +-ro subcarrier-dwdm-n*      int16
        +-:(cwdm)
            +-ro cwdm-n?                int16
    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:
    +-:(wson)
        +-rw (grid-type)?
        +-:(dwdm)
            +-rw (single-or-super-channel)?
            +-:(single)
            | +-rw dwdm-n?                int16
            +-:(super)
            | +-rw subcarrier-dwdm-n*      int16

```

```

        +-:(cwdm)
            +-rw cwdm-n?                                int16
        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:
        +-:(wson)
            +-rw (grid-type)?
            +-:(dwdm)
                +-rw (single-or-super-channel)?
                +-:(single)
                |   +-rw dwdm-n?                                int16
                +-:(super)
                |   +-rw subcarrier-dwdm-n*                    int16
            +-:(cwdm)
                +-rw cwdm-n?                                int16
        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:
        +-:(wson)
            +-rw (grid-type)?
            +-:(dwdm)
                +-rw (single-or-super-channel)?
                +-:(single)
                |   +-rw dwdm-n?                                int16
                +-:(super)
                |   +-rw subcarrier-dwdm-n*                    int16
            +-:(cwdm)
                +-rw cwdm-n?                                int16
        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:
        +-:(wson)
            +-rw (grid-type)?
            +-:(dwdm)
                +-rw (single-or-super-channel)?
                +-:(single)
                |   +-rw dwdm-n?                                int16
                +-:(super)
                |   +-rw subcarrier-dwdm-n*                    int16
            +-:(cwdm)
                +-rw cwdm-n?                                int16
        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:
        +-rw grid-type?    identityref

```

```

    +-rw priority?      uint8
    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:
      +-(wson)
        +-rw (grid-type)?
          +-(dwdm)
            | +-rw dwdm-n?    int16
          +-(cwdm)
            +-rw cwdm-n?    int16
    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:
      +-(wson)
        +-rw (grid-type)?
          +-(dwdm)
            | +-rw dwdm-n?    int16
          +-(cwdm)
            +-rw cwdm-n?    int16
    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:
      +-rw grid-type?    identityref
      +-rw priority?      uint8
    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:
      +-(wson)
        +-rw (grid-type)?
          +-(dwdm)
            | +-rw dwdm-n?    int16
          +-(cwdm)
            +-rw cwdm-n?    int16
    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:
      +-(wson)
        +-rw (grid-type)?
          +-(dwdm)
            | +-rw dwdm-n?    int16
          +-(cwdm)
            +-rw cwdm-n?    int16
    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:te-label/te:label-hop/te:te-label/te:technology:

```

```

+-:(wson)
  +-ro (grid-type)?
  +-:(dwdm)
    +-ro (single-or-super-channel)?
    +-:(single)
      | +-ro dwdm-n? int16
    +-:(super)
      +-ro subcarrier-dwdm-n* int16
  +-:(cwdm)
    +-ro cwdm-n? int16
  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:
  +-:(wson)
    +-ro (grid-type)?
    +-:(dwdm)
      +-ro (single-or-super-channel)?
      +-:(single)
        | +-ro dwdm-n? int16
      +-:(super)
        +-ro subcarrier-dwdm-n* int16
    +-:(cwdm)
      +-ro cwdm-n? int16
    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:
    +-:(wson)
      +-ro (grid-type)?
      +-:(dwdm)
        +-ro (single-or-super-channel)?
        +-:(single)
          | +-ro dwdm-n? int16
        +-:(super)
          +-ro subcarrier-dwdm-n* int16
      +-:(cwdm)
        +-ro cwdm-n? int16
    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:
    +-:(wson)
      +-ro (grid-type)?
      +-:(dwdm)
        +-ro (single-or-super-channel)?
        +-:(single)
          | +-ro dwdm-n? int16

```



```

    |      +-:(super)
    |      +-ro subcarrier-dwdm-n*    int16
+-:(cwdm)
    +-ro cwdm-n?                      int16
augment /te:tunnels-rpc/te:input/te:tunnel-info/tepc:path-request:
  +- src-client-signal?              identityref
  +- dst-client-signal?              identityref
  +- fec-type?                       identityref
  +- termination-type?               identityref
  +- bit-stuffing?                   boolean
  +- wavelength-assignment?          identityref

```

### 3. TE Tunnel Model for WSON

<CODE BEGINS> file "ietf-wson-tunnel@2019-03-06.yang"

```

module ietf-wson-tunnel {
  yang-version 1.1;

  namespace "urn:ietf:params:xml:ns:yang:ietf-wson-tunnel";
  prefix "wson-tunnel";

  import ietf-te { prefix "te"; }
  import ietf-layer0-types { prefix "layer0-types"; }
  import ietf-te-path-computation { prefix "tepc"; }
  import ietf-otn-types { prefix "otn-types"; }

  organization
    "IETF CCAMP Working Group";

  contact
    "WG Web:    <http://tools.ietf.org/wg/ccamp/>
    WG List:    <mailto:ccamp@ietf.org>

    WG Chair: Daniele Ceccarelli
               <mailto:daniele.ceccarelli@ericsson.com>

    WG Chair: Fatai Zhang
               <mailto:zhangfatai@huawei.com>

    Editor: Young Lee <leeyoung@huawei.com>
    Editor: Aihua Guo <aihuaguo@huawei.com>

```

```
Editor: Dhruv Dhody <dhruv.ietf@gmail.com>
Editor: Ricard Vilalta <ricard.vilalta@cttc.es>;
description
  "This module defines a model for WSON Tunnel Services.";

revision "2019-03-06" {
  description
    "Updates to version 3";
  reference "version 3";
}

/* Groupings. */
grouping wson-tunnel-attributes {
  description "Parameters for WSON tunnel.";

  leaf src-client-signal {
    type identityref {
      base otn-types:client-signal;
    }
    description
      "Client signal at the source endpoint of
       the tunnel.";
  }

  leaf dst-client-signal {
    type identityref {
      base otn-types:client-signal;
    }
    description
      "Client signal at the destination endpoint of
       the tunnel.";
  }

  leaf fec-type {
    type identityref {
      base layer0-types:fec-type;
    }
    description
      "FEC type.";
  }

  leaf termination-type {
    type identityref {
      base layer0-types:term-type;
    }
  }
}
```

```
        description
            "Termination type.";
    }

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

grouping wson-path-constraints {
    description
        "Global named path constraints configuration
        grouping for WSON tunnel";

    leaf wavelength-assignment {
        type identityref {
            base layer0-types:wavelength-assignment;
        }
        description "Wavelength Allocation Method";
    }
}

/*
 * Data nodes
 */

augment "/te:te/te:tunnels/te:tunnel" {
    description
        "Augment with additional parameters required for WSON tunnel.";
    uses wson-tunnel-attributes;
}

/*
 * Augment TE bandwidth
 */

/* Augment bandwidth of named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/"
    + "te:te-bandwidth/te:technology" {
    description "WSO bandwidth.";
    case wson {
        uses layer0-types:wson-path-bandwidth;
    }
}
```

```
}

/* Augment bandwidth of tunnel */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:te-bandwidth/te:technology" {
  description "WSON bandwidth.";
  case wson {
    uses layer0-types:wson-path-bandwidth;
  }
}

/* Augment bandwidth of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:te-bandwidth/te:technology" {
  description "WSON bandwidth.";
  case wson {
    uses layer0-types:wson-path-bandwidth;
  }
}

/* Augment bandwidth 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:te-bandwidth/te:technology" {
  description "WSON bandwidth.";
  case wson {
    uses layer0-types:wson-path-bandwidth;
  }
}

/* Augment bandwidth of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-secondary-paths/te:p2p-secondary-path/"
  + "te:te-bandwidth/te:technology" {
  description "WSON bandwidth.";
  case wson {
    uses layer0-types:wson-path-bandwidth;
  }
}

/*
 * 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 "WSON label.";
  case wson {
    uses layer0-types:wson-path-label;
  }
}

/* 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 "WSON label.";
  case wson {
    uses layer0-types:wson-path-label;
  }
}

/* Augment label restrictions for the 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 "WSON label.";
  uses layer0-types:layer0-label-restriction;
}

/* Augment label restrictions start for the 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 "WSON label.";
  case wson {
    uses layer0-types:wson-link-label;
  }
}
```

```
}

/* Augment label restrictions end for the 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 "WSON label.";
  case wson {
    uses layer0-types:wson-link-label;
  }
}

/* Augment label restrictions for the 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 "WSON label.";
  uses layer0-types:layer0-label-restriction;
}

/* Augment label restrictions start for the 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 "WSON label.";
  case wson {
    uses layer0-types:wson-link-label;
  }
}

/* Augment label restrictions end for the 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 "WSON label.";
```

```
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

/* 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 "WSON label.";
  case wson {
    uses layer0-types:wson-path-label;
  }
}

/* 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 "WSON label.";
  case wson {
    uses layer0-types:wson-path-label;
  }
}

/* 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 "WSON label.";
  case wson {
    uses layer0-types:wson-path-label;
  }
}

/* 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 "WSON label.";
case wson {
    uses layer0-types:wson-path-label;
}
}

/* 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 "WSON label.";
uses layer0-types:layer0-label-restriction;
}

/* Augment label restrictions start 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/te:label-start/"
    + "te:te-label/te:technology" {
description "WSON label.";
case wson {
    uses layer0-types:wson-link-label;
}
}

/* Augment label restrictions end 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/te:label-end/"
    + "te:te-label/te:technology" {
description "WSON label.";
case wson {
    uses layer0-types:wson-link-label;
}
}

/* Augment label restrictions for the 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 "WSON label.";
    uses layer0-types:layer0-label-restriction;
  }

/* Augment label restrictions start for the 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 "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

/* Augment label restrictions end for the 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 "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

/* 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 "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }
```

```
    }
  }

/* 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 "WSON label.";
  case wson {
    uses layer0-types:wson-path-label;
  }
}

/* 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 "WSON label.";
  case wson {
    uses layer0-types:wson-path-label;
  }
}

/* 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 "WSON label.";
  case wson {
    uses layer0-types:wson-path-label;
  }
}

/* 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 "WSON label.";
case wson {
    uses layer0-types:wson-path-label;
}
}

/* 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 "WSON label.";
case wson {
    uses layer0-types:wson-path-label;
}
}

/* 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 "WSON label.";
case wson {
    uses layer0-types:wson-path-label;
}
}

/* Augment label restrictions for the 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 "WSON label.";
uses layer0-types:layer0-label-restriction;
}

/* Augment label restrictions start for the 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 "WSON label.";
case wson {
  uses layer0-types:wson-link-label;
}
}

/* Augment label restrictions end for the 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 "WSON label.";
case wson {
  uses layer0-types:wson-link-label;
}
}

/* Augment label restrictions for the 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 "WSON label.";
uses layer0-types:layer0-label-restriction;
}
```

```
/* Augment label restrictions start for the 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 "WSON label.";
  case wson {
    uses layer0-types:wson-link-label;
  }
}

/* Augment label restrictions end for the 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 "WSON label.";
  case wson {
    uses layer0-types:wson-link-label;
  }
}

/* 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 "WSON label.";
  case wson {
    uses layer0-types:wson-path-label;
  }
}

/* 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: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 "WSON label.";
case wson {
    uses layer0-types:wson-path-label;
}
}

/* 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: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 "WSON label.";
case wson {
    uses layer0-types:wson-path-label;
}
}

/* 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 "WSON label.";
case wson {
    uses layer0-types:wson-path-label;
}
}

/* 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 "WSON label.";
case wson {
  uses layer0-types:wson-path-label;
}

/* 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 "WSON label.";
case wson {
  uses layer0-types:wson-path-label;
}
}

/* 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 "WSON label.";
case wson {
  uses layer0-types:wson-path-label;
}
}

/* Augment label restrictions for the 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 "WSON label.";
uses layer0-types:layer0-label-restriction;
}

/* Augment label restrictions start for the 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 "WSON label.";
    case wson {
        uses layer0-types:wson-link-label;
    }
}

/* Augment label restrictions end for the 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 "WSON label.";
    case wson {
        uses layer0-types:wson-link-label;
    }
}

/* Augment label restrictions for the 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 "WSON label.";
    uses layer0-types:layer0-label-restriction;
}

/* Augment label restrictions start for the 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 "WSON label.";
    case wson {
        uses layer0-types:wson-link-label;
    }
}

/* Augment label restrictions end for the 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 "WSON label.";
case wson {
    uses layer0-types:wson-link-label;
}
}

/* 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 "WSON label.";
case wson {
    uses layer0-types:wson-path-label;
}
}

/* 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 "WSON label.";
case wson {
    uses layer0-types:wson-path-label;
}
}

/* 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 "WSON label.";
case wson {
```

```
        uses layer0-types:wson-path-label;
    }
}

/* 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 "WSON label.";
    case wson {
        uses layer0-types:wson-path-label;
    }
}

augment "/te:tunnels-rpc/te:input/te:tunnel-info/"
    + "tepc:path-request" {
    description
        "Augment with additional constraints WSON
        tunnel.";
    uses wson-tunnel-attributes;
    uses wson-path-constraints;
}
}
```

<CODE ENDS>

#### 4. 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 writable/deletable (i.e., "config true") These data nodes may be considered sensitive or vulnerable in some network environments.

## 5. IANA Considerations

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

```
-----  
URI: urn:ietf:params:xml:ns:yang:ietf-wson-tunnel  
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-wson-tunnel  
namespace:     urn:ietf:params:xml:ns:yang:ietf-wson-tunnel  
reference:     RFC XXXX (TDB)  
-----
```

## 6. Acknowledgments

This document was prepared using 2-Word-v2.0.template.dot.

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A YANG Data Model for WSON (Wavelength Switched Optical Networks)

draft-ietf-ccamp-wson-yang-19

## Abstract

This document provides a YANG data model for the routing and wavelength assignment (RWA) TE topology in wavelength switched optical networks (WSONs). The YANG data model defined in this document conforms to the Network Management Datastore Architecture defined in RFC 8342.

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## 1. Introduction

This document provides a YANG data model for the routing and wavelength assignment (RWA) Traffic Engineering (TE) topology in wavelength switched optical networks (WSONs). The YANG model described in this document is a WSON 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].

This document augments the generic TE topology draft [TE-TOPO].

What is not in scope of this document is both impairment-aware WSON and flex-grid.

This document defines two YANG models: ietf-wson-topology (Section 3) and ietf-layer0-types (Section 4).

There are multiple applications for the yang data model defined in this document. For example, nodes within the network can use the data model to capture their understanding of the overall WSON topology and expose it to a controller. A controller can further propagate the topology to other controllers. The YANG model is used by NETCONF [RFC6020], [RFC8341] or a RESTCONF [RFC8040] protocol. The YANG data model defined in this document conforms to the Network Management Datastore Architecture [RFC8342].

### 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.

### 1.2. Terminology

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:

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

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

- o configuration data
- o state data

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

### 1.3. Tree diagram

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

### 1.4. Prefixes in Data Node Names

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

Prefix	YANG module	Reference
layer0-type	ietf-layer0-types	[RFCXXXX]
wson	ietf-wson-topology	[RFCXXXX]
nw	ietf-network	[RFC8345]
nt	ietf-network-topology	[RFC8345]
tet	ietf-te-topology	[TE-TOPO]

Table 1: Prefixes and corresponding YANG modules

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

YANG module "ietf-layer0-types" (defined in Section 4) references [RFC6163], [RFC7205], and [RFC7698].

## 2. YANG Model (Tree Structure)

```

module: ietf-wson-topology
  augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
    +--rw wson-topology!

```

```

    augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-
attributes:
    augment /nw:networks/nw:network/nw:node/nt:termination-point/tet:te:
        +--rw supported-payload-types* [index]
        |   +--rw index          uint16
        |   +--rw payload-type?  string
        +--rw client-facing?      boolean
    augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
attributes:
    +--rw wson-node
        +--rw node-type?  identityref
    augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-
termination-point:
    +--rw supported-operational-modes*      layer0-types:operational-mode
    +--rw configured-operational-modes?     layer0-types:operational-mode
    +--rw supported-fec-types*              identityref
    +--rw supported-termination-types*      identityref
    +--rw supports-bit-stuffing?            boolean
    +--rw is-tunable?                      boolean
    +--rw max-subcarrier-channel-num?       uint8
    augment /nw:networks/nw:network/nw:node/nt:termination-
point/tet:te/tet:interface-switching-capability/tet:max-lsp-
bandwidth/tet:te-bandwidth/tet:technology:
    +--:(wson)
        +--rw bandwidth-type?  identityref
    augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
attributes/tet:connectivity-matrices/tet:path-constraints/tet:te-
bandwidth/tet:technology:
    +--:(wson)
        +--rw supported-bandwidth-list*  identityref
    augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
attributes/tet:connectivity-matrices/tet:connectivity-matrix/tet:path-
constraints/tet:te-bandwidth/tet:technology:
    +--:(wson)
        +--rw supported-bandwidth-list*  identityref
    augment /nw:networks/nw:network/nw:node/tet:te/tet:information-
source-entry/tet:connectivity-matrices/tet:path-constraints/tet:te-
bandwidth/tet:technology:
    +--:(wson)
        +--ro supported-bandwidth-list*  identityref

```

```
augment /nw:networks/nw:network/nw:node/tet:te/tet:information-
source-entry/tet:connectivity-matrices/tet:connectivity-
matrix/tet:path-constraints/tet:te-bandwidth/tet:technology:
  +--:(wson)
    +--ro supported-bandwidth-list*   identityref
  augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-
termination-point/tet:client-layer-adaptation/tet:switching-
capability/tet:te-bandwidth/tet:technology:
  +--:(wson)
    +--rw supported-bandwidth-list*   identityref
  augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-
termination-point/tet:local-link-connectivities/tet:path-
constraints/tet:te-bandwidth/tet:technology:
  +--:(wson)
    +--rw supported-bandwidth-list*   identityref
  augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-
termination-point/tet:local-link-connectivities/tet:local-link-
connectivity/tet:path-constraints/tet:te-bandwidth/tet:technology:
  +--:(wson)
    +--rw supported-bandwidth-list*   identityref
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-
attributes/tet:interface-switching-capability/tet:max-lsp-
bandwidth/tet:te-bandwidth/tet:technology:
  +--:(wson)
    +--rw bandwidth-type?   identityref
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-
attributes/tet:max-link-bandwidth/tet:te-bandwidth/tet:technology:
  +--:(wson)
    +--rw supported-bandwidth-list*   identityref
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-
attributes/tet:max-resv-link-bandwidth/tet:te-bandwidth/tet:technology:
  +--:(wson)
    +--rw supported-bandwidth-list*   identityref
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-
attributes/tet:unreserved-bandwidth/tet:te-bandwidth/tet:technology:
  +--:(wson)
    +--rw supported-bandwidth-list*   identityref
  augment /nw:networks/nw:network/nt:link/tet:te/tet:information-
source-entry/tet:interface-switching-capability/tet:max-lsp-
bandwidth/tet:te-bandwidth/tet:technology:
  +--:(wson)
```

```
    +--ro bandwidth-type?   identityref
  augment /nw:networks/nw:network/nt:link/tet:te/tet:information-
source-entry/tet:max-link-bandwidth/tet:te-bandwidth/tet:technology:
    +--:(wson)
      +--ro supported-bandwidth-list*   identityref
    augment /nw:networks/nw:network/nt:link/tet:te/tet:information-
source-entry/tet:max-resv-link-bandwidth/tet:te-
bandwidth/tet:technology:
    +--:(wson)
      +--ro supported-bandwidth-list*   identityref
    augment /nw:networks/tet:te/tet:templates/tet:link-template/tet:te-
link-attributes/tet:interface-switching-capability/tet:max-lsp-
bandwidth/tet:te-bandwidth/tet:technology:
    +--:(wson)
      +--rw bandwidth-type?   identityref
    augment /nw:networks/tet:te/tet:templates/tet:link-template/tet:te-
link-attributes/tet:max-link-bandwidth/tet:te-bandwidth/tet:technology:
    +--:(wson)
      +--rw supported-bandwidth-list*   identityref
    augment /nw:networks/tet:te/tet:templates/tet:link-template/tet:te-
link-attributes/tet:max-resv-link-bandwidth/tet:te-
bandwidth/tet:technology:
    +--:(wson)
      +--rw supported-bandwidth-list*   identityref
    augment /nw:networks/tet:te/tet:templates/tet:link-template/tet:te-
link-attributes/tet:unreserved-bandwidth/tet:te-
bandwidth/tet:technology:
    +--:(wson)
      +--rw supported-bandwidth-list*   identityref
    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
    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:
```

```

    +--:(wson)
      +--rw (grid-type)?
        +--:(dwdm)
          | +--rw dwdm-n?   int16
        +--:(cwdm)
          +--rw cwdm-n?   int16
      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:
    +--:(wson)
      +--rw (grid-type)?
        +--:(dwdm)
          | +--rw dwdm-n?   int16
        +--:(cwdm)
          +--rw cwdm-n?   int16
      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:
    +--:(wson)
      +--rw (layer0-grid-type)?
        +--:(dwdm)
          | +--rw wson-dwdm?   identityref
        +--:(cwdm)
          +--rw wson-cwdm?   identityref
      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:
    +--:(wson)
      +--rw (grid-type)?
        +--:(dwdm)
          | +--rw (single-or-super-channel)?
            +--:(single)
              | +--rw dwdm-n?   int16
            +--:(super)
              +--rw subcarrier-dwdm-n*   int16
          +--:(cwdm)
            +--rw cwdm-n?   int16
      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:
  +--:(wson)
    +--rw (grid-type)?
      +--:(dwdm)
        +--rw (single-or-super-channel)?
          +--:(single)
            | +--rw dwdm-n? int16
          +--:(super)
            | +--rw subcarrier-dwdm-n* int16
      +--:(cwdm)
        +--rw cwdm-n? int16
  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:
  +--:(wson)
    +--rw (grid-type)?
      +--:(dwdm)
        +--rw (single-or-super-channel)?
          +--:(single)
            | +--rw dwdm-n? int16
          +--:(super)
            | +--rw subcarrier-dwdm-n* int16
      +--:(cwdm)
        +--rw cwdm-n? int16
  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:
  +--:(wson)
    +--rw (grid-type)?
      +--:(dwdm)
        +--rw (single-or-super-channel)?
          +--:(single)
            | +--rw dwdm-n? int16
          +--:(super)
            | +--rw subcarrier-dwdm-n* int16
      +--:(cwdm)

```



```

        +---rw cwdm-n?                                int16
    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:
    +---: (wson)
        +---ro (grid-type)?
            +---: (dwdm)
                +---ro (single-or-super-channel)?
                    +---: (single)
                        | +---ro dwdm-n?                int16
                    +---: (super)
                        | +---ro subcarrier-dwdm-n*      int16
            +---: (cwdm)
                +---ro cwdm-n?                int16
    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
    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:
    +---: (wson)
        +---rw (grid-type)?
            +---: (dwdm)
                | +---rw dwdm-n?    int16
            +---: (cwdm)
                +---rw cwdm-n?    int16
    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:
    +---: (wson)
        +---rw (grid-type)?
            +---: (dwdm)
                | +---rw dwdm-n?    int16
            +---: (cwdm)
                +---rw cwdm-n?    int16

```

```

    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:
    +--:(wson)
        +--rw (layer0-grid-type)?
            +--:(dwdm)
                | +--rw wson-dwdm?    identityref
            +--:(cwdm)
                +--rw wson-cwdm?    identityref
    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
    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:
    +--:(wson)
        +--rw (grid-type)?
            +--:(dwdm)
                | +--rw dwdm-n?    int16
            +--:(cwdm)
                +--rw cwdm-n?    int16
    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:
    +--:(wson)
        +--rw (grid-type)?
            +--:(dwdm)
                | +--rw dwdm-n?    int16
            +--:(cwdm)
                +--rw cwdm-n?    int16
    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:
    +--:(wson)
        +--rw (layer0-grid-type)?

```

```

    +--:(dwdm)
    |   +--rw wson-dwdm?   identityref
    +--:(cwdm)
    |   +--rw wson-cwdm?   identityref
    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:
    +--:(wson)
    |   +--rw (grid-type)?
    |   +--:(dwdm)
    |   |   +--rw (single-or-super-channel)?
    |   |   |   +--:(single)
    |   |   |   |   +--rw dwdm-n?               int16
    |   |   |   +--:(super)
    |   |   |   |   +--rw subcarrier-dwdm-n*    int16
    |   |   +--:(cwdm)
    |   |   |   +--rw cwdm-n?                   int16
    |   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:
    |   +--:(wson)
    |   |   +--rw (grid-type)?
    |   |   +--:(dwdm)
    |   |   |   +--rw (single-or-super-channel)?
    |   |   |   |   +--:(single)
    |   |   |   |   |   +--rw dwdm-n?           int16
    |   |   |   |   +--:(super)
    |   |   |   |   |   +--rw subcarrier-dwdm-n* int16
    |   |   +--:(cwdm)
    |   |   |   +--rw cwdm-n?                   int16
    |   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:
    |   +--:(wson)
    |   |   +--rw (grid-type)?
    |   |   +--:(dwdm)
    |   |   |   +--rw (single-or-super-channel)?

```

```

    |         +---:(single)
    |         |   +---rw dwdm-n?                int16
    |         +---:(super)
    |         |   +---rw subcarrier-dwdm-n*      int16
+---:(cwdm)
    |         +---rw cwdm-n?                    int16
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:
+---:(wson)
    +---rw (grid-type)?
    +---:(dwdm)
    |         +---rw (single-or-super-channel)?
    |         |   +---:(single)
    |         |   |   +---rw dwdm-n?                int16
    |         |   +---:(super)
    |         |   |   +---rw subcarrier-dwdm-n*      int16
+---:(cwdm)
    |         +---rw cwdm-n?                    int16
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:
+---:(wson)
    +---ro (grid-type)?
    +---:(dwdm)
    |         +---ro (single-or-super-channel)?
    |         |   +---:(single)
    |         |   |   +---ro dwdm-n?                int16
    |         |   +---:(super)
    |         |   |   +---ro subcarrier-dwdm-n*      int16
+---:(cwdm)
    |         +---ro cwdm-n?                    int16
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

```

```

    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:
    +--:(wson)
    +--ro (grid-type)?
    +--:(dwdm)
    |   +--ro dwdm-n?    int16
    +--:(cwdm)
    +--ro cwdm-n?    int16
    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:
    +--:(wson)
    +--ro (grid-type)?
    +--:(dwdm)
    |   +--ro dwdm-n?    int16
    +--:(cwdm)
    +--ro cwdm-n?    int16
    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:
    +--:(wson)
    +--ro (layer0-grid-type)?
    +--:(dwdm)
    |   +--ro wson-dwdm?    identityref
    +--:(cwdm)
    +--ro wson-cwdm?    identityref
    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:
    +--:(wson)
    +--ro (grid-type)?
    +--:(dwdm)
    |   +--ro (single-or-super-channel)?
    |   |   +--:(single)
    |   |   |   +--ro dwdm-n?                int16
    |   |   +--:(super)
    |   |   |   +--ro subcarrier-dwdm-n*    int16

```

```

    +--:(cwdm)
      +--ro cwdm-n? int16
    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:
    +--:(wson)
      +--ro (grid-type)?
        +--:(dwdm)
          +--ro (single-or-super-channel)?
            +--:(single)
              | +--ro dwdm-n? int16
            +--:(super)
              +--ro subcarrier-dwdm-n* int16
          +--:(cwdm)
            +--ro cwdm-n? int16
        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:
          +--:(wson)
            +--ro (grid-type)?
              +--:(dwdm)
                +--ro (single-or-super-channel)?
                  +--:(single)
                    | +--ro dwdm-n? int16
                  +--:(super)
                    +--ro subcarrier-dwdm-n* int16
                +--:(cwdm)
                  +--ro cwdm-n? int16
              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:
                +--:(wson)
                  +--ro (grid-type)?
                    +--:(dwdm)
                      +--ro (single-or-super-channel)?
                        +--:(single)

```

```

    |         | +--ro dwdm-n?                int16
    |         +---:(super)
    |         +--ro subcarrier-dwdm-n*      int16
+---:(cwdm)
    +--ro cwdm-n?                int16
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:
+---:(wson)
    +--ro (grid-type)?
    +---:(dwdm)
    |   +--ro (single-or-super-channel)?
    |   +---:(single)
    |   |   +--ro dwdm-n?                int16
    |   +---:(super)
    |   |   +--ro subcarrier-dwdm-n*      int16
    +---:(cwdm)
    +--ro cwdm-n?                int16
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
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:
+---:(wson)
    +--ro (grid-type)?
    +---:(dwdm)
    |   +--ro dwdm-n?    int16
    +---:(cwdm)
    +--ro cwdm-n?      int16
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:
+---:(wson)
    +--ro (grid-type)?
    +---:(dwdm)

```

```

        | +--ro dwdm-n?   int16
      +--:(cwdm)
        +--ro cwdm-n?   int16
    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:
  +--:(wson)
    +--ro (layer0-grid-type)?
    +--:(dwdm)
      | +--ro wson-dwdm?   identityref
    +--:(cwdm)
      +--ro wson-cwdm?   identityref
    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
    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:
  +--:(wson)
    +--ro (grid-type)?
    +--:(dwdm)
      | +--ro dwdm-n?   int16
    +--:(cwdm)
      +--ro cwdm-n?   int16
    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:
  +--:(wson)
    +--ro (grid-type)?
    +--:(dwdm)
      | +--ro dwdm-n?   int16
    +--:(cwdm)
      +--ro cwdm-n?   int16
    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:
  +--:(wson)
    +--ro (layer0-grid-type)?
      +--:(dwdm)
        | +--ro wson-dwdm?    identityref
      +--:(cwdm)
        +--ro wson-cwdm?    identityref
    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:
  +--:(wson)
    +--ro (grid-type)?
      +--:(dwdm)
        | +--ro (single-or-super-channel)?
        |   +--:(single)
        |   | +--ro dwdm-n?                int16
        |   +--:(super)
        |   +--ro subcarrier-dwdm-n*      int16
        +--:(cwdm)
          +--ro cwdm-n?                    int16
    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:
  +--:(wson)
    +--ro (grid-type)?
      +--:(dwdm)
        | +--ro (single-or-super-channel)?
        |   +--:(single)
        |   | +--ro dwdm-n?                int16
        |   +--:(super)
        |   +--ro subcarrier-dwdm-n*      int16
        +--:(cwdm)
          +--ro cwdm-n?                    int16
    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:

```

```

+--:(wson)
  +--ro (grid-type)?
    +--:(dwdm)
      +--ro (single-or-super-channel)?
        +--:(single)
          | +--ro dwdm-n? int16
        +--:(super)
          +--ro subcarrier-dwdm-n* int16
      +--:(cwdm)
        +--ro cwdm-n? int16
    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:
+--:(wson)
  +--ro (grid-type)?
    +--:(dwdm)
      +--ro (single-or-super-channel)?
        +--:(single)
          | +--ro dwdm-n? int16
        +--:(super)
          +--ro subcarrier-dwdm-n* int16
      +--:(cwdm)
        +--ro cwdm-n? int16
    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:
+--:(wson)
  +--ro (grid-type)?
    +--:(dwdm)
      +--ro (single-or-super-channel)?
        +--:(single)
          | +--ro dwdm-n? int16
        +--:(super)
          +--ro subcarrier-dwdm-n* int16
      +--:(cwdm)
        +--ro cwdm-n? int16

```

```

    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
    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:
    +--:(wson)
        +--rw (grid-type)?
            +--:(dwdm)
                | +--rw dwdm-n?    int16
            +--:(cwdm)
                +--rw cwdm-n?    int16
    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:
    +--:(wson)
        +--rw (grid-type)?
            +--:(dwdm)
                | +--rw dwdm-n?    int16
            +--:(cwdm)
                +--rw cwdm-n?    int16
    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:
    +--:(wson)
        +--rw (layer0-grid-type)?
            +--:(dwdm)
                | +--rw wson-dwdm?    identityref
            +--:(cwdm)
                +--rw wson-cwdm?    identityref
    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:
    +--:(wson)
        +--rw (grid-type)?
            +--:(dwdm)

```

```

    |   +--rw (single-or-super-channel)?
    |   |   +--:(single)
    |   |   |   +--rw dwdm-n?                int16
    |   |   +--:(super)
    |   |   |   +--rw subcarrier-dwdm-n*      int16
    |   +--:(cwdm)
    |   |   +--rw cwdm-n?                    int16
    |   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:
    |   +--:(wson)
    |   |   +--rw (grid-type)?
    |   |   |   +--:(dwdm)
    |   |   |   |   +--rw (single-or-super-channel)?
    |   |   |   |   |   +--:(single)
    |   |   |   |   |   |   +--rw dwdm-n?                int16
    |   |   |   |   |   +--:(super)
    |   |   |   |   |   |   +--rw subcarrier-dwdm-n*      int16
    |   |   |   |   +--:(cwdm)
    |   |   |   |   |   +--rw cwdm-n?                    int16
    |   |   |   augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-
    |   |   |   termination-point/tet:local-link-
    |   |   |   connectivities/tet:optimizations/tet:algorithm/tet:metric/tet:optimizat
    |   |   |   ion-metric/tet:explicit-route-exclude-objects/tet:route-object-exclude-
    |   |   |   object/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
    |   |   |   +--:(wson)
    |   |   |   |   +--rw (grid-type)?
    |   |   |   |   |   +--:(dwdm)
    |   |   |   |   |   |   +--rw (single-or-super-channel)?
    |   |   |   |   |   |   |   +--:(single)
    |   |   |   |   |   |   |   |   +--rw dwdm-n?                int16
    |   |   |   |   |   |   |   +--:(super)
    |   |   |   |   |   |   |   |   +--rw subcarrier-dwdm-n*      int16
    |   |   |   |   |   |   |   +--:(cwdm)
    |   |   |   |   |   |   |   |   +--rw cwdm-n?                    int16
    |   |   |   |   |   |   augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-
    |   |   |   |   |   |   termination-point/tet:local-link-
    |   |   |   |   |   |   connectivities/tet:optimizations/tet:algorithm/tet:metric/tet:optimizat
    |   |   |   |   |   |   ion-metric/tet:explicit-route-include-objects/tet:route-object-include-
    |   |   |   |   |   |   object/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:

```

```

+--:(wson)
  +--rw (grid-type)?
    +--:(dwdm)
      | +--rw (single-or-super-channel)?
      |   +--:(single)
      |     | +--rw dwdm-n?          int16
      |     +--:(super)
      |       +--rw subcarrier-dwdm-n*  int16
      +--:(cwdm)
        +--rw cwdm-n?          int16
  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:
+--:(wson)
  +--ro (grid-type)?
    +--:(dwdm)
      | +--ro (single-or-super-channel)?
      |   +--:(single)
      |     | +--ro dwdm-n?          int16
      |     +--:(super)
      |       +--ro subcarrier-dwdm-n*  int16
      +--:(cwdm)
        +--ro cwdm-n?          int16
  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
  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:
+--:(wson)
  +--rw (grid-type)?
    +--:(dwdm)
      | +--rw dwdm-n?  int16
    +--:(cwdm)
      +--rw cwdm-n?  int16
  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:
  +--:(wson)
    +--rw (grid-type)?
      +--:(dwdm)
        | +--rw dwdm-n?    int16
      +--:(cwdm)
        +--rw cwdm-n?    int16
    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:
      +--:(wson)
        +--rw (layer0-grid-type)?
          +--:(dwdm)
            | +--rw wson-dwdm?    identityref
          +--:(cwdm)
            +--rw wson-cwdm?    identityref
        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:
          +--:(wson)
            +--rw (grid-type)?
              +--:(dwdm)
                | +--rw (single-or-super-channel)?
                  +--:(single)
                    | +--rw dwdm-n?                int16
                  +--:(super)
                    +--rw subcarrier-dwdm-n*      int16
                +--:(cwdm)
                  +--rw cwdm-n?                int16
            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:
              +--:(wson)
                +--rw (grid-type)?
                  +--:(dwdm)
                    | +--rw (single-or-super-channel)?
                      +--:(single)

```

```

    |         | +--rw dwdm-n?                int16
    |         +--:(super)
    |         +--rw subcarrier-dwdm-n*       int16
+--:(cwdm)
    +--rw cwdm-n?                            int16
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:optimizatio
n-metric/tet:explicit-route-exclude-objects/tet:route-object-exclude-
object/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
+--:(wson)
    +--rw (grid-type)?
    +--:(dwdm)
    |   +--rw (single-or-super-channel)?
    |   +--:(single)
    |   |   +--rw dwdm-n?                int16
    |   +--:(super)
    |   +--rw subcarrier-dwdm-n*       int16
    +--:(cwdm)
    +--rw cwdm-n?                            int16
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:optimizatio
n-metric/tet:explicit-route-include-objects/tet:route-object-include-
object/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
+--:(wson)
    +--rw (grid-type)?
    +--:(dwdm)
    |   +--rw (single-or-super-channel)?
    |   +--:(single)
    |   |   +--rw dwdm-n?                int16
    |   +--:(super)
    |   +--rw subcarrier-dwdm-n*       int16
    +--:(cwdm)
    +--rw cwdm-n?                            int16
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:
+--:(wson)
    +--ro (grid-type)?

```

```

    +---:(dwdm)
    |   +---ro (single-or-super-channel)?
    |       +---:(single)
    |           |   +---ro dwdm-n?                int16
    |       +---:(super)
    |           +---ro subcarrier-dwdm-n*         int16
    +---:(cwdm)
    |   +---ro cwdm-n?                            int16
    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:
    +---:(wson)
    |   +---rw (grid-type)?
    |       +---:(dwdm)
    |           +---rw (single-or-super-channel)?
    |               +---:(single)
    |                   |   +---rw dwdm-n?                int16
    |               +---:(super)
    |                   +---rw subcarrier-dwdm-n*         int16
    |       +---:(cwdm)
    |           +---rw cwdm-n?                            int16
    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:
    +---:(wson)
    |   +---rw (grid-type)?
    |       +---:(dwdm)
    |           +---rw (single-or-super-channel)?
    |               +---:(single)
    |                   |   +---rw dwdm-n?                int16
    |               +---:(super)
    |                   +---rw subcarrier-dwdm-n*         int16
    |       +---:(cwdm)
    |           +---rw cwdm-n?                            int16
    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
    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:

```



```
+--:(wson)
  +--rw (grid-type)?
    +--:(dwdm)
      | +--rw dwdm-n?  int16
    +--:(cwdm)
      +--rw cwdm-n?  int16
  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:
  +--:(wson)
    +--rw (grid-type)?
      +--:(dwdm)
        | +--rw dwdm-n?  int16
      +--:(cwdm)
        +--rw cwdm-n?  int16
    augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-
attributes/tet:label-restrictions/tet:label-restriction/tet:label-
step/tet:technology:
  +--:(wson)
    +--rw (layer0-grid-type)?
      +--:(dwdm)
        | +--rw wson-dwdm?  identityref
      +--:(cwdm)
        +--rw wson-cwdm?  identityref
    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
    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:
  +--:(wson)
    +--ro (grid-type)?
      +--:(dwdm)
        | +--ro dwdm-n?  int16
      +--:(cwdm)
        +--ro cwdm-n?  int16
    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:
  +--:(wson)
```

```

    +--ro (grid-type)?
      +--:(dwdm)
        | +--ro dwdm-n?   int16
      +--:(cwdm)
        +--ro cwdm-n?   int16
    augment /nw:networks/nw:network/nt:link/tet:te/tet:information-
source-entry/tet:label-restrictions/tet:label-restriction/tet:label-
step/tet:technology:
    +--:(wson)
      +--ro (layer0-grid-type)?
        +--:(dwdm)
          | +--ro wson-dwdm?   identityref
        +--:(cwdm)
          +--ro wson-cwdm?   identityref
    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:
    +--:(wson)
      +--rw (grid-type)?
        +--:(dwdm)
          | +--rw (single-or-super-channel)?
          |   +--:(single)
          |   | +--rw dwdm-n?               int16
          |   +--:(super)
          |   | +--rw subcarrier-dwdm-n*    int16
          +--:(cwdm)
            +--rw cwdm-n?               int16
    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:
    +--:(wson)
      +--rw (grid-type)?
        +--:(dwdm)
          | +--rw (single-or-super-channel)?
          |   +--:(single)
          |   | +--rw dwdm-n?               int16
          |   +--:(super)
          |   | +--rw subcarrier-dwdm-n*    int16
          +--:(cwdm)
            +--rw cwdm-n?               int16

```

```

    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
    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:
    +--: (wson)
        +--rw (grid-type)?
            +--: (dwdm)
                | +--rw dwdm-n?    int16
            +--: (cwdm)
                +--rw cwdm-n?    int16
    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:
    +--: (wson)
        +--rw (grid-type)?
            +--: (dwdm)
                | +--rw dwdm-n?    int16
            +--: (cwdm)
                +--rw cwdm-n?    int16
    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:
    +--: (wson)
        +--rw (layer0-grid-type)?
            +--: (dwdm)
                | +--rw wson-dwdm?    identityref
            +--: (cwdm)
                +--rw wson-cwdm?    identityref

```

### 3. IETF-WSO-Topology YANG Model

<CODE BEGINS> file ietf-wson-topology@2019-02-27.yang

```

module ietf-wson-topology {

    yang-version 1.1;

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

    prefix "wson";

```

```
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 YYYY: YANG Data Model for
    Traffic Engineering (TE) Topologies";
}

/* Note: The RFC Editor will replace YYYY with the number assigned to
the RFC once draft-ietf-teas-yang-te-topo becomes an RFC.*/

import ietf-layer0-types {
  prefix "layer0-types";
  reference
    "RFC XXXX: A YANG Data Model for WSON
    (Wavelength Switched Optical Networks)";
}

/* Note: The RFC Editor will replace XXXX with the number assigned to
the RFC once draft-ietf-ccamp-wson-yang becomes an RFC.*/

organization
  "IETF CCAMP Working Group";

contact
  "Editor:   Young Lee   <leeyoung@huawei.com>
   Editor:   Aihua Guo  <aihuaguo@huawei.com>";

description
  "This module provides a YANG data model for the routing and
  wavelength assignment (RWA) Traffic Engineering (TE)
  topology in wavelength switched optical networks (WSONs).
  The YANG model described in this document is a WSON
  technology-specific YANG model augmenting the generic TE
  topology module [TE-TOPO] based on the information model
  developed in [RFC7446] and the two encoding documents
  [RFC7581] and [RFC7579] that developed protocol independent
  encodings based on [RFC7446]."
```

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```
revision 2019-02-27 {
  description
    "Initial Version";

  reference
    "RFC XXXX: A YANG Data Model for WSON (Wavelength Switched
      Optical Networks)";
}

/*
 * Groupings
 */
grouping wson-node-attributes {
  description "WSON node attributes";
  container wson-node {
    description "WSON node attributes";
    leaf node-type {
      type identityref {
        base layer0-types:layer0-node-type;
      }
      description "WSON node type";
    }
  }
}

grouping wson-link-attributes {
  description
    "Future WSON link attributes extensions";
}

grouping wson-tp-attributes {
  description "wson-tp-attributes";

  list supported-payload-types {
    key "index";
    description
      "Supported payload types of a TP (Termination Point).
      The payload type is defined as the generalized PIDs
```

```
        (Payload Identifiers) in GMPLS";
    leaf index {
        type uint16;
        description "payload type index";
    }
    leaf payload-type {
        type string;
        description "the payload type supported by this client TP";
        reference
            "http://www.iana.org/assignments/gmpls-sig-parameters
            /gmpls-sig-parameters.xhtml";
    }
}
leaf client-facing {
    type boolean;
    default 'false';
    description
        "Indicates if it is a client-facing TP";
}
}

grouping wson-ttp-attributes {
    description
        "WSON tunnel termination point (e.g., tranponder) attributes";

    leaf-list supported-operational-modes {
        type layer0-types:operational-mode;
        description
            "List of all supported vendor-specific
            mode identifiers";
    }

    leaf configured-operational-modes {
        type layer0-types:operational-mode;
        description
            "Vendor-specific mode identifier configured
            on the TTP (TE-tunnel Termination Point)";
    }

    leaf-list supported-fec-types {
        type identityref {
            base layer0-types:fec-type;
        }
        description
            "List of all supported FEC (Forward Error Correction)
            types by this TTP";
    }

    leaf-list supported-termination-types {
```

```
    type identityref {
      base layer0-types:term-type;
    }
    description
      "List of all supported termination types by this TTP";
  }

  leaf supports-bit-stuffing {
    type boolean;
    description
      "Indicates whether bit stuffing is supported by this TTP";
  }

  leaf is-tunable {
    type boolean;
    description
      "Indicates if the TTP, or transponder, is tunable. Tunable
      transponders are assumed to be fully tunable to any of the
      96 channels within DWDM C-band";
  }

  leaf max-subcarrier-channel-num {
    type uint8 {
      range "1..max";
    }
    default 1;
    description
      "Indicates the maximum number of subcarrier channels for
      super-channel transponders. When the value equals 1 it
      represents regular single-channel transponder";
  }
}

/*
 * Data nodes
 */

augment "/nw:networks/nw:network/nw:network-types"
+ "/tet:te-topology" {
  description "wson-topology augmented";
  container wson-topology {
    presence "indicates a topology of WSON";
    description
      "Container to identify WSON topology type";
  }
}

augment "/nw:networks/nw:network/nt:link/tet:te"
+ "/tet:te-link-attributes" {
```

```

    when "/nw:networks/nw:network/nw:network-types"
      + "/tet:te-topology/wson:wson-topology" {
        description "This augment is only valid for WSON";
      }
    description "WSON Link augmentation.";
    uses wson-link-attributes;
  }

augment "/nw:networks/nw:network/nw:node/nt:termination-point/"
  + "tet:te" {
    when "/nw:networks/nw:network/nw:network-types"
      + "/tet:te-topology/wson:wson-topology" {
        description "This augment is only valid for WSON";
      }
    description "WSON TP attributes";
    uses wson-tp-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/wson:wson-topology" {
        description "This augment is only valid for WSON";
      }
    description "WSON Node augmentation";
    uses wson-node-attributes;
  }

augment "/nw:networks/nw:network/nw:node/tet:te"
  + "/tet:tunnel-termination-point" {
    when "/nw:networks/nw:network/nw:network-types"
      + "/tet:te-topology/wson:wson-topology" {
        description "This augment is only valid for WSON";
      }
    description "WSON tunnel termination point augmentation";
    uses wson-ttp-attributes;
  }

/*
 * Augment TE bandwidth
 */

augment "/nw:networks/nw:network/nw:node/nt:termination-point/"
  + "tet:te/"
  + "tet:interface-switching-capability/tet:max-lsp-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
    when "../..../nw:network-types/tet:te-topology/"
      + "wson:wson-topology" {
        description "Augment WSON TE bandwidth";
    }
  }

```



```

    }
    description
      "Augment maximum LSP WSON bandwidth of link termination point
      (LTP)";
    case wson {
      uses layer0-types:wson-path-bandwidth;
    }
  }

  augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:path-constraints/tet:te-bandwidth/tet:technology" {
    when "../..../nw:network-types/tet:te-topology/"
      + "wson:wson-topology" {
      description "Augment WSON TE bandwidth";
    }
    description
      "Augment WSON bandwidth path constraints of
      connectivity-matrices";
    case wson {
      uses layer0-types:wson-link-bandwidth;
    }
  }

  augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/"
    + "tet:path-constraints/tet:te-bandwidth/tet:technology" {
    when "../..../nw:network-types/tet:te-topology/"
      + "wson:wson-topology" {
      description "Augment WSON TE bandwidth";
    }
    description
      "Augment WSON bandwidth path constraints of
      connectivity-matrix";
    case wson {
      uses layer0-types:wson-link-bandwidth;
    }
  }

  augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:information-source-entry/tet:connectivity-matrices/"
    + "tet:path-constraints/tet:te-bandwidth/tet:technology" {
    when "../..../nw:network-types/tet:te-topology/"
      + "wson:wson-topology" {
      description "Augment WSON TE bandwidth";
    }
    description
      "Augment WSON bandwidth path constraints of

```

```

        connectivity-matrices information-source";
    case wson {
        uses layer0-types:wson-link-bandwidth;
    }
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:information-source-entry/tet:connectivity-matrices/"
+ "tet:connectivity-matrix/"
+ "tet:path-constraints/tet:te-bandwidth/tet:technology" {
when "../..../..../..../nw:network-types/tet:te-topology/"
+ "wson:wson-topology" {
    description "Augment WSON TE bandwidth";
}
description
    "Augment WSON bandwidth path constraints of
    connectivity-matrix information-source";
case wson {
    uses layer0-types:wson-link-bandwidth;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:tunnel-termination-point/"
+ "tet:client-layer-adaptation/tet:switching-capability/"
+ "tet:te-bandwidth/tet:technology" {
when "../..../..../..../nw:network-types/tet:te-topology/"
+ "wson:wson-topology" {
    description "Augment WSON TE bandwidth";
}
description
    "Augment client WSON bandwidth of tunnel termination point
    (TTP)";
case wson {
    uses layer0-types:wson-link-bandwidth;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:tunnel-termination-point/"
+ "tet:local-link-connectivities/tet:path-constraints/"
+ "tet:te-bandwidth/tet:technology" {
when "../..../..../..../nw:network-types/tet:te-topology/"
+ "wson:wson-topology" {
    description "Augment WSON TE bandwidth";
}
description
    "Augment WSON bandwidth path constraints of
    local-link-connectivities";

```

```
    case wson {
      uses layer0-types:wson-link-bandwidth;
    }
  }

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:tunnel-termination-point/"
+ "tet:local-link-connectivities/"
+ "tet:local-link-connectivity/tet:path-constraints/"
+ "tet:te-bandwidth/tet:technology" {
  when "../..../nw:network-types/tet:te-topology/"
  + "wson:wson-topology" {
    description "Augment WSON TE bandwidth";
  }
  description
    "Augment WSON bandwidth path constraints of
    local-link-connectivity (LLC)";
  case wson {
    uses layer0-types:wson-link-bandwidth;
  }
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
+ "tet:te-link-attributes/"
+ "tet:interface-switching-capability/tet:max-lsp-bandwidth/"
+ "tet:te-bandwidth/tet:technology" {
  when "../..../nw:network-types/tet:te-topology/"
  + "wson:wson-topology" {
    description "WSON TE bandwidth";
  }
  description "Augment maximum LSP WSON bandwidth of TE link";
  case wson {
    uses layer0-types:wson-path-bandwidth;
  }
}

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/"
  + "wson:wson-topology" {
    description "WSON TE bandwidth";
  }
  description
    "Augment maximum WSON bandwidth of TE link";
  case wson {
    uses layer0-types:wson-link-bandwidth;
  }
}
```

```

}

augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:te-link-attributes/"
  + "tet:max-resv-link-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
  when "../..../nw:network-types/tet:te-topology/"
    + "wson:wson-topology" {
    description "WSON TE bandwidth";
  }
  description
    "Augment maximum reservable WSON bandwidth of
    TE link";
  case wson {
    uses layer0-types:wson-link-bandwidth;
  }
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:te-link-attributes/"
  + "tet:unreserved-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
  when "../..../nw:network-types/tet:te-topology/"
    + "wson:wson-topology" {
    description "WSON TE bandwidth";
  }
  description
    "Augment unreserved WSON bandwidth of TE Link";
  case wson {
    uses layer0-types:wson-link-bandwidth;
  }
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:information-source-entry/"
  + "tet:interface-switching-capability/"
  + "tet:max-lsp-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
  when "../..../nw:network-types/tet:te-topology/"
    + "wson:wson-topology" {
    description "WSON TE bandwidth";
  }
  description
    "Augment maximum LSP WSON bandwidth of TE link
    information-source";
  case wson {
    uses layer0-types:wson-path-bandwidth;
  }
}

```

```
augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:information-source-entry/"
  + "tet:max-link-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
when "../..../nw:network-types/tet:te-topology/"
  + "wson:wson-topology" {
  description "WSON TE bandwidth";
}
description
  "Augment maximum WSON bandwidth of TE link
  information-source";
case wson {
  uses layer0-types:wson-link-bandwidth;
}
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:information-source-entry/"
  + "tet:max-resv-link-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
when "../..../nw:network-types/tet:te-topology/"
  + "wson:wson-topology" {
  description "WSON TE bandwidth";
}
description
  "Augment maximum reservable WSON bandwidth of TE link
  information-source";
case wson {
  uses layer0-types:wson-link-bandwidth;
}
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:information-source-entry/"
  + "tet:unreserved-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
when "../..../nw:network-types/tet:te-topology/"
  + "wson:wson-topology" {
  description "WSON TE bandwidth";
}
description
  "Augment unreserved WSON bandwidth of TE link
  information-source";
case wson {
  uses layer0-types:wson-link-bandwidth;
}
}
```

```
augment "/nw:networks/tet:te/tet:templates/"
  + "tet:link-template/tet:te-link-attributes/"
  + "tet:interface-switching-capability/"
  + "tet:max-lsp-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
  description
    "Augment maximum WSON LSP bandwidth of TE link
    template";
  case wson {
    uses layer0-types:wson-path-bandwidth;
  }
}

augment "/nw:networks/tet:te/tet:templates/"
  + "tet:link-template/tet:te-link-attributes/"
  + "tet:max-link-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
  description
    "Augment maximum WSON bandwidth of TE link template";
  case wson {
    uses layer0-types:wson-link-bandwidth;
  }
}

augment "/nw:networks/tet:te/tet:templates/"
  + "tet:link-template/tet:te-link-attributes/"
  + "tet:max-resv-link-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
  description
    "Augment maximum reservable WSON bandwidth of TE link
    template";
  case wson {
    uses layer0-types:wson-link-bandwidth;
  }
}

augment "/nw:networks/tet:te/tet:templates/"
  + "tet:link-template/tet:te-link-attributes/"
  + "tet:unreserved-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
  description
    "Augment unreserved WSON bandwidth of TE link template";
  case wson {
    uses layer0-types:wson-link-bandwidth;
  }
}

/*
 * 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" {
  when "../..../nw:network-types/tet:te-topology/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
  description
    "Augment WSON label restrictions of connectivity-matrices";
  uses layer0-types:layer0-label-restriction;
}

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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
  description
    "Augment WSON label restrictions start of
    connectivity-matrices";
  case wson {
    uses layer0-types:wson-link-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-end/"
  + "tet:te-label/tet:technology" {
  when "../..../nw:network-types/tet:te-topology/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
  description
    "Augment WSON label restrictions end of
    connectivity-matrices";
  case wson {
    uses layer0-types:wson-link-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-step/"
    + "tet:technology" {
when "../..../..../..../..../..../"
    + "nw:network-types/tet:te-topology/"
    + "wson:wson-topology" {
        description "Augment WSON TE label";
    }
description
    "Augment WSON label restrictions step of
    connectivity-matrices";
case wson {
    uses layer0-types:wson-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/"
    + "wson:wson-topology" {
        description "Augment WSON TE label";
    }
description
    "Augment WSON label hop of underlay primary path of
    connectivity-matrices";
case wson {
    uses layer0-types:wson-path-label;
}
}

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/"
    + "wson:wson-topology" {
        description "Augment WSON TE label";
    }
description
    "Augment WSON label hop of underlay backup path of
    connectivity-matrices";
case wson {
    uses layer0-types:wson-path-label;
}
}

```



```

    }
  }

  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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
  description
    "Augment WSON label hop of route-exclude of
    connectivity-matrices";
  case wson {
    uses layer0-types:wson-path-label;
  }
}

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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
  description
    "Augment WSON label hop of route-include of
    connectivity-matrices";
  case wson {
    uses layer0-types:wson-path-label;
  }
}

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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
}
description
    "Augment WSON label hop of path-route of
    connectivity-matrices";
case wson {
    uses layer0-types:wson-path-label;
}
}

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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
}
description
    "Augment ingress WSON label restrictions of
    connectivity-matrix";
uses layer0-types:layer0-label-restriction;
}

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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
}
description
    "Augment ingress WSON label restrictions start of
    connectivity-matrix ";
case wson {
    uses layer0-types:wson-link-label;
}
}

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/"
    + "wson:wson-topology" {
        description "Augment WSON TE label";
    }
description
    "Augment ingress WSON label restrictions end of
    connectivity-matrix";
case wson {
    uses layer0-types:wson-link-label;
}
}

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/"
    + "wson:wson-topology" {
        description "Augment WSON TE label";
    }
description
    "Augment ingress WSON label restrictions step of
    connectivity-matrix";
case wson {
    uses layer0-types:wson-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" {
when "../..../..../..../..../..../..../..../..../"
    + "nw:network-types/tet:te-topology/"
    + "wson:wson-topology" {
        description "Augment WSON TE label";
    }
description
    "Augment egress WSON label restrictions of
    connectivity-matrix";

```

```

    uses layer0-types:layer0-label-restriction;
}

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/"
+ "wson:wson-topology" {
    description "Augment WSON TE label";
}
description
    "Augment egress WSON label restrictions start of
    connectivity-matrix";
case wson {
    uses layer0-types:wson-link-label;
}
}

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/"
+ "wson:wson-topology" {
    description "Augment WSON TE label";
}
description
    "Augment egress WSON label restrictions end of
    connectivity-matrix";
case wson {
    uses layer0-types:wson-link-label;
}
}

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/"

```

```

    + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
  description
    "Augment egress WSON label restrictions step of
    connectivity-matrix";
  case wson {
    uses layer0-types:wson-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/"
    + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
  description
    "Augment WSON label hop of underlay primary path of
    connectivity-matrix";
  case wson {
    uses layer0-types:wson-path-label;
  }
}

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/"
    + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
  description
    "Augment WSON label hop of underlay backup path of
    connectivity-matrix";
  case wson {
    uses layer0-types:wson-path-label;
  }
}

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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
    }
description
    "Augment WSON label hop of route-exclude of
    connectivity-matrix";
case wson {
    uses layer0-types:wson-path-label;
}
}

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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
    }
description
    "Augment WSON label hop of route-include of
    connectivity-matrix";
case wson {
    uses layer0-types:wson-path-label;
}
}

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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
    }

```

```
    }
    description
      "Augment WSON label hop of path-route of
       connectivity-matrix";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
  description
    "Augment WSON label restrictions of connectivity-matrices
     information-source";
  uses layer0-types:layer0-label-restriction;
}

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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
  description
    "Augment WSON label restrictions start of
     connectivity-matrices information-source";
  case wson {
    uses layer0-types:wson-link-label;
  }
}

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/"
    + "wson:wson-topology" {
```

```

    description "Augment WSON TE label";
  }
  description
    "Augment WSON label restrictions end of
    connectivity-matrices information-source";
  case wson {
    uses layer0-types:wson-link-label;
  }
}

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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
  description
    "Augment WSON label restrictions step of
    connectivity-matrices information-source";
  case wson {
    uses layer0-types:wson-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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
  description
    "Augment WSON label hop of underlay primary path of
    connectivity-matrices information-source";
  case wson {
    uses layer0-types:wson-path-label;
  }
}

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/"
  + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
description
  "Augment label hop of underlay backup path of
  connectivity-matrices information-source";
case wson {
  uses layer0-types:wson-path-label;
}
}

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/"
  + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
description
  "Augment WSON label hop of route-exclude of
  connectivity-matrices information-source";
case wson {
  uses layer0-types:wson-path-label;
}
}

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/"
  + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
description
  "Augment WSON label hop of route-include of
  connectivity-matrices information-source";
case wson {

```

```

    uses layer0-types:wson-path-label;
  }
}

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/"
+ "wson:wson-topology" {
  description "Augment WSON TE label";
}
description
  "Augment WSON label hop of path-route of connectivity-matrices
  information-source";
case wson {
  uses layer0-types:wson-path-label;
}
}

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/"
+ "wson:wson-topology" {
  description "Augment WSON TE label";
}
description
  "Augment ingress WSON label restrictions of
  connectivity-matrix information-source";
uses layer0-types:layer0-label-restriction;
}

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/"
+ "wson:wson-topology" {
  description "Augment WSON TE label";
}
description

```

```

    "Augment ingress WSON label restrictions start of
    connectivity-matrix information-source";
  case wson {
    uses layer0-types:wson-link-label;
  }
}
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/"
+ "wson:wson-topology" {
    description "Augment WSON TE label";
  }
  description
    "Augment ingress WSON label restrictions end of
    connectivity-matrix information-source";
  case wson {
    uses layer0-types:wson-link-label;
  }
}

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" {
  when "../..../..../..../..../..../..../..../"
+ "nw:network-types/tet:te-topology/"
+ "wson:wson-topology" {
    description "Augment WSON TE label";
  }
  description
    "Augment ingress WSON label restrictions step of
    connectivity-matrix information-source";
  case wson {
    uses layer0-types:wson-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" {
  when "../..../..../..../..../..../..../..../"

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    + "nw:network-types/tet:te-topology/"
    + "wson:wson-topology" {
description "Augment WSON TE label";
}
description
  "Augment egress WSON label restrictions of connectivity-matrix
  information-source";
uses layer0-types:layer0-label-restriction;
}

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/"
  + "wson:wson-topology" {
description "Augment WSON TE label";
}
description
  "Augment egress WSON label restrictions start of
  connectivity-matrix information-source";
case wson {
  uses layer0-types:wson-link-label;
}
}

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/"
  + "wson:wson-topology" {
description "Augment WSON TE label";
}
description
  "Augment egress WSON label restrictions end of
  connectivity-matrix information-source";
case wson {
  uses layer0-types:wson-link-label;
}
}

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

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    + "tet:to/tet:label-restrictions/tet:label-restriction/"
    + "tet:label-step/tet:technology" {
when "../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
    }
description
    "Augment egress WSON label restrictions step of
    connectivity-matrix information-source";
case wson {
    uses layer0-types:wson-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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
    }
description
    "Augment WSON label hop of underlay primary path of
    connectivity-matrix information-source";
case wson {
    uses layer0-types:wson-path-label;
}
}

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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
    }
description
    "Augment WSON label hop of underlay backup path of
    connectivity-matrix information-source";
case wson {
    uses layer0-types:wson-path-label;
}
}

```

```

}

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/"
+ "wson:wson-topology" {
description "Augment WSON TE label";
}
description
  "Augment label hop of route-exclude of connectivity-matrix
  information-source";
case wson {
  uses layer0-types:wson-path-label;
}
}

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" {
when "../..../..../..../..../..../..../..../..../"
+ "nw:network-types/tet:te-topology/"
+ "wson:wson-topology" {
description "Augment WSON TE label";
}
description
  "Augment WSON label hop of route-include of
  connectivity-matrix information-source";
case wson {
  uses layer0-types:wson-path-label;
}
}

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/"

```

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    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "wson:wson-topology" {
description "Augment WSON TE label";
}
description
    "Augment WSON label hop of path-route of connectivity-matrix
    information-source";
case wson {
    uses layer0-types:wson-path-label;
}
}

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/"
    + "wson:wson-topology" {
description "Augment WSON TE label";
}
description
    "Augment WSON label restrictions of
    local-link-connectivities";
uses layer0-types:layer0-label-restriction;
}

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" {
when "../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "wson:wson-topology" {
description "Augment WSON TE label";
}
description
    "Augment WSON label restrictions start of
    local-link-connectivities";
case wson {
    uses layer0-types:wson-link-label;
}
}

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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
}
description
    "Augment WSON label restrictions end of
    local-link-connectivities";
case wson {
    uses layer0-types:wson-link-label;
}
}

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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
}
description
    "Augment WSON label restrictions step of
    local-link-connectivities";
case wson {
    uses layer0-types:wson-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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
}
description
    "Augment WSON label hop of underlay primary path of
    local-link-connectivities";

```



```

    case wson {
      uses layer0-types:wson-path-label;
    }
  }

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/"
  + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
  description
    "Augment WSON label hop of underlay backup path of
    local-link-connectivities";
  case wson {
    uses layer0-types:wson-path-label;
  }
}

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/"
  + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
  description
    "Augment WSON label hop of route-exclude of
    local-link-connectivities";
  case wson {
    uses layer0-types:wson-path-label;
  }
}

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/"
+ "wson:wson-topology" {
description "Augment WSON TE label";
}
description
    "Augment label hop of route-include of
        local-link-connectivities";
case wson {
    uses layer0-types:wson-path-label;
}
}

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/"
+ "wson:wson-topology" {
description "Augment WSON TE label";
}
description
    "Augment WSON label hop of path-route of
        local-link-connectivities";
case wson {
    uses layer0-types:wson-path-label;
}
}

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/"
+ "wson:wson-topology" {
description "Augment WSON TE label";
}
description
    "Augment WSON label restrictions of
        local-link-connectivity (LLC)";
uses layer0-types:layer0-label-restriction;
}
```

```

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/"
  + "wson:wson-topology" {
  description "Augment WSON TE label";
}
description
  "Augment WSON label restrictions start of
  local-link-connectivity (LLC)";
case wson {
  uses layer0-types:wson-link-label;
}
}

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/"
  + "wson:wson-topology" {
  description "Augment WSON TE label";
}
description
  "Augment WSON label restrictions end of
  local-link-connectivity (LLC)";
case wson {
  uses layer0-types:wson-link-label;
}
}

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/"
  + "wson:wson-topology" {
  description "Augment WSON TE label";
}

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}
description
    "Augment WSON label restrictions step of
    local-link-connectivity (LLC)";
case wson {
    uses layer0-types:wson-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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
}
description
    "Augment WSON label hop of underlay primary path of
    local-link-connectivity (LLC)";
case wson {
    uses layer0-types:wson-path-label;
}
}

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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
}
description
    "Augment WSON label hop of underlay backup path of
    local-link-connectivity (LLC)";
case wson {
    uses layer0-types:wson-path-label;
}
}

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:tunnel-termination-point/"

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    + "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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
}
description
    "Augment WSON label hop of route-exclude of
    local-link-connectivity (LLC)";
case wson {
    uses layer0-types:wson-path-label;
}
}

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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
}
description
    "Augment WSON label hop of route-include of
    local-link-connectivity (LLC)";
case wson {
    uses layer0-types:wson-path-label;
}
}

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/"
  + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
description
  "Augment WSON label hop of path-route of
  local-link-connectivity (LLC)";
case wson {
  uses layer0-types:wson-path-label;
}
}
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/"
  + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
description
  "Augment WSON label hop of underlay primary path of TE link";
case wson {
  uses layer0-types:wson-path-label;
}
}

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/"
  + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
description
  "Augment WSON label hop of underlay backup path of TE link";
case wson {
  uses layer0-types:wson-path-label;
}
}

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/"
  + "wson:wson-topology" {

```

```

    description "Augment WSON TE label";
  }
  description
    "Augment WSON label restrictions of TE link";
  uses layer0-types:layer0-label-restriction;
}

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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
  description
    "Augment WSON label restrictions start of TE link";
  case wson {
    uses layer0-types:wson-link-label;
  }
}

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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
  description
    "Augment WSON label restrictions end of TE link";
  case wson {
    uses layer0-types:wson-link-label;
  }
}

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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
  }
  description
    "Augment WSON label restrictions step of TE link";
  case wson {
    uses layer0-types:wson-label-step;
  }
}

```

```

    }
  }

  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/"
      + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description
      "Augment WSON label restrictions of TE link
      information-source";
    uses layer0-types:layer0-label-restriction;
  }

  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/"
      + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description
      "Augment WSON label restrictions start of TE link
      information-source";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  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/"
      + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description
      "Augment WSON label restrictions end of TE link
      information-source";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  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/"
    + "wson:wson-topology" {
    description "Augment WSON TE label";
}
description
    "Augment WSON label restrictions step of TE link
    information-source";
case wson {
    uses layer0-types:wson-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 WSON label hop of underlay primary path of TE link
    template";
case wson {
    uses layer0-types:wson-path-label;
}
}

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 WSON label hop of underlay backup path of TE link
    template";
case wson {
    uses layer0-types:wson-path-label;
}
}

augment "/nw:networks/tet:te/tet:templates/"
    + "tet:link-template/tet:te-link-attributes/"
    + "tet:label-restrictions/tet:label-restriction" {
description
    "Augment WSON label restrictions of TE link template";
    uses layer0-types:layer0-label-restriction;
}

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 WSON label restrictions start of TE link template";
    case wson {
        uses layer0-types:wson-link-label;
    }
}

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 WSON label restrictions end of TE link template";
    case wson {
        uses layer0-types:wson-link-label;
    }
}

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 WSON label restrictions step of TE link template";
    case wson {
        uses layer0-types:wson-label-step;
    }
}
}

<CODE ENDS>

```

#### 4. IETF-Layer0-Types YANG Model

<CODE BEGINS> file ietf-layer0-types@2019-02-07.yang

```

module ietf-layer0-types {
    namespace "urn:ietf:params:xml:ns:yang:ietf-layer0-types";
    prefix "layer0-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@huawei.com>

Editor: Young Lee  
<mailto:leeyoung@huawei.com>

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

description

"This module defines Optical Layer 0 types. This module provides groupings that can be applicable to Layer 0 Fixed Optical Networks (e.g., CWDM (Coarse Wavelength Division Multiplexing) and DWDM (Dense Wavelength Division Multiplexing)) and Flexi-grid Optical Networks.

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```
revision "2018-02-07" {
  description
    "Initial Version";
  reference
    "RFC XXXX: A YANG Data Model for WSON (Wavelength Switched
    Optical Networks)";
}

typedef operational-mode {
  type string;
  description
    "Vendor-specific mode that guarantees interoperability.";
}

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 (11/2009) Section 5.3";
}

typedef vendor-identifier {
    type string;
    description
        "vendor identifier that uses vendor-specific mode";
    reference "TBD";
}

typedef frequency-thz {
    type decimal64 {
        fraction-digits 5;
    }
    units THz;
    description
        "The DWDM frequency in THz, e.g., 193.12500";
    reference
        "RFC6205";
}

typedef frequency-ghz {
    type decimal64 {
        fraction-digits 5;
    }
    units GHz;
    description
        "The DWDM frequency in GHz, e.g., 193125.00";
    reference
        "RFC6205";
}

identity layer0-node-type {
    description
        "layer0 node type.";
    reference
        "RFC6163";
}

identity flex-grid-node {
    base layer0-node-type;
    description
```

```
    "Flex Grid node";
}

identity wson-node-foadm {
    base layer0-node-type;
    description
        "Fixed OADM (Optical Add-Drop Multiplexer) node";
}

identity wson-node-roadm {
    base layer0-node-type;
    description
        "ROADM (Reconfigurable Optical Add-Drop Multiplexer)
        or OXC (Optical Cross Connect) node";
}

identity wson-node-ila {
    base layer0-node-type;
    description
        "ILA (In-Line Amplifier) node";
}

identity wavelength-assignment {
    description
        "Wavelength selection base";
}

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 layer0-grid-type {
        description
            "Layer0 grid type.";
    }

    identity flex-grid-dwdm {
        base layer0-grid-type;
        description
            "Flex grid";
    }

    identity wson-grid-dwdm {
        base layer0-grid-type;
        description
            "DWDM grid";
    }

    identity wson-grid-cwdm {
        base layer0-grid-type;
        description
            "CWDM grid";
    }

    identity term-type {
        description
            "Termination type.";
    }

    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 term-section {
  base term-type;
  description
    "Section Layer Termination";
}

identity layer0-bandwidth-type {
  description
    "Bandwidth type carried by a single wavelength channel";
}

identity bw-otul {
  base layer0-bandwidth-type;
  description
    "OTU1 (2.66G)";
}

identity bw-otule {
  base layer0-bandwidth-type;
  description
    "OTU1e (11.04G)";
}

identity bw-otulf {
  base layer0-bandwidth-type;
  description
    "OTU1f (11.27G)";
}
```

```
}  
  
identity bw-otu2 {  
    base layer0-bandwidth-type;  
    description  
        "OTU2 (10.70G)";  
}  
  
identity bw-otu2e {  
    base layer0-bandwidth-type;  
    description  
        "OTU2e (11.09G)";  
}  
  
identity bw-otu2f {  
    base layer0-bandwidth-type;  
    description  
        "OTU2f (11.31G)";  
}  
  
identity bw-otu3 {  
    base layer0-bandwidth-type;  
    description  
        "OTU3 (43.01G)";  
}  
  
identity bw-otu3e1 {  
    base layer0-bandwidth-type;  
    description  
        "OTU3e1 (44.57G)";  
}  
  
identity bw-otu3e2 {  
    base layer0-bandwidth-type;  
    description  
        "OTU3e2 (44.58G)";  
}  
  
identity bw-otu4 {  
    base layer0-bandwidth-type;  
    description  
        "OTU4 (111.80G)";  
}  
  
identity bw-otucn {
```



```
    base layer0-bandwidth-type;
    description
        "OTUCn (beyond 100G)";
}

identity dwdm-ch-spc-type {
    description
        "DWDM channel spacing type";
}

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

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

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

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

identity flex-ch-spc-type {
    description
        "Flex-grid channel spacing type";
}

identity flex-ch-spc-6p25ghz {
    base flex-ch-spc-type;
    description
        "6.25GHz channel spacing";
}
```

```
identity flex-slot-width-granularity {
  description
    "Flex-grid slot width granularity";
}

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

identity cwdm-ch-spc-type {
  description
    "CWDM channel spacing type";
}

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

identity fec-type {
  description
    "FEC (Forward Error Correction) type";
}

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";
}

/* Groupings. */
grouping wson-path-bandwidth {
```

```
    description "WSON (Wavelength Switched Optical Network)
                  path bandwidth attributes";
    leaf bandwidth-type {
      type identityref {
        base layer0-bandwidth-type;
      }
      description "WSON bandwidth type";
    }
  }

  grouping wson-link-bandwidth {
    description "WSON link bandwidth attributes";
    leaf-list supported-bandwidth-list {
      type identityref {
        base layer0-bandwidth-type;
      }
      description "WSON bandwidth type";
    }
  }

  grouping wson-link-label {
    description
      "Generic label for WSON links";
    choice grid-type {
      description
        "Label for DWDM or CWDM grid";
      case dwdm {
        leaf dwdm-n {
          type int16;
          description
            "N is used to determine the Nominal Central Frequency.
            The set of nominal central frequencies can be
            built using the following expression
             $f = 193.1 \text{ THz} + N \times 0.00625 \text{ THz}$ ,
            where 193.1 THz is ITU-T 'anchor frequency'
            for transmission over the C band, N is a positive or
            negative integer including 0.";
          reference
            "RFC6205";
        }
      }
      case cwdm {
        leaf cwdm-n {
          type int16;
          description
```

```

        "N is a two's-complement integer to take either a
        positive, negative, or zero value. This value is
        used to compute the channel wavelength as such
        in G.694.2:
        Wavelength (nm) = 1471 nm + N * 20 nm";
        reference
        "RFC6205";
    }
}
}

grouping wson-path-label {
    description
    "Generic label for WSON paths";
    choice grid-type {
        description
        "Label for DWDM or CWDM grid";
        case dwdm {
            choice single-or-super-channel {
                description "single or super channel";
                case single {
                    leaf dwdm-n {
                        type int16;
                        description
                        "N is used to determine the Nominal Central Frequency.
                        The set of nominal central frequencies can be
                        built using the following expression
                        f = 193.1 THz + N x 0.00625 THz,
                        where 193.1 THz is ITU-T 'anchor frequency'
                        for transmission over the C band, N is a positive or
                        negative integer including 0.";
                    }
                }
                case super {
                    leaf-list subcarrier-dwdm-n {
                        type int16;
                        description
                        "List of subcarrier channels for super channel.
                        Each of the channels is represented by an
                        integer, n, a two's-complement integer to take
                        either a positive, negative, or zero value.
                        This value is used to compute the frequency as
                        such in G.694.1:
                        Frequency (THz) =

```

```

        193.1 THz + n * channel spacing (THz)";
    }
}

}

case cwdm {
  leaf cwdm-n {
    type int16;
    description
      "Represented by an integer, n, a two's-complement
       integer to take either a positive, negative, or
       zero value. This value is used to compute the
       channel wavelength as such in G.694.2:
       Wavelength (nm) = 1471 nm + n * 20 nm";
    reference
      "RFC6205";
  }
}

}

grouping layer0-label-restriction {
  description
    "layer0 label restriction.";

  leaf grid-type {
    type identityref {
      base layer0-grid-type;
    }
    description "Grid type";
  }
  leaf priority {
    type uint8;
    description "priority";
  }
}

grouping wson-label-step {
  description "Label step information for WSON";
  choice layer0-grid-type {
    description
      "Grid type: DWDM, CWDM, etc.";
    case dwdm {
      leaf wson-dwdm {

```

```
        type identityref {
            base dwdm-ch-spc-type;
        }
        description
            "Label-step is the channel-spacing (GHz), e.g.,
            100, 50, 25, or 12.5 GHz for DWDM";
        reference
            "RFC6205";
    }
}
case cwdm {
    leaf wson-cwdm {
        type identityref {
            base cwdm-ch-spc-type;
        }
        description
            "label-step is the channel-spacing (nm), i.e., 20 nm
            for CWDM, which is the only value defined for CWDM";
        reference
            "RFC6205";
    }
}
}
}

grouping flex-grid-node-attributes {
    description "Flex-grid node attributes";

    container flex-grid-node {
        description "Flex-grid node attributes";
        leaf node-type {
            type identityref {
                base layer0-node-type;
            }
            description "Flex-grid node type";
        }
    }
}

grouping flex-grid-path-bandwidth {
    description "Flex-grid path bandwidth attributes";
    leaf bandwidth-type {
        type identityref {
            base layer0-bandwidth-type;
        }
    }
}
```

```
        description "Flex-grid bandwidth type";
    }
}

grouping flex-grid-link-bandwidth {
    description "flex-grid link bandwidth attributes";
    leaf-list supported-bandwidth-list {
        type identityref {
            base layer0-bandwidth-type;
        }
        description "Flex-grid bandwidth type";
    }
}

grouping flex-grid-link-label {
    description "Flex-grid link label.";
    leaf flex-n {
        type uint16;
        description
            "N is used to determine the Nominal Central Frequency.
            The set of nominal central frequencies can be
            built using the following expression
             $f = 193.1 \text{ THz} + N \times 0.00625 \text{ THz}$ ,
            where 193.1 THz is ITU-T 'anchor frequency'
            for transmission over the C band, N is a positive or
            negative integer including 0.";
        reference
            "RFC7698";
    }
}

grouping flex-grid-channel {
    description "Flex-grid channel grouping.";

    uses flex-grid-link-label;

    leaf flex-m {
        type uint16 {
            range "1..max";
        }
        description
            "M is used to determine the slot width. A slot width is
            constrained to be M x SWG (that is, M x 12.5 GHz),
            where M is an integer greater than or equal to 1.";
        reference
    }
}
```

```
        "RFC7698";
    }
}
grouping flex-grid-path-label {
    description "Flex-grid path label.";
    choice single-or-super-channel {
        description "single of super channel";
        case single {
            uses flex-grid-channel;
        }
        case super {
            list subcarrier-flex-n {
                key flex-n;
                uses flex-grid-channel;
                description
                    "List of subcarrier channels for flex-grid
                     super channel.";
            }
        }
    }
}

grouping flex-grid-label-restriction {
    description
        "Flex Grid-specific label restriction";
    uses layer0-label-restriction;

    container flex-grid {
        description "flex-grid definition";
        leaf nominal-central-frequency-granularity {
            type identityref {
                base flex-ch-spc-type;
            }
            default flex-ch-spc-6p25ghz;
            description
                "It is the spacing between allowed nominal central
                 frequencies. Default is 6.25 GHz";
            reference
                "RFC7698";
        }

        leaf slot-width-granularity {
            type identityref {
                base flex-slot-width-granularity;
            }
        }
    }
}
```



```
    default flex-swg-12p5ghz;
    description
        "Minimum space between slot widths. Default is
        12.5 GHz";
    reference
        "RFC7698";
}

leaf min-slot-width-factor {
    type uint16 {
        range "1..max";
    }
    default 1;
    description
        "Minimum slot width is calculated by:
        Minimum slot width (GHz) =
        min-slot-width-factor * slot-width-granularity";
    reference
        "RFC8363";
}

leaf max-slot-width-factor {
    type uint16 {
        range "1..max";
    }
    description
        "Maximum slot width is calculated by:
        Maximum slot width (GHz) =
        max-slot-width-factor * slot-width-granularity";
    reference
        "RFC8363";
}

}

}

grouping flex-grid-label-step {
    description "Label step information for flex grid";
    leaf flex {
        type identityref {
            base flex-ch-spc-type;
        }
    }
    default flex-ch-spc-6p25ghz;
    description
        "Label-step is the nominal central frequency
```

```
        granularity (GHz), e.g., 6.25 GHz";
    reference
        "RFC7698";
    }
}
}

<CODE ENDS>
```

## 5. Security Considerations

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

The NETCONF access control model [RFC6536] 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 over Secure Shell (SSH) [RFC6242] describes a method for invoking and running NETCONF within a Secure Shell (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
```

## 6. IANA Considerations

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

---

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

---

URI: urn:ietf:params:xml:ns:yang:ietf-layer0-types  
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] & [RFC6020]:

---

name:	ietf-wson-topology
namespace:	urn:ietf:params:xml:ns:yang:ietf-wson-topology
reference:	RFC XXXX (TDB)

---

name:	ietf-layer0-types
namespace:	urn:ietf:params:xml:ns:yang:ietf-layer0-types
reference:	RFC XXXX (TDB)

---

## 7. Acknowledgments

This document was prepared using 2-Word-v2.0.template.dot.

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YANG Data Model for FlexE Interface Management  
draft-jiang-ccamp-flex-e-yang-00

Abstract

This document defines a YANG data model for the configuration of FlexE 2.0 interface, and its FlexE clients. The YANG module in this document conforms to the Network Management Datastore Architecture (NMDA).

Status of this Memo

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## 1. Introduction

The Flex Ethernet (FlexE) 2.0 Implementation Agreement [FLEXE] defined by the OIF provides the support of a variety of Ethernet MAC rates that may or may not correspond to any existing Ethernet PHY rate. This includes MAC rates that are both greater than (through bonding) and less than (through sub-rate and channelization) the Ethernet PHY rates used to carry FlexE. FlexE 2.0 further supports the bonding of 200GBASE-R PHYs or the bonding of 400GBASE-R PHYs.

In the FlexE, multiple Ethernet PHYs (each PHY can further consist of one or more FlexE Instances) are bonded into a FlexE Group, and the total capacity of the FlexE Group is represented as a collection of slots (e.g., each slot has a granularity of 5Gbps or 25Gbps). Based on their bandwidth needs, FlexE Clients are each mapped into one or more slots. The FlexE mechanism operates using a calendar consisting of these slots.

This calendar is partitioned into sub-calendars for each FlexE instance. For example, the calendar for a FlexE Group composed of  $n$  100G PHYs is partitioned into  $20n$  slots (each representing 5Gbps of bandwidth when the slot granularity is 5Gbps).

This document defines a YANG data model for the configuration of a Flex Ethernet interface (i.e., FlexE Group). The data model is augmented based on the generic interfaces data model as defined in [RFC8343], the FlexE attributes are based on the FlexE 2.0

Implementation Agreement as specified in [FLEXE]. With the help of this YANG module, the FlexE Groups can be managed just as network interfaces on a network device (e.g., a router or bridge).

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

### 1.1. Conventions used in this document

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

### 1.2. Terminology

Most terminologies used in this document are extracted from [FLEXE].

FlexE: Flex Ethernet

FlexE Client: An Ethernet flow based on a MAC data rate that may or may not correspond to any Ethernet PHY rate.

FlexE Group: A FlexE Group is composed of from 1 to n Ethernet PHYs.

FlexE Instance: A FlexE Instance is a unit of information consisting of 100G of capacity able to carry FlexE Client data, together with its associated overhead.

Ethernet PHY: an entity representing Ethernet Physical Coding Sublayer (PCS), Physical Media Attachment (PMA), and Physical Media Dependent (PMD) layers. Each PHY is consisted of one or more FlexE Instance (e.g., a 400GBASE-R PHY has four FlexE Instances)

FlexE Calendar: The total capacity of a FlexE Group is represented as a collection of slots. The calendar for a FlexE Group composed of n 100G PHYs is represented as an array of 20n slots (each representing 5Gbps of bandwidth). This calendar is partitioned into sub-calendars, e.g., a sub-calendar with 20 slots per 100G PHY.

## 2. YANG model hierarchy for FlexE interface

This section describes the hierarchy of the YANG module for FlexE interface management.

Configuration and status of FlexE interface information include:

- flexe-group specifies a FlexE group consisting of multiple PHYs.
- flexe-client-list specifies a list of FlexE client, each client is mapped to some slots in this FlexE group. flexe-client-status indicates whether there is any fault in any mapped slot for this client.

The readers are assumed to be familiar with FlexE 2.0, as all FlexE terminologies are described in details in [FLEXE].

In order to simplify the YANG module of the FlexE interface and to follow the YANG style of terminology, neither sub-calendar nor calendar in FlexE are modelled explicitly. However, a sub-calendar is represented by a calendar-slot-list per instance, and calendar is actually a conglomerate of all the slots in calendar slot lists for all FlexE instances in all FlexE PHYs of this FlexE Group.

A simplified YANG tree diagram [RFC8340] representing the data model is typically used by YANG modules. This document uses the same tree diagram syntax as described in [RFC8340].

```

module: ietf-flexe
  augment /if:interfaces/if:interface:
    +--rw flexe-group
      +--rw group-number?          uint32
      +--rw slot-granularity?      slot-granularity-enumeration
      +--rw flexe-phy-type?        flexe-phy-enumeration
      +--rw flexe-calendar-inuse?  calendar-enumeration
      +--rw flexe-phy-list* [phy-number]
        +--rw phy-number          uint8
        +--rw flexe-inst-list* [instance-number]
          +--rw instance-number    uint8
          +--rw calendar-slot-list* [slot-id]
            +--rw slot-id          uint8
            +--rw flexe-slot-status? slot-status-enumeration
      +--rw flexe-client-list* [client-id]
        +--rw client-id            uint16
        +--rw group-number?        uint32

```

```

+--rw mapped-slot-list* [mapped-slot-id]
|   +--rw mapped-slot-id      uint8
|   +--rw mapped-phy-number?   uint8
|   +--rw mapped-inst-number?  uint8
+--ro flexe-client-status?     uint8

```

### 3. YANG Module for FlexE interface

This module imports typedef "interface-ref" from [RFC8343].

```
<CODE BEGINS> file "ietf-flexex@2019-02-25.yang"
module ietf-flexex {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-flexex";
  prefix "flexex";

  import iana-if-type {
    prefix ianaift;
  }
  import ietf-interfaces {
    prefix if;
    reference
      "RFC8343: A YANG Data Model for Interface Management";
  }

  organization "IETF CCAMP Working Group";
  contact
    "WG Web:  http://tools.ietf.org/wg/ccamp/
    WG List:  <mailto:ccamp@ietf.org>
    Author:   Yuanlong Jiang
              <mailto:jiangyuanlong@huawei.com>
    Author:   Xiang He
              <mailto:hexiang@huawei.com>
    Author:   Weiqiang Cheng
              <mailto:chengweiqiang@chinamobile.com>";

  description
    "This YANG module defines a data model for the configuration
    of FlexE interface.";

  revision "2019-02-25" {
    description "Initial version";
    reference
      "draft-jiang-ccamp-flexex-yang-00: YANG Data Model for FlexE
      Interface Management ";
  }

  typedef slot-granularity-enumeration {
    type enumeration {
      enum slot-5g {
        value 1;
        description
          "5Gbps per slot.";
      }
    }
  }
```

```
    enum slot-25g {
        value 2;
        description
            "25Gbps per slot.";
    }
    enum slot-others {
        value 254;
        description
            "Other type of granularities per slot.";
    }
}
description
    "The bandwidth granularity of a slot. Options for this
    enumeration are specified by the OIF standard, currently only
    5G and 25G are defined.";
reference
    "OIF Flex 2.0: Section 6.7";
}

typedef slot-status-enumeration {
    type enumeration {
        enum unavailable {
            value 1;
            description
                "slot is unavailable for FlexE client.";
        }
        enum unused {
            value 2;
            description
                "slot is unused.";
        }
        enum used {
            value 3;
            description
                "slot is used.";
        }
    }
}
description
    "The status of a slot. Options for this enumeration are
    specified by the OIF standard, 'used' is implicit.";
reference
    "OIF Flex 2.0: Section 7.3.4 and Section 7.6";
}

typedef flexe-phy-enumeration {
    type enumeration {
        enum 'PHY-100GBASE-R' {
```



```
        value 1;
        description
            "100GBASE-R PHY, as defined in FlexE 1.0.";
    }
    enum 'PHY-200GBASE-R' {
        value 2;
        description
            "200GBASE-R PHY, as defined in FlexE 2.0.";
    }
    enum 'PHY-400GBASE-R' {
        value 3;
        description
            "400GBASE-R PHY, as defined in FlexE 2.0.";
    }
}

description
    "The current type of PHYs bonded in a FlexE Group. Values for
    this enumeration are specified by the OIF standard.";
reference
    "OIF Flex 2.0: Section 5.2.1.5";
}

typedef calendar-enumeration {
    type enumeration {
        enum "CALENDAR-A" {
            description "Using Calendar A";
        }
        enum "CALENDAR-B" {
            description "Using Calendar B";
        }
    }
}
description
    "FlexE Calendar in use, values for this enumeration
    are specified by the OIF standard.";
reference
    "OIF Flex 2.0: Section 6.7";
}

augment "/if:interfaces/if:interface" {

    when "if:type = 'ianaift:flexethernet'" {
        description "Applies to Flex Ethernet interfaces";
    }

    description
```

"Augment interface model with OIF Flex Ethernet interface specific configuration nodes. Each FlexE interface represents a FlexE Group configured in a device.";

```
container flexe-group {
  description
    "The struct containing all FlexE related configuration
    (see OIF FlexE 2.0 Section 6.1).
    Note that max number of FlexE groups in a network is 63.";

  leaf group-number {
    type uint32 {
      range "1..1048574";
    }
    description
      "FlexE Group Number as defined in Section 7.3.6 of FlexE
      2.0.";
  }

  leaf slot-granularity {
    type slot-granularity-enum;
    default "slot-5g";
    description
      "The granularity of a slot in a FlexE group.";
  }

  leaf flexe-phy-type {
    type flexe-phy-enum;
    default "PHY-100GBASE-R";
    description
      "The type of PHYs bonded in a FlexE Group.";
  }

  leaf flexe-calendar-inuse {
    type calendar-enum;
    default "CALENDAR-A";
    description
      "The FlexE Calendar in use for a FlexE Group.";
  }

  list flexe-phy-list {
    key "phy-number";
    description
      "List of PHYs bonded in a FlexE group per FlexE 2.0.";
  }
}
```

```
leaf phy-number {
  type uint8 {
    range "1 .. 254";
  }
  description
    "PHY number of a FlexE PHY.
    If PHY type is 100GBASE-R, phy-number is [1,254].
    If PHY type is 200GBASE-R, phy-number is [1,126].
    If PHY type is 400GBASE-R, phy-number is [1, 62].";
}

list flexe-inst-list {
  key "instance-number";
  description
    "List of instances in a FlexE PHY as defined in OIF.
    Max elements of flexe-inst-list in a FlexE PHY:
    If PHY type is 100GBASE-R, max-elements is 1.
    If PHY type is 200GBASE-R, max-elements is 2.
    If PHY type is 400GBASE-R, max-elements is 4.";

  leaf instance-number {
    type uint8;
    description
      "Instance number of an instance. Its range relies on
      phy-number of the PHY wherein this instance belongs:
      If PHY type is 100GBASE-R:
        instance-number=phy-number
      If PHY type is 200GBASE-R:
        instance-number=2*phy-number+[0, 1]
      If PHY type is 400GBASE-R:
        instance-number=4*phy-number+[0, 3] ";
  }

  list calendar-slot-list {
    key "slot-id";
    leaf slot-id {
      type uint8;
      description
        "slot id of a slot in an instance.";
    }
    description
      "List of slots in a FlexE instance, i.e., sub-
      calendar per instance in FlexE 2.0. Max elements of
      calendar-slot-list for a FlexE instance is:
      If slot-granularity=slot-5g, max-elements is 20.
      If slot-granularity=slot-25g, max-elements is 4.";
  }
}
```

```
        leaf flexe-slot-status {
            type slot-status-enumeration;
            default unused;
            description
                "Slot status of a slot in an instance.";
        }
    } //calendar-slot-list
} //flexe-inst-list
} //flexe-phy-list

list flexe-client-list {

    key "client-id";
    description
        "List of FlexE clients in a FlexE Group.";
    leaf client-id {
        type uint16;
        description
            "FlexE client ID as defined in FlexE IA.";
    }
    leaf group-number {
        type uint32 {
            range "1..1048574";
        }
        description
            "FlexE Group Number of the FlexE group for this client.";
    }

    list mapped-slot-list {
        key "mapped-slot-id";
        description
            "List of mapped-slots for a FlexE client.";
        leaf mapped-slot-id {
            type uint8;
            description
                "Slot id of a slot in an instance for a client.";
        }
        leaf mapped-phy-number {
            type uint8;
            description
                "PHY number of a slot for a client.";
        }
        leaf mapped-inst-number {
            type uint8;
            description
                "Instance number of a slot for a client.";
        }
    }
}
```

```
    } // mapped-slot-list

    leaf flexe-client-status {
        type uint8;
        config false;
        description
            "Fault status for a client indicated in its mapped
            slots. If any slot is in fault, the client status
            is indicated in fault. Status includes:
            OK, Local Fault, Remote Fault and etc.";
    }

    } //flexe-client-list
} //flexe-group
} //augment
}

<CODE ENDS>
```

#### 4. Security Considerations

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

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

There are a number of data nodes defined in this YANG module are writable, and the involved subtrees that are sensitive include:

/flexe/flexe-group-list specifies a list of FlexE Group, and each group consists of multiple PHYs.

/flexe/flexe-client-list specifies a list of FlexE Client, and each client is mapped to some slots in a FlexE Group.

Write operations (e.g., edit-config) to these data nodes without proper protection can have a negative effect on network operations. Specifically, an inappropriate configuration of them may cause an

interrupt of a client flow or even break down of a whole FlexE interface.

## 5. IANA Considerations

It is proposed that IANA register the following URI in the "IETF XML registry" [RFC3688]:

URI: urn:ietf:params:xml:ns:yang:ietf-flex

Registrant Contact: The IESG

XML: N/A; the requested URI is an XML namespace

It is proposed that IANA register the following YANG module in the "YANG Module Names" registry:

Name: ietf-flex

Namespace: urn:ietf:params:xml:ns:yang:ietf-flex

Prefix: flex

Reference: this document

It is proposed that IANA register a new IANAifType TBD for the interface type of Flex Ethernet in the "IANA Interface Type YANG Module" [RFC7224].

## 6. References

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A Yang Data Model for Optical Impairment-aware Topology

draft-lee-ccamp-optical-impairment-topology-yang-01

## 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 Assigment (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]. Similarly, this model can also be exported by the MDSC to a Customer Network Controller (CNC), which can run an offline planning process to map latter the services in the network.

This document augments the generic TE topology draft [TE-TOPO] where possible.

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

### 1.1. Terminology

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

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

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

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

- o configuration data
- o state data

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

### 1.2. Tree diagram

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

### 1.3. Prefixes in Data Node Names

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

Prefix	YANG module	Reference
optical-imp-topo	ietf-optical-impairment-topology	[RFC XXXX]
layer0-types	ietf-layer0-types	[WSON-topo]
nw	ietf-network	[RFC8345]
nt	ietf-network-topology	[RFC8345]
tet	ietf-te-topology	[TE-TOPO]

Table 1: Prefixes and corresponding YANG modules

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.

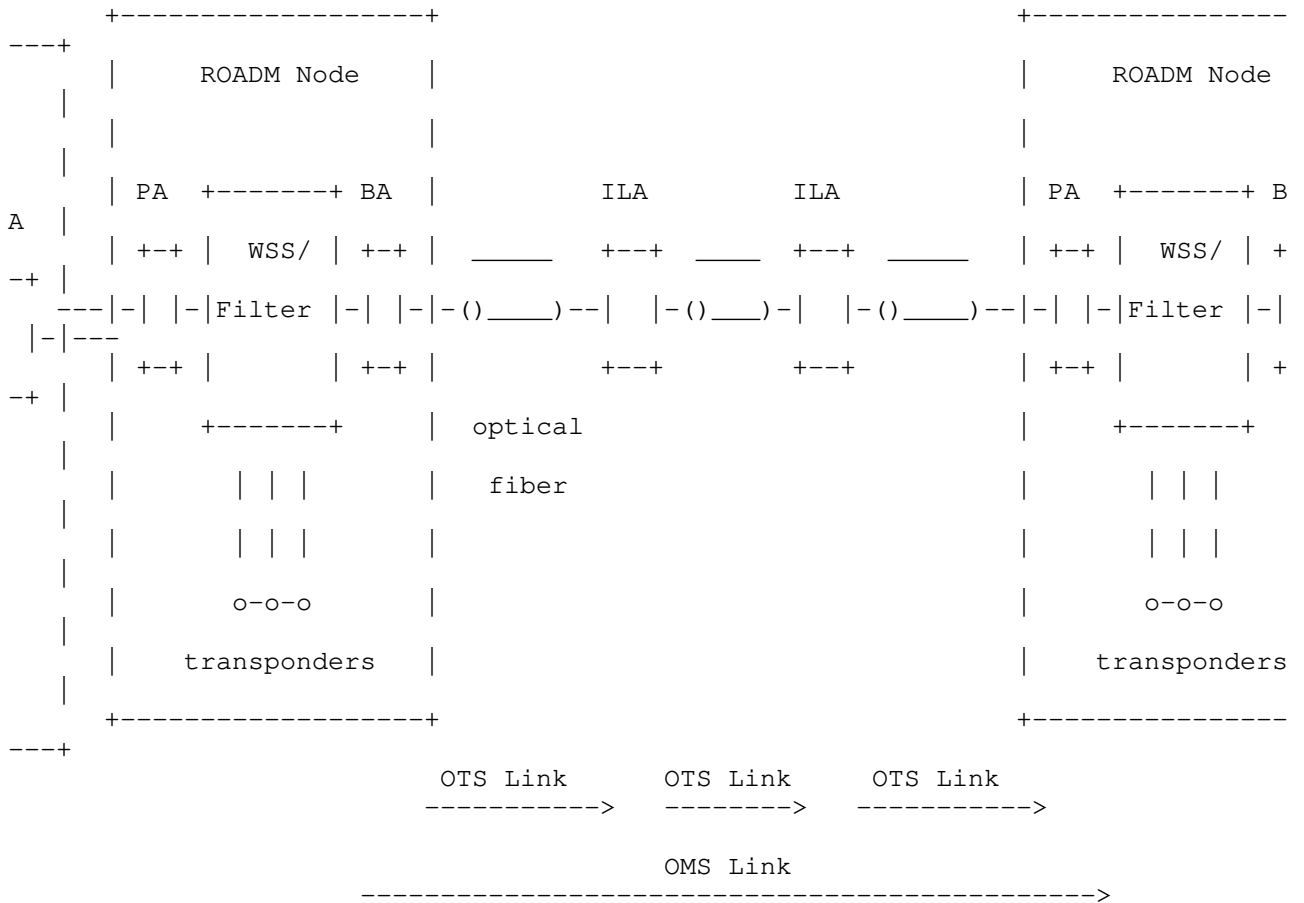
Figure 1. Control Plane Architecture

The models developed in this document is an abstracted Yang model that may be used in the interfaces colored in yellow in Figure 1. It is not intended to support detailed device configuration model. Device configuration model is supported by the models presented in [draft-ietf-ccamp-dwdm-if-parameter-yang].

## 2.2. Transport Data Plane

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

Figure 2 shows the reference architecture.



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

Figure 2. Reference Architecture for Optical Transport Network

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

## 2.3. OMS Media Links

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

OTS Media Link represents a media link:





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

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

#### 2.3.1. Optical Tributary Signal Group (OTSiG)

The Media Channel and Network Media Channel are well modelled by the RFC7698, RFC7699 and RFC7792 reflecting the ITU-T Recommendations G.694.1 and G.698.2.

Some work is in progress in ITU-T SG15/Q12 to define Network Media Channel (group) that is capable of accommodating the optical tributary signals (OTSi) belonging to optical tributary signal group (OTSiG). ( see new ITU-T Draft Recommendation G.807)).

Currently, no models exist (in the IETF nor ITU-T SG15) that define how the optical tributary signals are described inside the Network Media Channel Group in terms of OTSi identifier, OTSi carrier frequency and OTSi signal width.

There are several options how the mentioned parameters can be described. One option is to use the description defined in draft-ggalimbe-ccamp-flexigrid-carrier-label.

A second option is to describe the OTSi carrier frequency relative to the anchor frequency 193.1THz based on a well-defined granularity (e.g. OTSi carrier frequency = 193100 (GHz) + K \* granularity (GHz) where K is a signed integer value).

A third option is to explicitly describe the OTSi carrier frequency and the OTSi signal width in GHz with a certain accuracy.

It is proposed to use the third option which is independent of the n, m values already define in ITU-T Recommendation G.694.1.

The OTSi carrier frequency is described in GHz with 3 fractional digits (decimal 64 fraction digits 3).

The OTSi signal width is described in GHz with 3 fractional digits (decimal 64 fraction digits 3) and includes the signal roll off as well as some guard band.

The accuracy of 0.001 GHz does not impose a requirement on the optical transceiver components (optical transmitter) in terms of carrier frequency tuneability precision. Today's components typically provide a tunability precision in the range of 1..1.5GHz (carrier frequency offset compared to the configured nominal carrier frequency). Future components may provide a better precision as technology evolves.

If needed, a controller may retrieve the transceiver properties in terms of carrier frequency tuneability precision in order to be capable of properly configuring the underlying transceiver.

[Note from the Editor]:

As this description is arbitrarily proposed by the authors to cover a lack of information in IETF and ITU-T, a liaison request to ITU-T is needed.

The authors are willing to contribute to Liaison editing and to consider any feedback and proposal from ITU-T.

## 2.4. Amplifiers

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

One modeling consideration of the ROADM internal is to model power parameter through the ROADM, factoring the output power from the Pre-Amplifier minus the ROADM power loss would give the input power to the Booster Amplifier. In other words, Power\_in (@ ROADM Booster)

= Power\_out (@ ROADM Pre-Amplifier) - Power\_loss (@ ROADM WSS/Filter).

#### 2.4.1. In-Line Amplifier

(Need to explain details including VOA)

### 2.5. Transponders

A Transponder is the element that sends and receives the optical signal from a fiber. A transponder is typically characterized by its data rate and the maximum distance the signal can travel. Channel frequency, per channel input power, FEC and Modulation are also associated with a transponder. From a path computation point of view, the selection of the compatible source and destination transponders is an important factor for optical signal to traverse through the fiber. There are three main approaches to determine optical signal compatibility. Application Code based on G.682.2 is one approach that only checks the code at both ends of the interface. Another approach is organization codes that are specific to an organization or a vendor. The third approach is specify all the relevant parameters explicitly, e.g., FEC type, Modulation type, etc.

#### 2.6. WSS/Filter

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

#### 2.7. Optical Fiber

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

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

## 3. YANG Model (Tree Structure)

```

module: ietf-optical-impairment-topology
  augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
    +--rw optical-impairment-topology!
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes:
    +--ro OMS-attributes
      +--ro generalized-snr? decimal64
      +--ro equalization-mode identityref
      +--ro (power-param)?
        +--:(channel-power)
          | +--ro nominal-channel-power? decimal64
          +--:(power-spectral-density)
            +--ro nominal-power-spectral-density? decimal64
      +--ro network-media-channel-group* [i]
        +--ro i int16
        +--ro current-channels* [flex-n]
          | +--ro flex-n uint16
          | +--ro flex-m? uint16
          +--ro OTSiG-container* [carrier-id]
            +--ro carrier-id int16
            +--ro OTSi-carrier-frequency? decimal64
            +--ro OTSi-signal-width? decimal64
            +--ro channel-delta-power? decimal64
      +--ro OMS-elements* [elt-index]
        +--ro elt-index uint16
        +--ro uid? string
        +--ro type identityref
        +--ro element
          +--ro (element)?
            +--:(amplifier)
              +--ro amplifier
                +--ro type_variety string
                +--ro operational
                  +--ro actual-gain decimal64
                  +--ro tilt-target decimal64
                  +--ro out-voa decimal64
                  +--ro in-voa decimal64
                  +--ro (power-param)?
                    +--:(channel-power)
                      | +--ro nominal-channel-power? decimal6
                      |
                      +--:(power-spectral-density)
                        +--ro nominal-power-spectral-density? decimal6
                +--:(fiber)
                  +--ro fiber

```

```

        |         +--ro type_variety      string
        |         +--ro length            decimal64
        |         +--ro loss_coef         decimal64
        |         +--ro total_loss        decimal64
        |         +--ro pmd?              decimal64
        |         +--ro conn_in?          decimal64
        |         +--ro conn_out?         decimal64
        +---:(concentratedloss)
            +--ro concentratedloss
            +--ro loss?      decimal64
augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-point
:
    +--ro transponders-list* [transponder-id]
    +--ro transponder-id      uint32
    +--ro (mode)?
    |   +---:(G.692.2)
    |   |   +--ro G.692.2?      layer0-types:standard-mode
    |   +---:(organizational_mode)
    |   |   +--ro operational-mode?      layer0-types:operational-mode
    |   |   +--ro organization-identifier? layer0-types:vendor-identifier
    |   +---:(explicit_mode)
    |   |   +--ro available-modulation*    identityref
    |   |   +--ro modulation-type?        identityref
    |   |   +--ro available-baud-rates*    uint32
    |   |   +--ro configured-baud-rate?    uint32
    |   |   +--ro available-FEC*           identityref
    |   |   +--ro FEC-type?                identityref
    |   |   +--ro FEC-code-rate?           decimal64
    |   |   +--ro FEC-threshold?           decimal64
    |   +--ro power?                      int32
    |   +--ro power-min?                  int32
    |   +--ro power-max?                  int32
    +---:(augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-point
:
    +--ro transponder-list* [carrier-id]
    +--ro carrier-id      uint32

```

#### 4. Optical Impairment Topology YANG Model

<CODE BEGINS> file ietf-optical-impairment-topology@2018-02-27.yang

```

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 "layer0-types";
}

organization
  "IETF CCAMP Working Group";

contact
  "Editor:   Young Lee   <leeyoung@huawei.com>
   Editor:   Haomian Zheng <zhenghaomian@huawei.com>
   Editor:   Nicola Sambo <nicosambo@gmail.com>
   Editor:   Victor Lopez <victor.lopezalvarez@telefonica.com>
   Editor:   Gabriele Galimberti <ggalimbe@cisco.com>
   Editor:   Auge Jean-Luc <jeanluc.auge@orange.com>
   Editor:   Le Rouzic Esther <esther.lerouzic@orange.com>
   Editor:   Julien Meuric <julien.meuric@orange.com>
   Editor:   Italo Busi <Italo.Busi@huawei.com>";

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

   Copyright (c) 2019 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).";

revision 2019-02-27 {
  description
    "Initial Version";
  reference
```

```
    "RFC XXXX: A Yang Data Model for Impairment-aware
      Optical Networks";
  }

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

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

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

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

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

  identity DP_QAM8 {
    base modulation;
    description
      "DP-QAM8 (Dual Polarization Quadrature Amplitude Modulation)";
  }

  identity DC_DP_QAM8 {
    base modulation;
    description
      "DC DP-QAM8 (Dual Polarization Quadrature Amplitude Modulation)";
  }

  identity DP_QAM16 {
    base modulation;
    description
      "DP-QAM16 (Dual Polarization Quadrature Amplitude Modulation)";
  }

  identity DC_DP_QAM16 {
    base modulation;
    description
      "DC DP-QAM16 (Dual Polarization Quadrature Amplitude Modulation)";
```



```
}

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

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

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

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

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

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

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

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

  leaf FEC-type {
```

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

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

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

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

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

```
    config false;
    description "fiber-type";
}

leaf span-length {
    type decimal64 {
        fraction-digits 2;
    }
    units "km";
    config false;
    description "the lenght of the fiber span in km";
}

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

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

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

leaf cd {
    type decimal64 {
        fraction-digits 5;
    }
    units "ps/nm/km";
}
```

```
    config false;
    description
      "Cromatic Dispersion";
  }

  leaf osnr {
    type decimal64 {
      fraction-digits 5;
    }
    units "dB";
    config false;
    description
      "Optical Signal-to-Noise Ratio (OSNR) estimated
       at the receiver";
  }

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

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

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

```
}

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

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

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

leaf ch-osnr {
    type decimal64 {
        fraction-digits 5;
    }
    units "dB";
    config false;
    description
        "per channel Optical Signal-to-Noise Ratio
         (OSNR) estimated at the receiver";
}

leaf q-factor {
    type decimal64 {
        fraction-digits 5;
    }
}
```

```
        units "dB";
        config false;
        description
            "q-factor estimated at the receiver";
    }
}

grouping standard_mode {
    description
        "ITU-T G.698.2 standard mode that guarantees interoperability.
        It must be an string with the following format:
        B-DScW-ytz(v) where all these attributes are conformant
        to the ITU-T recomendation";

    leaf standard_mode {
        type layer0-types: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 layer0-types:operational-mode;
        config false;
        description
            "configured organization- or vendor-specific
            application identifiers (AI) supported by the transponder";
    }

    leaf organization-identifier {
        type layer0-types:vendor-identifier;
        config false;
        description
            "organization identifier that uses organizational
            mode";
    }
}

/*
* Identities
*/
identity type-element {
```

```
    description
      "Base identity for element type";
  }

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

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

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

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

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

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

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

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



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

grouping fiber-params {
```

```
description "String identifier of fiber type referencing a specification in
a
separate equipment catalog";
container fiber {
  description "fiber characteristics";
  leaf type_variety {
    type string ;
    mandatory true ;
    description "fiber type";
  }
  leaf length {
    type decimal64 {
      fraction-digits 2;
    }
    units km;
    mandatory true ;
    description "length of fiber";
  }
  leaf loss_coef {
    type decimal64 {
      fraction-digits 2;
    }
    units dB/km;
    mandatory true ;
    description "loss coefficient of the fiber";
  }
  leaf total_loss {
    type decimal64 {
      fraction-digits 2;
    }
    units dB;
    mandatory true ;
    description
      "includes all losses: fiber loss and conn_in and conn_out losses";
  }
  leaf pmd{
    type decimal64 {
      fraction-digits 2;
    }
    units sqrt(ps);
    description "pmd of the fiber";
  }
  leaf conn_in{
    type decimal64 {
      fraction-digits 2;
    }
    units dB;
    description "connector-in";
  }
  leaf conn_out{
```

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

grouping roadm-params{
    description "roadm parameters description";
    container roadm{
        description "roadm parameters";
        leaf type_variety {
            type string ;
            mandatory true ;
            description "String identifier of roadm type referencing a specification
in a
separate equipment catalog";
        }
        leaf loss {
            type decimal64 {
                fraction-digits 2;
            }
            units dB ;
            description "..";
        }
    }
}

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

grouping power-param{
    description
        "optical power or PSD after the ROADM or after the out-voa";
    choice power-param {
        description
            "select the mode: channel power or power spectral density";
    }
}
```

```

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

grouping oms-general-optical-params {
  description "OMS link optical parameters";
  leaf generalized-snr {
    type decimal64 {
      fraction-digits 5;
    }
    units "dB@0.1nm";
    description "generalized snr";
  }
  leaf equalization-mode{
    type identityref {
      base type-power-mode;
    }
    mandatory true;
    description "equalization mode";
  }
  uses power-param;
}

grouping network-media-channel-group {
  description "network media channel group";
  list network-media-channel-group {
    key "i";
  }
}
```

```
description
  "list of network media channel group's member";
leaf i {
  type int16;
  description "index of network media channel group member";
}

list current-channels {
  key "flex-n";
  description
    "list of media channels in the OMS";

  uses layer0-types:flex-grid-channel;
}

list OTSiG-container {
  key "carrier-id";
  description
    "list of OTSi under OTSi-G";
  leaf carrier-id {
    type int16;
    description "carrier-id under OTSi-G";
  }
  leaf OTSi-carrier-frequency {
    type decimal64 {
      fraction-digits 3;
    }
    units GHz;
    config false;
    description
      "OTSi carrier frequency";
  }
  leaf OTSi-signal-width {
    type decimal64 {
      fraction-digits 3;
    }
    units GHz;
    config false;
    description
      "OTSi signal width";
  }
  leaf channel-delta-power {
    type decimal64 {
      fraction-digits 2;
    }
    units dB;
    config false;
    description
```

```

        "optional ; delta power to ref channel input-power applied to this
channel";
    }
}
}

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

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

```

```
    }
  }
}

/* Data nodes */

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

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

```
type uint32;
description "transponder identifier";
}

choice mode {
    description "standard mode, organizational mode or explicit mode";

    case G.692.2 {
        uses standard_mode;
    }

    case organizational_mode {
        uses organizational_mode;
    }

    case explicit_mode {
        uses transponder-attributes;
    }
}

leaf power {
    type int32;
    units "dBm";
    config false;
    description "per channel power";
}

leaf power-min {
    type int32;
    units "dBm";
    config false;
    description "minimum power of the transponder";
}

leaf power-max {
    type int32;
    units "dBm";
    config false;
    description "maximum power of the transponder";
}
}

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;
}
}
<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 [RFC6536] 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
```

reference: RFC XXXX (TDB)

---

## 7. Acknowledgments

We thank Dieter Bella and Sergio Belotti for useful discussions and motivation for this work.

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Analysis for FlexE control model  
draft-wang-ccamp-flex-e-control-analysis-00

Abstract

This document gives some analysis about the control of FlexE.

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

OIF published the first version of FlexE Implementation Agreement in March 2016, aiming to provide a generic mechanism for supporting a variety of Ethernet MAC rates that may or may not correspond to any existing Ethernet PHY rate. SG15 in ITU-T has endorsed the OIF FlexE data plane and parts of [ITU-T G.872], [ITU-T G.709], [ITU-T G.798] and [ITU-T G.8023]. The Recommendations depend on or are based on the FlexE data plane.

This draft is intended to trigger discussion of the FlexE control architecture according to the analysis in section 2. What kind of architecture should we employed when configuring FlexE equipments, how to configure the FlexE group and FlexE client, and what kind of parameters do we need to take into consideration? The analysis is mainly based on the description in section 7 and 8 of [ITU-T G.8023], which is "Characteristics of equipment functional blocks supporting Flex Ethernet interfaces".

## 2. Terminology

### 2.1. 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].

## 3. Analysis

### 3.1. General Introduction of FlexE

The FlexE shim is built into the Ethernet PCS (physical coding sublayer). If a FlexE group is set up, a corresponding  $n \times 100\text{G}$  (or  $n \times 200\text{G}$ ,  $n \times 400\text{G}$ ) PCS module is created as well.

The difference between the FlexE and the traditional 100G Ethernet is that the traditional Ethernet PCS has a 1:1 relationship with the client MAC flow, while with FlexE one bonded huge PCS module can be used to transport more than one client MAC flow i.e., the relationship is 1:n.

#### 3.1.1. FlexE Group

A FlexE Group is consisted of 1 to  $m$  bonded Ethernet PHYs. The rate of the Ethernet PHY could be 100G, 200G or 400G. All PHYs in the group must operate at the same rate.

FlexE group is consisted of a number of PHYs, and each PHY is consisted of 66B blocks stream. Section monitoring overhead is added/extracted as one 66B block at the FlexE group source and destination (i.e., trail termination) to determine the status of the FlexE group (i.e., FlexE trail). Currently, only RPF (Remote PHY Fault) indication is used to report the state of FlexE group.

One FlexE group exists between two FlexE shim, there is no switching defined in FlexE. In addition, only one fault indication is defined, there is no other OAM function developed yet. Based on these analysis, we may understand FlexE is just an interface technology, and once a FlexE group is configured, it only functions as one Ethernet link, same as Ethernet PHY.

#### 3.1.2. FlexE Client

A FlexE Client is an Ethernet flow based on a MAC data rate that may or may not correspond to any Ethernet PHY rate. The FlexE Client MAC rates supported by a FlexE Groups could be 10, 40, and  $m \times 25\text{ Gb/s}$ . The FlexE Client MAC rates supported by FlexE Groups may support all,

or only a subset of these FlexE Client rates, e.g.,  $m \times 25$  Gb/s. Each FlexE Client is presented to the FlexE Shim as a 64B/66B encoded bit-stream according to clause 82 of [IEEE 802.3].

According to the description in clause 8.1 of [ITU-T G.8023], there is no overhead defined for monitoring a FlexE client, so the trail for FlexE client in the equipment does not exist. The FlexE client trail termination function is a null function. Therefore, there is no need to model FlexE client as a layer.

### 3.1.3. Adaptation function between FlexE Client and FlexE Group

In order to distribute the FlexE client over PHYs of one FlexE group, a number of management information command should be sent to the adaptation function which performs the mapping of FlexE client over FlexE group.

According to the description in clause 7.2 of [ITU-T G.8023], the external management information command sent to the source adaptation function is listed below:

TxCC, TxCCA, TxCCB, TxCR, TxCA

TxGID, TxPHYMAP

The TxCC, TxCCA and TxCCB are used to configure the calendar for use, which could be type A or type B calendar configuration, and FlexE client number.

TxCR and TxCA are used to coordinate the switch of calendar configuration between the FlexE source and destination node.

The TxGID is used to configure the FlexE group identifier. The TxPHYMAP is used to configure the set of PHYs in the FlexE group.

The built-in function multiplexer performs the action of assigning the individual FlexE Client to specific calendar slots of the FlexE group.

At the destination side, the overhead should be extracted first to compare the GID and PID. The Demultiplexer function activates the FlexE Client and assigns the calendar slots of the FlexE group payload area to the individual FlexE client as defined by the client calendar information carried in the overhead.

#### 3.1.4. MAC Frame

Defined in IEEE.

#### 3.1.5. Adaptation between MAC frames and FlexE Client

It can be seen from the Figure 8-6 of [ITU-T G.8023] that the external management information commands used as input to the adaptation function are defined by [IEEE 802.3]. The [IEEE 802.3] process mainly includes the 64B/66B encoding, as well as MAC frame check sequence generation and frame counting. The FlexE client stream is generated at the determined FlexE Client MAC rate and 64B/66B encoded.

#### 3.2. General requirements

It can be inferred from section 2.1.2 and section 2.1.5 that process mainly involved when producing the FlexE Client from MAC frames is 64b/66b encoding, and this encoding has already been defined by [IEEE 802.3]. No extra overhead is added. Therefore, configuration for FlexE client layer is needed. Based on the above analysis, two general requirements for control/management of FlexE are considered in this draft.

Configuration of FlexE group

Allocation of one or more FlexE group calendar slot resources to a client MAC flow.

##### 3.2.1. Configuration of FlexE group

It can be concluded from the above analysis that external configuration tools should be involved to bring one FlexE group into service. The initial configuration commands can come from external management system, SDN controller etc.

A FlexE group must be configured first before any client signals are carried over it. When a new FlexE Group is brought into service, the initial configuration must be provisioned from both ends, and the initial configuration must be the same. The group is configured to consist of from 1 to n 100G FlexE Instances carried over from 1 to m PHYs of the same rate (100GBASE-R, 200GBASE-R, or 400GBASE-R). Each PHY tunnel may consist of multiple hops.

### 3.2.2. Allocate Resources for Client MAC flows

The FlexE client MAC flows are encapsulated in one or more FlexE calendar slots. Questions that may be raised when considering whether external control/management tools are needed.

How is the bandwidth (number of calendar slots) allocated to a MAC client?

How are the calendar slots assigned to each FlexE clients?

Does the external management/control system need to be involved?

According to the analysis in section 2.1.3, it can be inferred that the built-in multiplexer and demultiplexer function can work together to insert/extract FlexE Client stream from some calendar slots correctly, as well as the trail termination function for FlexE client is a null function. Therefore, only the bandwidth information of the FlexE Client is needed, the number of calendar slots required can be derived from the bandwidth information.

The FlexE client physical port is an internal port which only perform the function of encapsulating upper layer packets into MAC frames, 64b/66b encoding. The bandwidth capability of these internal ports should be known by external management/control tools in order to multiplex and demultiplex the upper layer flow correctly.

### 3.3. FlexE Client Configuration Procedures

Example below is depicted to set up a 25G MPLS-TP P2P path (from MPLS-TP-1 to MPLS-TP-2) over one FlexE link[two FlexE Groups] between Route-1 and Router-2. This is to help understand why control of FlexE client is not needed. FlexE group is assumed configured in this case.

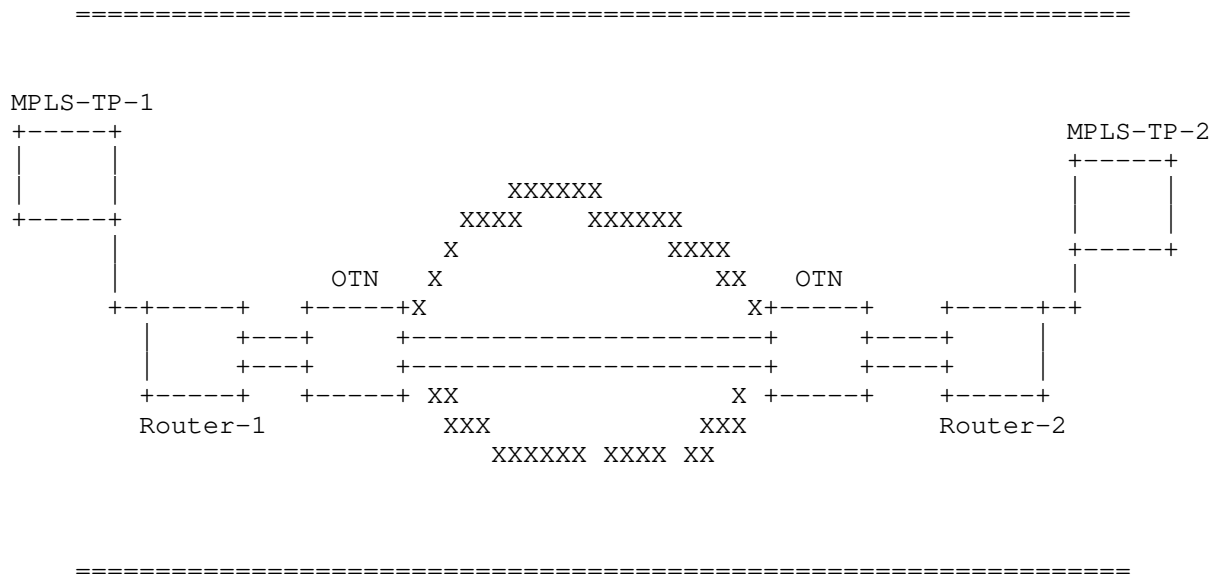


Figure 1: Network Scenario

Configuration needed for each node when setting up MPLS-TP path:

```
Outgoing MPLS label and output port, 25G --> MPLS-TP-1;
```

```
Incoming MPLS label and input port, 25G --> Router-1;
```

```
MPLS traffic over FlexE link, from Router-1 to Router-2;
```

Outgoing MPLS label and outgoing port, 25G --> Routing-2;

Incoming label and input port, 25G --> MPLS-TP-2

What else would be done by Router-1 and Router-2 if we want to put MPLS packets over FlexE link?

Router-1, perform the generally used data link (i.e., MAC) encapsulation procedures to transmit the packet to next hop Router-2, which includes:

encapsulation of the packets into MAC frames. The source and destination MAC address can be derived by searching Router-1's internal mapping table, i.e., (outgoing label, outgoing port, MAC address) table, then do the 64b/66b encoding for these MAC frames.

in addition, Router-1 would announce the required bandwidth required from Router-1 to Router-2 to local FlexE multiplexer, the local FlexE multiplexer then allocates 5\*5G calendar slots to the MPLS-TP client signal, and insert FlexE overhead onto each PHY.

Router-1's configuration is finished.

Router-2's configuration would be different, as its function is to extract the FlexE client signal from the calendar slots according to the information carried in the FlexE overhead and route the packets based on the MPLS label. As there is no switching of calendar slots in FlexE, the calendar slots allocated to certain client signal would not change.

It can be inferred from the above procedures that the configuration of a MPLS client is not impacted by the use of FlexE comparing to traditional Ethernet.

### 3.4. Control Requirements Derived

- a. Using control plane method to configure FlexE group, which may include the configuration of group number, PHY number and correlation between logical PHY number and physical port number.
- b. Configuration of "logical" PHY, which includes initial configuration of bandwidth (number of calendar slots); change of bandwidth while in service.
- c. External control command should be provide to trigger the switch of calendar slots.
- d. Interworking between 5G slot granularity capable node and 25G slot granularity node.
- e. Configuration of aware case. As calendar slots is not visible to external management/control tools. Bandwidth information of the Ethernet PHYs selected can be used to infer the unavailable slot information, as the unavailable slots are placed at the end of each relevant sub-calendar (the highest numbered slots). [RFC6002] defines a new switching type DCSC (Data Channel Switching Capable) to describe the switching of whole digital channel presented on single channel interface, which can describe the Ethernet terminated at the physical (port) level and all traffic received on a port is switched to a physical port at the LSP egress. The FlexE digital channel presented at each PHY interface can be described with DCSC switching type. However, FlexE aware case may not be depicted with DCSC, as described in section 17.12 of [ITU-T G.709], each FlexE (sub) groups (i.e.,

each 100G FlexE signals) are crunched, padded and interleaved in FlexE, the bandwidth of digital channel links presented in one tunnel may varies. Therefore, a new switching type DCSC-flexE is needed in aware case to depict the end-to-end tunnel with bandwidth varies at each digital channel links. The configuration of FlexE instance and unavailable slot information can be derived through the bandwidth of each hop.

Different kinds of alarms should be taken into consideration when modelling FlexE technology, which may include PHY failed, skew exceed threshold, inconsistent configuration between two ends.

#### 4. Summary

According to the analysis in section 2, the main control/management requirement for FlexE technology is to configure the FlexE group. Once a FlexE group is configured and the capability information of the internal FlexE client ports associated with this FlexE group is known, use of the FlexE technology is the same as that in traditional Ethernet.

#### 5. Acknowledgements

#### 6. IANA Considerations

This memo includes no request to IANA.

#### 7. Security Considerations

None.

#### 8. References

##### 8.1. Normative References

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A YANG Data Model for Flex Ethernet (FlexE)  
draft-xiaobn-ccamp-flex-e-yang-mod-00

## Abstract

Flex Ethernet (FlexE) implementation agreement have been published by OIF. FlexE provides a generic mechanism for supporting a variety of Ethernet MAC rates that may or may not correspond to any existing Ethernet PHY rate.

This document describes a YANG data model for FlexE. It can be used to manage and control devices supporting FlexE functions.

## Status of This Memo

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## 1. Introduction

Flex Ethernet (FlexE) implementation agreement version 1.0 [OIFFLEXE1] and 2.0 [OIFFLEXE2] have been published by OIF. FlexE provides a generic mechanism for supporting a variety of Ethernet MAC rates that may or may not correspond to any existing Ethernet PHY rate. This includes MAC rates that are both greater than (through bonding) and less than (through sub-rate and channelization) the Ethernet PHY rates used to carry FlexE.

This document defines a data model of FlexE, using YANG[RFC7950]. This model mainly deals with the data model of the FlexE Group and the FlexE client. It can be used by an application to configure and modify the parameters of the FlexE Group and the FlexE client, and to receive notifications, e.g. mismatch errors, from devices supporting FlexE functions.

Requirements for the FlexE YANG model are considered. And FlexE YANG tree and YANG files are given.

## 2. Terminology

A simplified graphical representation of the data model is used in this document. The meaning of the symbols in the YANG data tree presented later in this document is defined in [RFC8340]. They are provided below for reference.

- o Brackets "[" and "]" enclose list keys.
- o Abbreviations before data node names: "rw" means configuration (read-write) and "ro" state data (read-only).
- o Symbols after data node names: "?" means an optional node, "!" means a presence container, and "\*" denotes a list and leaf-list.
- o Parentheses enclose choice and case nodes, and case nodes are also marked with a colon (":").
- o Ellipsis ("...") stands for contents of subtrees that are not shown.
- o Some of the key terms used in this document are listed as follow.

### 2.1. 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].

### 2.2. FlexE terminology used in this document

- a. CSG: Calendar Slot Granularity. It can be 5G or 25G.
- b. FlexE Calendar: In FlexE IA v1.0, the total capacity of a FlexE Group is represented as a collection of slots which have a granularity of 5G. The calendar for a FlexE Group composed of n 100G PHYs is represented as an array of 20n slots (each representing 5G of bandwidth). This calendar is partitioned into sub-calendars, with 20 slots per 100G PHY. Each FlexE client is mapped into one or more calendar slots (based on the bandwidth the FlexE client flow will need). In FlexE IA v2.0[OIFFLEXE2], the total capacity of a FlexE Group is represented as a collection of slots which may have a granularity of 5G or 25G. The calendar for a FlexE Group composed of n 100G FlexE instances from m 100G/200G/400G PHYs is represented as an array of 20n slots (each representing 5G of bandwidth) or 4n slots (25G granularity).

- c. FlexE Client: An Ethernet flow based on a MAC data rate that may or may not correspond to any Ethernet PHY rate.
- d. FlexE Group: A FlexE Group is composed of from 1 to n 100G FlexE Instances that are carried by a group of from 1 to m bonded Ethernet PHYs.
- e. FlexE instance: A 100G FlexE Instance is a unit of information consisting of 100G of capacity able to carry FlexE Client data, together with its associated overhead.

Detailed description of these terms can be found in [OIFFLEXE1] and [OIFFLEXE2] .

### 3. FlexE Reference Configuration Model

FlexE can be implemented between the FlexE mux and demux in two end devices connected directly by the FlexE links. In this case, FlexE is just a link connection technology.

FlexE can also be transported by transport networks. There are three kinds of transport network mapping mechanisms for FlexE signals, that is, FlexE unaware transport, FlexE termination in the transport network and FlexE aware transport.

How to configure the ingress or egress of transport network about FlexE mapping relationship may be application specific. In this document, the part of YANG data model for the transport network mapping for FlexE is not included at present.

### 4. Requirements

#### 4.1. Requirements

This section summarizes the management requirements for the FlexE Group and the FlexE Client.

Req-1 The model SHALL support the management of the FlexE Group, consisting of one or more 100G FlexE instances which carried by one or more 100GE, 200GE, 400GE Ethernet PHY(s).

The detailed management covers the CURD functions (create, update, read and delete), and lock/unlock.

Req-2 The model SHOULD be able to verify that the collection of Ethernet PHY(s) included in a FlexE Group have the same characteristics (e.g. number of PHYs, rate of PHYs, etc.) at the

local FlexE shims. If inconsistency exists, notifications (e.g. errors) SHOULD be invoked.

Req-3 The model SHOULD be able to verify that the collection of FlexE instances included in a FlexE Group have the same characteristics (e.g. calendar slot granularity, unequipped slots, etc.) at the local FlexE shims. If inconsistency exists, notifications (e.g. errors) SHOULD be invoked.

Req-4 The model SHALL allow the addition (or removal) of one or more FlexE clients on a FlexE Group. The addition (or removal) of a FlexE client flow SHALL NOT affect the services for the other FlexE client signals whose size and calendar slot assignments are not changed.

Req-5 The model SHALL allow FlexE client signals to flexibly span the set of FlexE instances which comprise the FlexE Group.

Req-6 The model SHALL support a FlexE client flow resizing without affecting any existing FlexE clients within the same FlexE Group.

Req-7 The model SHALL support the switching of a calendar configuration. There are two calendar configurations, A and B.

## 5. YANG Data Model for FlexE (Tree Structure)

```

module: ietf-flexe-yang
  +--rw flexe-configuration
    +--rw flexe-groups
      +--rw flexe-group* [group-number]
        +--rw group-number          uint32
        +--rw group-attributes
          +--rw flexe-group-available-bandwidth?  rt-types:bandwidth-ieee-float32
          +--rw calendar-slot-granularity?        fe-types:calendar-slot-granularity
          +--rw flexe-phy-type?                    fe-types:flexe-phy-type
          +--rw bonded-phys
            +--rw flexe-phys* [phy-number-in-group]
              +--rw phy-number-in-group          uint8
              +--rw local-phy-interface?         if:interface-ref
              +--rw remote-phy-interface?        if:interface-ref
            +--rw flexe-instances
              +--rw flexe-instance* [flexe-instance-number]
                +--rw flexe-instance-number      uint8
                +--rw unavailable-sub-calendar-slot-list* [sub-calendar-slot-id]
                  +--rw sub-calendar-slot-id      uint8
                  +--rw unequipped-flexe-instance* [flexe-instance-number]
                    +--rw flexe-instance-number    uint8
              +--rw tx-calendar?                  fe-types:calendar-AorB
              +--rw rx-calendar?                  fe-types:calendar-AorB
              +--rw tx-calendar-neg?              enumeration
              +--rw reply-ca-mode?                enumeration
          +--rw flexe-clients
            +--rw flexe-client* [client-number]
              +--rw client-number                uint16
              +--rw bandwidth
                +--rw signal-type?               flexe-client-signal-rate
                +--rw mac-rate?                  rt-types:bandwidth-ieee-float32
              +--rw client-interface?            if:interface-ref
              +--rw group-number?                uint32

```

Figure 1

## 6. FlexE types Module

```
<CODE BEGINS> file "ietf-flexex-types@2019-03-11.yang"
module ietf-flexex-types {
  yang-version 1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-flexex-types";
  prefix "fe-types";
  import ietf-routing-types {
    prefix rt-types;
```



```
}
organization
  "Internet Engineering Task Force (IETF) CCAMP WG";
contact
  "WG List: <mailto:ccamp@ietf.org>
  Editor: Xiaobing Niu (niu.xiaobing@zte.com.cn);
  Editor: Qilei Wang (wang.qilei@zte.com.cn); ";
description
  "This module defines a YANG data model for FlexE.";
revision 2019-03-11{
  description
    "Initial version.";
  reference
    "draft-xiaobn-ccamp-flex-e-yang-mod-00.txt";
}

/* typedefs */
typedef calendar-slot-granularity {
  type enumeration {
    enum csg-5G {
      value 1;
      description "Calendar slot with a 5G granularity";
    }
    enum csg-25G {
      value 2;
      description "Calendar slot with a 25G granularity";
    }
  }
  description
    "Defines a type representing the granularity of a calendar slot.";
}

typedef flexe-client-signal-rate {
  type enumeration {
    enum flexe-client-signal-10Gbps{
      value 1;
      description
        "FlexE Client signal rate of 10Gbps";
    }
    enum flexe-client-signal-40Gbps{
      value 2;
      description
        "FlexE Client signal rate of 40Gbps";
    }
    enum flexe-client-signal-25mGbps{
      value 3;
      description
        "FlexE Client signal rate of m*25Gbps";
    }
  }
}
```

```
    }
  }
  description
    "Defines FlexE Client signal rate, including 10, 40, m*25Gbps.";
}
typedef flexe-phy-type {
  type enumeration {
    enum flexe-phy-100GBASE-R {
      value 1;
      description "100GBASE-R PHY";
    }
    enum flexe-phy-200GBASE-R {
      value 2;
      description "200GBASE-R PHY";
    }
    enum flexe-phy-400GBASE-R {
      value 3;
      description "400GBASE-R PHY";
    }
  }
  description
    "Defines types of PHYs in a FlexE group";
}
typedef calendar-AorB {
  type enumeration {
    enum calendar-A {
      value 0 ;
      description
        "Set the A calendar configuration.";
    }
    enum calendar-B {
      value 1 ;
      description
        "Set the B calendar configuration.";
    }
  }
  description
    "Calendar configuration A or B";
}
/* interface states: OK, SF, SD */
typedef intf-state {
  type enumeration {
    enum ok {
      value 0 ;
      description
        "The interface state of the FlexE Group is OK.";
    }
    enum sf {
```

```
        value 1 ;
        description
            "The interface state of the FlexE Group is SF." ;
    }
    enum sd {
        value 2 ;
        description
            "The interface state of the FlexE Group is SD.";
    }
}
description
    "Interface state of port group.";
}
/* grouping */
grouping flexe-client-bandwidth{
    leaf signal-type{
        type flexe-client-signal-rate;
        description
            "Client signal types: 10, 40, m*25 Gbps.";
    }
    leaf mac-rate {
        type rt-types:bandwidth-ieee-float32;
        description
            "Bandwidth of clients.";
    }
}
description
    "The bandwidth of a FlexE client.";
}
}
```

<CODE ENDS>

## 7. FlexE YANG Module

```
<CODE BEGINS> file "ietf-flex-e-yang@2019-03-11.yang"
module ietf-flex-e-yang {
    yang-version 1;
    namespace "urn:ietf:params:xml:ns:yang:ietf-flex-e-yang";
    prefix "flex-e";
    import ietf-routing-types {
        prefix rt-types;
    }
    import ietf-interfaces {
        prefix if;
    }
    import ietf-flex-e-types {
        prefix fe-types;
    }
}
```

```

organization
  "Internet Engineering Task Force (IETF) CCAMP WG";
contact
  "WG List: <mailto:ccamp@ietf.org>
  Editor: Xiaobing Niu (niu.xiaobing@zte.com.cn);
  Editor: Qilei Wang (wang.qilei@zte.com.cn); ";
description
  "This module defines a YANG data model for FlexE.";
revision 2019-03-11 {
  description
    "Initial version.";
  reference
    "draft-xiaobn-ccamp-flex-e-yang-mod-00.txt";
}

/* Configuration of FlexE */
container flexe-configuration{
  description
    "FlexE configuration, including configurations of FlexE groups
    and FlexE clients.";
  container flexe-groups {
    description
      "Container for the FlexE Group";
    list flexe-group {
      key group-number;
      description
        "List of FlexE Group";
      leaf group-number {
        type uint32 {
          range 1..1048574 ;
        }
      }
      description
        "The FlexE Group number is selected from the range 1~0xFFFFFE.
        The value of 0x00000 and 0xFFFFF may not be used to designate
        a FlexE Group.";
    }
    container group-attributes {
      description
        "The attributes of a FlexE Group";
      leaf flexe-group-available-bandwidth{
        type rt-types:bandwidth-ieee-float32;
        description
          "Availbale bandwidth allocated in the FlexE Group.
          Considering the FlexE Client MAC rates supported by FlexE
          Groups are 10, 40, m*25 Gbps, or a subset of these rat
es,
          it's recommended to confine the bandwidth allocated for a
          FlexE group into a integer compound from litmited types of
          MAC rateds.";
      }
    }
  }
}

```

```

    }
    leaf calendar-slot-granularity{
        type fe-types:calendar-slot-granularity;
        description
            "The granularity of calendar slot is 5G or 25G";
        reference
            "OIF FlexE IA 2.0";
    }
    leaf flexe-phy-type{
        type fe-types:flexe-phy-type;
        description
            "Types of PHYs, such as 100/200/400GBASE-R";
        reference
            "OIF FlexE IA 2.0";
    }
    container bonded-phys {
        description
            "PHYs bonded to form a FlexE Group";
        list flexe-phys {
            key phy-number-in-group;
            description
                "One of bonded PHYs in a FlexE Group";
            leaf phy-number-in-group{
                type uint8{
                    range "1 .. 254";
                }
                description
                    "Refer to the clause 6.1 in FlexE IA 2.0.
                    For 100GBASE-R, the FlxeE PHY number and the 100G FlexE
                    instance number are the same and in the range [1-254];
                    For 200GBASE-R, each PHY number is in the range [1-126].
                    For 400GBASE-R, each PHY number is in the range [1-62].";
            }
            leaf local-phy-interface{
                type if:interface-ref;
                description
                    "Local PHY interface related to the current PHY in a FlexE gro
up.";
            }
            leaf remote-phy-interface{
                type if:interface-ref;
                description
                    "Remote PHY interface related to the current PHY in a FlexE gr
oup.";
            }
        }
    }
    container flexe-instances {
        description

```

```

    "FlexE instances in a FlexE Group";
list flexe-instance {
    key flexe-instance-number;
    description
        "List of a FlexE instance in a FlexE Group.
        Not including those unequipped instances in the bonded PHYs.";
    leaf flexe-instance-number{
        type uint8 ;
        description
            "Logical FlexE instance number";
        reference
            "Clause 6.1 FlexE Group in FlexE IA 2.0.
            For 100G, instance num=PHY num;
            For 200G, 8-bit instance num consists of the PHY num in the upper
r
            seven bits, and 0 or 1 in the lower order bit.
            For 400G, 8-bit instance num consists of the PHY num in the upper
r
            six bits, and 0,1,2, or 3 in the two lower order bits. ";
    }
    list unavailable-sub-calendar-slot-list {
    key sub-calendar-slot-id;
    description
        "List of sub-calendar slots unavailable in a FlexE Instance.";
    leaf sub-calendar-slot-id {
        type uint8;
        description
            "Identification number of a sub-calendar slot in a FlexE instance.
nce.
            For 5G granularity, the range of slot-id is [0,19];
            For 25G granularity, the range of slot-id is [0,3];
            Refer to clause 6.7 in FlexE IA 2.0. ";
    }
    }
}
list unequipped-flexe-instance {
    key flexe-instance-number;
    description
        "Unequipped FlexE instances in the bonded PHYs.
        Strictly speaking, a unequipped instance does not belong
        to any FlexE Group, because in the overhead frame, the FlexE
        Group number is set to 0x00000.
        Refer to Clause 6.5 Unequipped 100G FlexE Instances.";
    leaf flexe-instance-number{
        type uint8 ;
        description
            "Clause 6.1 FlexE Group in FlexE IA 2.0";
    }
}
leaf tx-calendar {

```

```
    type fe-types:calendar-AorB;
    description
        "Calendar configuration in the transmit direction";
}
leaf rx-calendar {
    type fe-types:calendar-AorB;
    description
        "Calendar configuration in the receive direction";
}
leaf tx-calendar-neg {
    type enumeration {
        enum manual {
            value 1 ;
            description
                "Manually configured";
        }
        enum protocol-force {
            value 2 ;
            description
                "Protocol forced";
        }
        enum protocol-normal {
            value 3 ;
            description
                "Protocol normal";
        }
    }
    description
        "TX calendar negotiation methods";
}
leaf reply-ca-mode {
    type enumeration {
        enum never {
            value 1 ;
            description
                "never reply CA (Configuration Ack)";
        }
        enum immediately {
            value 2 ;
            description
                "immediately reply CA (Configuration Ack)";
        }
        enum ask-controller {
            value 3 ;
            description
                "Ask controller for more control";
        }
    }
}
```

```

        description
            "Reply CA mode";
        }
    }
}
container flexe-clients {
    description
        "FlexE clients information";
    list flexe-client {
        key client-number ;
        description
            "Attributes of FlexE client" ;
        leaf client-number {
            type uint16 {
                range 1..65534 ;
            }
            description
                "Client number in the range of 1~0xFFFE.
                The value 0x0000 indicates a calendar slot which is unused (but available).
                The value 0xFFFF (all ones) indicates a calendar slot that is unavailable.
                Refer to Clause 7.3.4 in FlexE IA 2.0.";
        }
        container bandwidth {
            description "Client bandwidth";
            uses fe-types:flexe-client-bandwidth;
        }
        leaf client-interface {
            type if:interface-ref;
            description
                "A FlexE Client is used as an interface.";
        }
        leaf group-number {
            type uint32 {
                range 1..1048574 ;
            }
            description
                "The FlexE Group is used to transport the FlexE client.";
        }
    }
}
}
}
<CODE ENDS>

```



8. Acknowledgements

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11. IANA Considerations

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

URI: urn:ietf:params:xml:ns:yang:ietf-flex-e-yang

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[RFC6020] :

name: ietf-flex-e-yang

namespace: urn:ietf:params:xml:ns:yang:ietf-flex-e-yang

reference: RFC XXXX (TDB)

## 12. 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]. Proper standardized security measures should be implemented.

There are a number of data nodes defined in this YANG module that are writable/creatable/deletable. 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.

## 13. References

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- [RFC8340] Bjorklund, M. and L. Berger, Ed., "YANG Tree Diagrams", BCP 215, RFC 8340, DOI 10.17487/RFC8340, March 2018, <<https://www.rfc-editor.org/info/rfc8340>>.

## 13.2. Informative References

## [I-D.izh-ccamp-flex-e-fwk]

Hussain, I., Valiveti, R., Wang, Q., Andersson, L., Chen, M., and z. zhenghaomian@huawei.com, "GMPLS Routing and Signaling Framework for Flexible Ethernet (FlexE)", draft-izh-ccamp-flex-e-fwk-05 (work in progress), March 2018.

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March 11, 2019

A YANG Data Model for Transport Network Client Signals  
draft-zheng-ccamp-client-signal-yang-06

Abstract

A transport network is a server-layer network to provide connectivity services to its client. The topology and tunnel information in the transport layer has already been defined by generic Traffic-engineered models and technology-specific models (e.g., OTN, WSON). However, how the client signals are accessing to the network has not been described. These information is necessary to both client and provider.

This draft describes how the client signals are carried over transport network and defines YANG data models which are required during configuration procedure. More specifically, several client signal (of transport network) models including ETH, STM-n, FC and so on, are defined in this draft.

Status of This Memo

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

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

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## 1. Introduction

### 1.1. Overview

A transport network is a server-layer network designed to provide connectivity services for a client-layer network to carry the client traffic transparently across the server-layer network resources. Currently the topology and tunnel models which have been defined for transport networks, such as [I-D.ietf-ccamp-otn-topo-yang] and [I-D.ietf-ccamp-otn-tunnel-model], provide server-layer topology abstraction and tunnel configuration between PEs. However, there is a missing piece for configuring how the PEs should map the client-layer traffic, received from the CE, over the server-layer-tunnels: this gap is expected to be solved in this document.

This document defines a data model of all transport network client signals, using YANG language defined in [RFC7950]. The model can be used by applications exposing to a transport controller via a RESTconf interface. Furthermore, it can be used by an application for the following purposes (but not limited to):

- o To request/update an end-to-end service by driving a new tunnel to be set up to support this service;
- o To request/update an end-to-end service by using an existing tunnel;
- o To receive notification with regard to the information change of the given service;

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

### 1.2. Prefixs in Model 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, including [RFC6991], [RFC8294] and [I-D.ietf-ccamp-otn-tunnel-model], which are shown as follow.

Prefix	YANG module	Reference
yang	ietf-yang-types	[RFC6991]
te-types	ietf-te-types	[ietf-teas-yang-te-types]
rt-types	ietf-routing-types	[RFC8294]
otn-types	ietf-otn-types	[ietf-ccamp-otn-tunnel-model]
eth-types	ietf-eth-tran-types	This Document
clntsvc	ietf-trans-client-service	This Document
ethsvc	ietf-eth-tran-service	This Document

## 2. Terminology and Notations

A simplified graphical representation of the data model is used in this document. The meaning of the symbols in the YANG data tree presented later in this document is defined in [RFC8340]. They are provided below for reference.

- o Brackets "[" and "]" enclose list keys.
- o Abbreviations before data node names: "rw" means configuration (read-write) and "ro" state data (read-only).
- o Symbols after data node names: "?" means an optional node, "!" means a presence container, and "\*" denotes a list and leaf-list.
- o Parentheses enclose choice and case nodes, and case nodes are also marked with a colon (":").
- o Ellipsis ("...") stands for contents of subtrees that are not shown.

## 3. Transport Network Client Signal Overview

### 3.1. Overview of Service Request and Network Configuration Scenarios

A global view of a multi-domain service can be described as the Figure 1 . The customer is usually responsible to configure the CE nodes and to request to the provider the service intent, from the CE nodes perspective, while the provider is responsible to configure the whole network (including the PE nodes) to support the customer service intent. Generally speaking, the network configurations required to support a customer service can be split into two different groups: CE-PE and PE-PE. The CE-PE configuration deals with the client layer one-hop access link, while PE-PE configuration deals with the server layer tunnel. In Figure 1 we mark the



intermediate nodes as 'P', which has same switching capability of PE but just not the 'end-point'. In this example, the link P-P and PE-P are a server-layer intra-domain or inter-domain link.

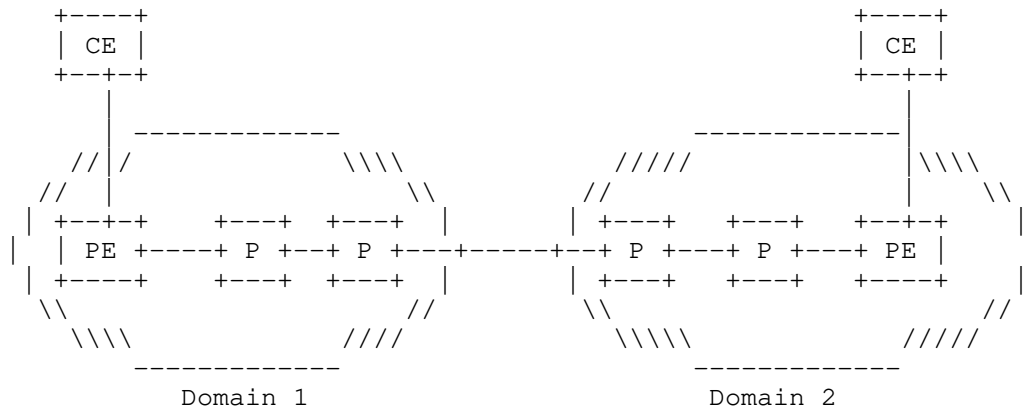


Figure 1: Global view of Client Service with the Network Provider

According to the responsibilities of each controller in [RFC8453], the controllers have different views of the service request and network configuration. The duty of CNC is to give the MDSC a description of the customer service intent: candidate YANG models include L1CSM [I-D.ietf-ccamp-llcsm-yang], L2SM [RFC8466] and L3SM [RFC8299], which are classified as customer service models, according to [RFC8309]. These models provide necessary attributes to describe the customer service intent from the customer/CE perspective, and do not provide any specific network configuration. These models also implies that the customer service description can be considered in a separate manner rather than integratig with network configurations, which also enable the controllers to abstract/virtualize the network resource to make them visible to the customer and also easier to manage. In other words, the network knowledge is not necessary at CNC and CMI, which is seen in an abstracted form as shown in Figure 2.

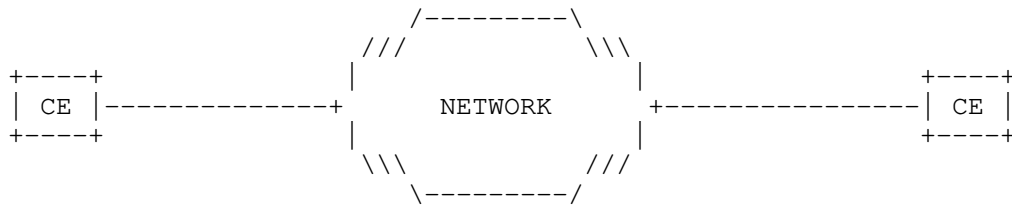


Figure 2: CNC Viewpoint on the Client Service

The functionalities of MDSC have been described in [RFC8453], which include the customer mapping/translation and multi-domain coordination. By receiving the request from CNC, MDSC need to understand what network configuration can support the customer service intent and turn to the corresponding PNCs for configuration. The service request is therefore decomposed by MDSC into a few network configurations and forwarded to one or multiple PNCs respectively in single-domain and multi-domain scenario. In general, the MDSC has the view of both PE and CE nodes and of some abstract information regarding the P nodes, as shown in Figure 3. It is worth noting that this MDSC view is different with Figure 1 at the intra-domain link. Usually these details are hidden, for scalability purposes, and therefore the MDSC has only an abstract view of each domain internal topology.

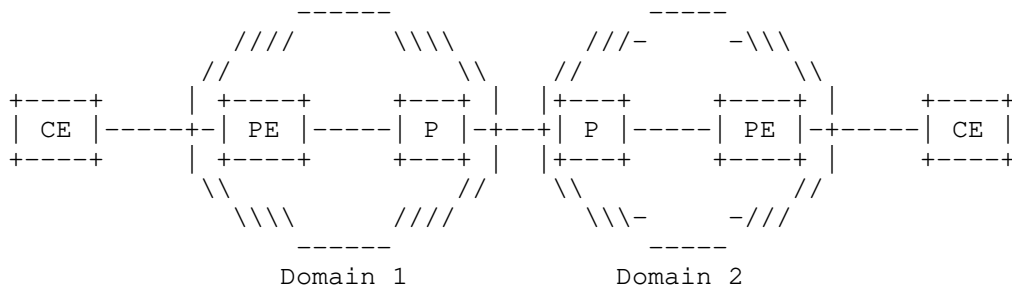


Figure 3: MDSC view of both Client Service and Network Abstraction

PNC is the controller that configure the physical devices, based on the network configuration received from the MDSC. Each PNC has the detailed view of its own domain, the example of view from PNC in domain 1 is shown in Figure 4. The PNC has all the detailed topology information on PE and P nodes and on the intra-domain links. The PNC configures the tunnel/tunnel segment within its domain based on the network configuration provided by the MDSC. The PNC also configures

the network part of the CE-PE access links as well as the mapping of the client-layer traffic and the server-layer tunnels, based on the network configuration provided by the MDSC. The interaction between PNC and MDSC for the client-layer network configuration is accomplished by the models defined in this draft.

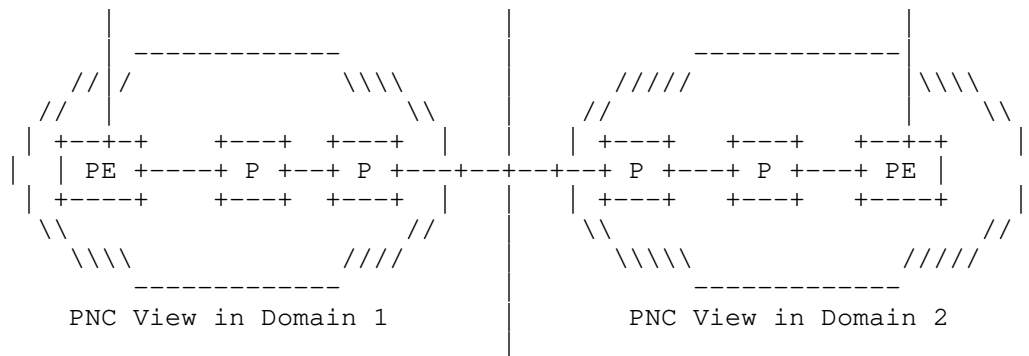


Figure 4: PNC view on Network Configuration

### 3.2. Applicability of Proposed Model

Existing TE and technology-specific models, such as topology models and tunnel models, support the network configuration among PEs and Ps. The customer service models, such as L1CSM, L2SM and L3SM, focus on describing the attributes among CEs. However, there is a missing piece on how to configure the CE-PE session. The models defined in this document provide the configuration on CE-PE when the provider server-layer network is TE-based technology.

In the example of OTN as the server-layer transport network, a full list of G-PID was summarized in [RFC7139], which can be divided into a few categories. The G-PID signals can be categorized into transparent and non-transparent. Examples of transparent signals may include Ethernetphysical interfaces, FC, STM-n and so on. In this approach the OTN devices is not aware of the client signal type, and this information is only necessary among the controllers. Once the OTN tunnel is set up, there is no switching requested on the client layer, and therefore only signal mapping is needed, without a client tunnel set up. The models that supporting the configuration of transparent signals are defined in Section 4.2. The other category would be non-transparent, such as Carrier Ethernet and MPLS-TP, with a switching request on the client layer. Once the OTN tunnel is set up, a corresponding tunnel in the client layer has to be set up to

carry services. The models that supporting the configuration of transparent signals are defined in Section 4.1.

It is also worth noting that some client signal can be carried over multiple types of networks. For example, the Ethernet services can be carried over either OTN or Ethernet TE tunnels (over optical or microwave networks). The model specified in this document allows the support from networks with different technologies.

#### 4. YANG Model for Transport Network Client Signal

##### 4.1. YANG Tree for Ethernet Service

```

module: ietf-eth-tran-service
  +--rw etht-svc
    +--rw globals
      +--rw named-bandwidth-profiles* [bandwidth-profile-name]
        +--rw bandwidth-profile-name      string
        +--rw bandwidth-profile-type?     etht-types:bandwidth-profile-type
        +--rw CIR?                        uint64
        +--rw CBS?                        uint64
        +--rw EIR?                        uint64
        +--rw EBS?                        uint64
        +--rw color-aware?                boolean
        +--rw coupling-flag?              boolean
      +--rw etht-svc-instances* [etht-svc-name]
        +--rw etht-svc-name                string
        +--rw etht-svc-id?                 string
        +--rw etht-svc-descr?              string
        +--rw etht-svc-customer?           string
        +--rw etht-svc-type?               etht-types:service-type
        +--rw etht-svc-lifecycle?          etht-types:lifecycle-status
        +--rw te-topology-identifier
          +--rw provider-id?               te-global-id
          +--rw client-id?                 te-global-id
          +--rw topology-id?               te-topology-id
        +--rw resilience
        +--rw etht-svc-end-points* [etht-svc-end-point-name]
          +--rw etht-svc-end-point-name    string
          +--rw etht-svc-end-point-id?     string
          +--rw etht-svc-end-point-descr?  string
          +--rw topology-role?              identityref
          +--rw resilience
        +--rw etht-svc-access-points* [access-point-id]
          +--rw access-point-id            string
          +--rw access-node-id?             te-types:te-node-id
          +--rw access-ltp-id?              te-types:te-tp-id

```

```

    +--rw access-role?          identityref
    +--rw pm-config
    |   +--rw pm-enable?        boolean
    |   +--rw sending-rate-high? uint64
    |   +--rw sending-rate-low?  uint64
    |   +--rw receiving-rate-high? uint64
    |   +--rw receiving-rate-low? uint64
    +--ro state
    |   +--ro operational-state? identityref
    |   +--ro provisioning-state? identityref
    +--ro performance?          identityref
+--rw service-classification-type? identityref
+--rw (service-classification)?
|   +--:(port-classification)
|   +--:(vlan-classification)
|   |   +--rw outer-tag!
|   |   |   +--rw tag-type?      etht-types:eth-tag-classify
|   |   |   +--rw (individual-bundling-vlan)?
|   |   |   |   +--:(individual-vlan)
|   |   |   |   |   +--rw vlan-value?  etht-types:vlanid
|   |   |   |   +--:(vlan-bundling)
|   |   |   |   |   +--rw vlan-range?  etht-types:vid-range-type
|   |   +--rw second-tag!
|   |   |   +--rw tag-type?      etht-types:eth-tag-classify
|   |   |   +--rw (individual-bundling-vlan)?
|   |   |   |   +--:(individual-vlan)
|   |   |   |   |   +--rw vlan-value?  etht-types:vlanid
|   |   |   |   +--:(vlan-bundling)
|   |   |   |   |   +--rw vlan-range?  etht-types:vid-range-type
+--rw split-horizon-group?      string
+--rw (direction)?
|   +--:(symmetrical)
|   |   +--rw ingress-egress-bandwidth-profile
|   |   |   +--rw (style)?
|   |   |   |   +--:(named)
|   |   |   |   |   +--rw bandwidth-profile-name?  string
|   |   |   |   +--:(value)
|   |   |   |   |   +--rw bandwidth-profile-type?  etht-types:bandwidth-
profile-type
|   |   |   +--rw CIR?          uint64
|   |   |   +--rw CBS?          uint64
|   |   |   +--rw EIR?          uint64
|   |   |   +--rw EBS?          uint64
|   |   |   +--rw color-aware?  boolean
|   |   |   +--rw coupling-flag? boolean
|   +--:(asymmetrical)
|   |   +--rw ingress-bandwidth-profile
|   |   |   +--rw (style)?
|   |   |   |   +--:(named)

```

```

| | | | | +---rw bandwidth-profile-name?    string
+--:(value)
| | | | | +---rw bandwidth-profile-type?    etht-types:bandwidth-
profile-type
| | | | | +---rw CIR?                        uint64
| | | | | +---rw CBS?                        uint64
| | | | | +---rw EIR?                        uint64
| | | | | +---rw EBS?                        uint64
| | | | | +---rw color-aware?              boolean
| | | | | +---rw coupling-flag?            boolean
+---rw egress-bandwidth-profile
| | | | | +---rw (style)?
| | | | | +---:(named)
| | | | | | | +---rw bandwidth-profile-name?    string
+---:(value)
| | | | | +---rw bandwidth-profile-type?    etht-types:bandwidth-
profile-type
| | | | | +---rw CIR?                        uint64
| | | | | +---rw CBS?                        uint64
| | | | | +---rw EIR?                        uint64
| | | | | +---rw EBS?                        uint64
| | | | | +---rw color-aware?              boolean
| | | | | +---rw coupling-flag?            boolean
+---rw vlan-operations
| | | | | +---rw (direction)?
| | | | | +---:(symmetrical)
| | | | | | | +---rw symmetrical-operation
| | | | | | | +---rw pop-tags?      uint8
| | | | | | | +---rw push-tags
| | | | | | | +---rw outer-tag!
| | | | | | | | | +---rw tag-type?      etht-types:eth-tag-type
| | | | | | | | | +---rw vlan-value?   etht-types:vlanid
| | | | | | | | | +---rw default-pcp?  uint8
| | | | | | | +---rw second-tag!
| | | | | | | | | +---rw tag-type?      etht-types:eth-tag-type
| | | | | | | | | +---rw vlan-value?   etht-types:vlanid
| | | | | | | | | +---rw default-pcp?  uint8
+---:(asymmetrical)
| | | | | +---rw asymmetrical-operation
| | | | | | | +---rw ingress
| | | | | | | +---rw pop-tags?      uint8
| | | | | | | +---rw push-tags
| | | | | | | +---rw outer-tag!
| | | | | | | | | +---rw tag-type?      etht-types:eth-tag-type
| | | | | | | | | +---rw vlan-value?   etht-types:vlanid
| | | | | | | | | +---rw default-pcp?  uint8
| | | | | | | +---rw second-tag!
| | | | | | | | | +---rw tag-type?      etht-types:eth-tag-type
| | | | | | | | | +---rw vlan-value?   etht-types:vlanid
| | | | | | | | | +---rw default-pcp?  uint8

```

```

    +--rw egress
      +--rw pop-tags?      uint8
      +--rw push-tags
        +--rw outer-tag!
          +--rw tag-type?  etht-types:eth-tag-type
          +--rw vlan-value? etht-types:vlanid
          +--rw default-pcp? uint8
        +--rw second-tag!
          +--rw tag-type?  etht-types:eth-tag-type
          +--rw vlan-value? etht-types:vlanid
          +--rw default-pcp? uint8
+--rw etht-svc-tunnels* [tunnel-name]
  +--rw tunnel-name          string
  +--rw (svc-multiplexing-tag)?
    +--:(other)
    +--:(none)
    +--:(vlan-tag)
    +--:(pw-segment)
      +--rw pw-id?          string
      +--rw pw-name?        string
      +--rw transmit-label? rt-types:mpls-label
      +--rw receive-label?  rt-types:mpls-label
      +--rw encapsulate-type? identityref
      +--ro oper-status?    identityref
      +--rw ingress-bandwidth-profile
        +--rw (style)?
          +--:(named)
            +--rw bandwidth-profile-name? leafref
          +--:(value)
            +--rw bandwidth-profile-type? etht-types:bandwidth-
profile-type
          +--rw CIR?        uint64
          +--rw CBS?        uint64
          +--rw EIR?        uint64
          +--rw EBS?        uint64
      +--rw src-split-horizon-group?  string
      +--rw dst-split-horizon-group?  string
+--rw admin-status?    identityref
+--ro state
  +--ro operational-state? identityref
  +--ro provisioning-state? identityref
  +--ro creation-time?    yang:date-and-time
  +--ro last-updated-time? yang:date-and-time

```

#### 4.2. YANG Tree for other Transport Network Client Signal Model

```

module: ietf-trans-client-service
  +--rw client-svc
    +--rw client-svc-instances* [client-svc-name]
      +--rw client-svc-name      string
      +--rw client-svc-id?      string
      +--rw client-svc-descr?    string
      +--rw client-svc-customer? string
      +--rw resilience
      +--rw te-topology-identifier
        | +--rw provider-id?    te-types:te-global-id
        | +--rw client-id?      te-types:te-global-id
        | +--rw topology-id?    te-types:te-topology-id
      +--rw admin-status?        identityref
      +--rw src-access-ports
        | +--rw access-node-id? te-types:te-node-id
        | +--rw access-ltp-id?  te-types:te-tp-id
        | +--rw client-signal?  identityref
      +--rw dst-access-ports
        | +--rw access-node-id? te-types:te-node-id
        | +--rw access-ltp-id?  te-types:te-tp-id
        | +--rw client-signal?  identityref
      +--rw svc-tunnels* [tunnel-name]
        | +--rw tunnel-name     string
      +--ro operational-state?   identityref
      +--ro provisioning-state?  identityref
      +--ro creation-time?       yang:date-and-time
      +--ro last-updated-time?   yang:date-and-time

```

#### 5. YANG Code for Transport Network Client Signal

##### 5.1. The ETH Service YANG Code

This module imports typedefs and modules from [RFC6991], [RFC8294], [I-D.ietf-teas-yang-te-types].

```

<CODE BEGINS> file "ietf-eth-tran-service.yang"
module ietf-eth-tran-service {

  namespace "urn:ietf:params:xml:ns:yang:ietf-eth-tran-service";

  prefix "ethtsvc";

```



```
import ietf-yang-types {
  prefix "yang";
  //reference "RFC 6991 - Common YANG Data Types";
}

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

import ietf-eth-tran-types {
  prefix "eth-types";
  //reference "RFC XXXX - This Document.";
}

import ietf-routing-types {
  prefix "rt-types";
  //reference "RFC 8294 - Common YANG Data Types for the
  //          Routing Area";
}

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

    ID-draft editor:
      Haomian Zheng (zhenghaomian@huawei.com);
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      Xufeng Liu (Xufeng_Liu@jabil.com);
      Giuseppe Fioccola (giuseppe.fioccola@huawei.com);
  ";

description
  "This module defines a YANG data model for describing
  the Ethernet services.

  Copyright (c) 2019 IETF Trust and the persons
  identified as authors of the code. All rights reserved.
```

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```
revision 2019-03-11 {
  description
    "version -06 as an I-D";
  reference
    "draft-zheng-ccamp-client-signal-yang";
}

/*
 * Groupings
 */

grouping vlan-classification {
  description
    "A grouping which represents classification on an 802.1Q VLAN tag.";

  leaf tag-type {
    type etht-types:eth-tag-classify;
    description
      "The tag type used for VLAN classification.";
  }

  choice individual-bundling-vlan {
    description
      "VLAN based classification can be individual
      or bundling.";

    case individual-vlan {
      leaf vlan-value {
        type etht-types:vlanid;
        description
          "VLAN ID value.";
      }
    }

    case vlan-bundling {
      leaf vlan-range {
        type etht-types:vid-range-type;
        description
          "List of VLAN ID values.";
      }
    }
  }
}
```

```
}

grouping vlan-write {
  description
    "A grouping which represents push/pop operations
    of an 802.1Q VLAN tag.";

  leaf tag-type {
    type etht-types:eth-tag-type;
    description
      "The VLAN tag type to push/swap.";
  }
  leaf vlan-value {
    type etht-types:vlanid;
    description
      "The VLAN ID value to push/swap.";
  }
}

/*
 * To be added: this attribute is used when:
 * a) the ETH service has only one CoS (as in current version)
 * b) as a default when a mapping between a given CoS value
 *    and the PCP value is not defined (in future versions)
 */
leaf default-pcp {
  type uint8 {
    range "0..7";
  }
  description
    "The default Priority Code Point (PCP) value to push/swap";
}

grouping vlan-operations {
  description
    "A grouping which represents VLAN operations.";

  leaf pop-tags {
    type uint8 {
      range "1..2";
    }
    description
      "The number of VLAN tags to pop (or swap if used in
      conjunction with push-tags)";
  }
  container push-tags {
    description
      "The VLAN tags to push (or swap if used in
      conjunction with pop-tags)";
  }
}
```

```
    container outer-tag {
      presence
        "Indicates existence of the outermost VLAN tag to
        push/swap";

      description
        "The outermost VLAN tag to push/swap.";

      uses vlan-write;
    }
    container second-tag {
      must
        '../outer-tag/tag-type = "eth-types:s-vlan-tag-type" and ' +
        'tag-type = "eth-types:c-vlan-tag-type"'
      {
        error-message
          "
            When pushing/swapping two tags, the outermost tag must
            be specified and of S-VLAN type and the second
            outermost tag must be of C-VLAN tag type.
          ";
        description
          "
            For IEEE 802.1Q interoperability, when pushing/swapping
            two tags, it is required that the outermost tag exists
            and is an S-VLAN, and the second outermost tag is a
            C-VLAN.
          ";
      }

      presence
        "Indicates existence of a second outermost VLAN tag to
        push/swap";

      description
        "The second outermost VLAN tag to push/swap.";

      uses vlan-write;
    }
  }
}

grouping named-or-value-bandwidth-profile {
  description
    "A grouping to configure a bandwidth profile either by
    referencing a named bandwidth profile or by
    configuring the values of the bandwidth profile attributes.";
}
```

```
choice style {
  description
    "Whether the bandwidth profile is named or defined by value";

  case named {
    description
      "Named bandwidth profile.";
    leaf bandwidth-profile-name {
      type "string";
      description
        "Name of the bandwidth profile.";
    }
  }
  case value {
    description
      "Bandwidth profile configured by value.";
    uses etht-types:etht-bandwidth-profiles;
  }
}

grouping bandwidth-profiles {
  description
    "A grouping which represent bandwidth profile configuration.";

  choice direction {
    description
      "Whether the bandwidth profiles are symmetrical or
      asymmetrical";
    case symmetrical {
      description
        "The same bandwidth profile is used to describe both
        the ingress and the egress bandwidth profile.";
      container ingress-egress-bandwidth-profile {
        description
          "The bandwidth profile used in both directions.";
        uses named-or-value-bandwidth-profile;
      }
    }
    case asymmetrical {
      description
        "Ingress and egress bandwidth profiles can be specified.";
      container ingress-bandwidth-profile {
        description
          "The bandwidth profile used in the ingress direction.";
        uses named-or-value-bandwidth-profile;
      }
      container egress-bandwidth-profile {
```

```
        description
            "The bandwidth profile used in the egress direction.";
        uses named-or-value-bandwidth-profile;
    }
}
}

grouping etht-svc-access-parameters {
    description
        "ETH services access parameters";

    leaf access-node-id {
        type te-types:te-node-id;
        description
            "The identifier of the access node in
             the ETH topology.";
    }
    leaf access-ltp-id {
        type te-types:te-tp-id;
        description
            "The TE link termination point identifier, used
             together with access-node-id to identify the
             access LTP.";
    }
    leaf access-role {
        type identityref {
            base etht-types:access-role;
        }
        description
            "Indicate the role of access, e.g., working or protection. ";
    }
}

container pm-config {
    uses pm-config-grouping;
    description
        "This grouping is used to set the threshold value for
         performance monitoring. ";
}

container state {
    config false;
    description
        "The state is used to monitor the status of service. ";
    leaf operational-state {
        type identityref {
            base te-types:tunnel-state-type;
        }
    }
}
```

```
        description
          "Indicating the operational state of client signal. ";
      }
      leaf provisioning-state {
        type identityref {
          base te-types:lsp-state-type;
        }
        description
          "Indicating the provisional state of client signal,
          especially when there is a change, i.e., revise, create. ";
      }
    }

    leaf performance {
      type identityref {
        base etht-types:performance;
      }
      config false;
      description
        "Performance Monitoring for the service. ";
    }
  }

  grouping etht-svc-tunnel-parameters {
    description
      "ETH services tunnel parameters";

    leaf tunnel-name {
      type string;
      description
        "TE service tunnel instance name.";
    }
    choice svc-multiplexing-tag {
      description
        "Service multiplexing is optional and flexible.";

      case other {
        /*
         placeholder to support proprietary multiplexing
         (for further discussion)
        */
      }

      case none {
        /* no additional information is needed */
      }
    }
  }
}
```

```
    case vlan-tag {
      /*
       No additional information is needed
       The C-Tag or S-Tag used for service mulitplexing is defined
       by the VLAN classification and operations configured in the
       etht-svc-access-parameters grouping
      */
    }

    case pw-segment {
      uses pw-segment-grouping;
    }
  }

/*
 * Open issue: can we constraints it to be used only with mp services?
 */
  leaf src-split-horizon-group {
    type string;
    description
      "Identify a split horizon group at the Tunnel source TTP";
  }
  leaf dst-split-horizon-group {
    type string;
    description
      "Identify a split horizon group at the Tunnel destination TTP";
  }
}

grouping etht-svc-pm-threshold_config {
  description
    "Configuraiton parameters for Ethernet service PM thresholds.";

  leaf sending-rate-high {
    type uint64;
    description
      "High threshold of packet sending rate in kbps.";
  }
  leaf sending-rate-low {
    type uint64;
    description
      "Low threshold of packet sending rate in kbps.";
  }
  leaf receiving-rate-high {
    type uint64;
    description
      "High threshold of packet receiving rate in kbps.";
  }
}
```



```
    leaf receiving-rate-low {
        type uint64;
        description
            "Low threshold of packet receiving rate in kbps.";
    }
}

grouping etht-svc-pm-stats {
    description
        "Ethernet service PM statistics.";

    leaf sending-rate-too-high {
        type uint32;
        description
            "Counter that indicates the number of times the sending rate is above the high threshold";
    }
    leaf sending-rate-too-low {
        type uint32;
        description
            "Counter that indicates the number of times the sending rate is below the low threshold";
    }
    leaf receiving-rate-too-high {
        type uint32;
        description
            "Counter that indicates the number of times the receiving rate is above the high threshold";
    }
    leaf receiving-rate-too-low {
        type uint32;
        description
            "Counter that indicates the number of times the receiving rate is below the low threshold";
    }
}

grouping etht-svc-instance_config {
    description
        "Configuraiton parameters for Ethernet services.";

    leaf etht-svc-name {
        type string;
        description
            "Name of the ETH service.";
    }

    leaf etht-svc-id {
        type string;
        description
            "The Identifier of the ETH service.";
    }
}
```

```
leaf etht-svc-descr {
    type string;
    description
        "Description of the ETH service.";
}

leaf etht-svc-customer {
    type string;
    description
        "Customer of the ETH service.";
}

leaf etht-svc-type {
    type etht-types:service-type;
    description
        "Type of ETH service (p2p, mp2mp or rmp).";
    /* Add default as p2p */
}

leaf etht-svc-lifecycle {
    type etht-types:lifecycle-status;
    description
        "Lifecycle state of ETH service.";
    /* Add default as installed */
}

uses te-types:te-topology-identifier;

uses resilience-grouping;

list etht-svc-end-points {
    key etht-svc-end-point-name;
    description
        "The logical end point for the ETH service. ";
    uses etht-svc-end-point-grouping;
}

list etht-svc-tunnels {
    key tunnel-name;
    description
        "List of the TE Tunnels supporting the ETH
        service.";

    uses etht-svc-tunnel-parameters;
}

leaf admin-status {
    type identityref {
```

```
        base te-types:tunnel-admin-state-type;
    }
    default te-types:tunnel-admin-state-up;
    description "ETH service administrative state.";
}

grouping etht-svc-instance_state {
    description
        "State parameters for Ethernet services.";

    leaf operational-state {
        type identityref {
            base te-types:tunnel-state-type;
        }
        default te-types:tunnel-state-up;
        description "ETH service operational state.";
    }
    leaf provisioning-state {
        type identityref {
            base te-types:lsp-state-type;
        }
        description "ETH service provisioning state.";
    }
    leaf creation-time {
        type yang:date-and-time;
        description
            "Time of ETH service creation.";
    }
    leaf last-updated-time {
        type yang:date-and-time;
        description
            "Time of ETH service last update.";
    }
}

/*
 * Data nodes
 */

container etht-svc {
    description
        "ETH services.";

    container globals {
        description
            "Globals Ethernet configuration data container";
    }
}
```

```
list named-bandwidth-profiles {
  key bandwidth-profile-name;
  description
    "List of named bandwidth profiles used by
    Ethernet services.";

  leaf bandwidth-profile-name {
    type string;
    description
      "Name of the bandwidth profile.";
  }
  uses etht-types:etht-bandwidth-profiles;
}

list etht-svc-instances {
  key etht-svc-name;
  description
    "The list of p2p ETH service instances";

  uses etht-svc-instance_config;

  container state {
    config false;
    description
      "Ethernet Service states.";

    uses etht-svc-instance_state;
  }
}

grouping resilience-grouping {
  description
    "Grouping for resilience configuration. ";
  container resilience {
    description
      "To configure the data plane protection parameters,
      currently a placeholder only, future candidate attributes
      include, Revert, WTR, Hold-off Timer, ...";
  }
}

grouping etht-svc-end-point-grouping {
  description
    "Grouping for the end point configuration.";
  leaf etht-svc-end-point-name {
    type string;
  }
}
```

```
    description
      "The name of the logical end point of ETH service. ";
  }

  leaf etht-svc-end-point-id {
    type string;
    description
      "The identifier of the logical end point of ETH service.";
  }

  leaf etht-svc-end-point-descr {
    type string;
    description
      "The description of the logical end point of ETH service. ";
  }

  leaf topology-role {
    type identityref {
      base etht-types:topology-role;
    }
    description
      "Indicating the underlay topology role, e.g., hub,spoke, any-to-any ";
  }

  container resilience {
    description
      "Placeholder for resilience configuration, for future study. ";
  }

  list etht-svc-access-points {
    key access-point-id;
    min-elements "1";
  }
/*
Open Issue:
Is it possible to limit the max-elements only for p2p services?

    max-elements "2";
*/
  description
    "List of the ETH trasport services access point instances.";

  leaf access-point-id {
    type string;
    description
      "ID of the service access point instance";
  }
  uses etht-svc-access-parameters;
}
```

```
leaf service-classification-type {
  type identityref {
    base etht-types:service-classification-type;
  }
  description
    "Service classification type.";
}

choice service-classification {
  description
    "Access classification can be port-based or
    VLAN based.";

  case port-classification {
    /* no additional information */
  }

  case vlan-classification {
    container outer-tag {
      presence "The outermost VLAN tag exists";
      description
        "Classifies traffic using the outermost VLAN tag.";

      uses vlan-classification;
    }
    container second-tag {
      must
        '../outer-tag/tag-type = "etht-types:classify-s-vlan" and ' +
        'tag-type = "etht-types:classify-c-vlan"'
      {
        error-message
          "
            When matching two tags, the outermost tag must be
            specified and of S-VLAN type and the second
            outermost tag must be of C-VLAN tag type.
          ";
        description
          "
            For IEEE 802.1Q interoperability, when matching two
            tags, it is required that the outermost tag exists
            and is an S-VLAN, and the second outermost tag is a
            C-VLAN.
          ";
      }
      presence "The second outermost VLAN tag exists";

      description
        "Classifies traffic using the second outermost VLAN tag.";
    }
  }
}
```

```
        uses vlan-classification;
    }
}

/*
 * Open issue: can we constraints it to be used only with mp services?
 */
leaf split-horizon-group {
    type string;
    description "Identify a split horizon group";
}

uses bandwidth-profiles;

container vlan-operations {
    description
        "Configuration of VLAN operations.";
    choice direction {
        description
            "Whether the VLAN operations are symmetrical or
            asymmetrical";
        case symmetrical {
            container symmetrical-operation {
                uses vlan-operations;
                description
                    "Symmetrical operations.
                    Expressed in the ingress direction, but
                    the reverse operation is applied to egress traffic";
            }
        }
        case asymmetrical {
            container asymmetrical-operation {
                description "Asymmetrical operations";
                container ingress {
                    uses vlan-operations;
                    description "Ingress operations";
                }
                container egress {
                    uses vlan-operations;
                    description "Egress operations";
                }
            }
        }
    }
}
}
```

```
grouping pm-config-grouping {
  description
    "Grouping used for Performance Monitoring Configuration. ";
  leaf pm-enable {
    type boolean;
    description
      "Whether to enable the performance monitoring.";
  }

  leaf sending-rate-high {
    type uint64;
    description
      "The upperbound of sending rate.";
  }

  leaf sending-rate-low {
    type uint64;
    description
      "The lowerbound of sending rate.";
  }

  leaf receiving-rate-high {
    type uint64;
    description
      "The upperbound of receiving rate.";
  }

  leaf receiving-rate-low {
    type uint64;
    description
      "The lowerbound of receiving rate.";
  }
}

grouping pw-segment-grouping {
  description
    "Grouping used for PW configuration. ";
  leaf pw-id {
    type string;
    description
      "The Identifier information of pseudowire. ";
  }

  leaf pw-name {
    type string;
    description
      "The name information of pseudowire.";
  }
}
```



```
leaf transmit-label {
  type rt-types:mpls-label;
  description
    "Transmit label information in PW. ";
}

leaf receive-label {
  type rt-types:mpls-label;
  description
    "Receive label information in PW. ";
}

leaf encapsulate-type {
  type identityref {
    base eth-types:encapsulate-type;
  }
  description
    "The encapsulation type, raw or tag. ";
}

leaf oper-status {
  type identityref {
    base te-types:tunnel-state-type;
  }
  config false;
  description
    "The operational state of the PW segment. ";
}

container ingress-bandwidth-profile {
  description
    "Bandwidth Profile for ingress. ";
  uses pw-segment-named-or-value-bandwidth-profile;
}

grouping pw-segment-named-or-value-bandwidth-profile {
  description
    "A grouping to configure a bandwidth profile either by
    referencing a named bandwidth profile or by
    configuring the values of the bandwidth profile attributes.";
  choice style {
    description
      "Whether the bandwidth profile is named or defined by value";
    case named {
      description
        "Named bandwidth profile.";
      leaf bandwidth-profile-name {
```

```
        type leafref {
            path "/ethtsvc:eth-t-svc/ethtsvc:globals/ethtsvc:named-bandwidth-profiles/ethtsvc:bandwidth-profile-name";
        }
        description
            "Name of the bandwidth profile.";
    }
}
case value {
    description
        "Bandwidth profile configured by value.";
    uses eth-t-types:pw-segement-bandwidth-profile-grouping;
}
}
}
<CODE ENDS>
```

## 5.2. YANG Code for ETH transport type

This module references a few documents including [RFC2697], [RFC2698], [RFC4115], [IEEE802.1ad], [IEEE802.1q] and [MEF10].

```
<CODE BEGINS> file "ietf-eth-tran-types.yang"
module ietf-eth-tran-types {

    namespace "urn:ietf:params:xml:ns:yang:ietf-eth-tran-types";

    prefix "eth-t-types";

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

            ID-draft editor:
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            Xufeng Liu (Xufeng_Liu@jabil.com);
            Giuseppe Fioccola (giuseppe.fioccola@huawei.com);
        ";
```

description

"This module defines the ETH transport types.

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

revision 2019-03-11 {

description

"version -06 as an I-D";

reference

"draft-zheng-ccamp-client-signal-yang";

}

/\*

\* Identities

\*/

identity eth-vlan-tag-type {

description

"ETH VLAN tag type.";

}

identity c-vlan-tag-type {

base eth-vlan-tag-type;

description

"802.1Q Customer VLAN";

}

identity s-vlan-tag-type {

base eth-vlan-tag-type;

description

"802.1Q Service VLAN (QinQ)";

}

identity service-classification-type {

description

"Service classification.";

}

identity port-classification {

base service-classification-type;

```
    description
      "Port classification.";
  }

  identity vlan-classification {
    base service-classification-type;
    description
      "VLAN classification.";
  }

  identity eth-vlan-tag-classify {
    description
      "VLAN tag classification.";
  }

  identity classify-c-vlan {
    base eth-vlan-tag-classify;
    description
      "Classify 802.1Q Customer VLAN tag.
       Only C-tag type is accepted";
  }

  identity classify-s-vlan {
    base eth-vlan-tag-classify;
    description
      "Classify 802.1Q Service VLAN (QinQ) tag.
       Only S-tag type is accepted";
  }

  identity classify-s-or-c-vlan {
    base eth-vlan-tag-classify;
    description
      "Classify S-VLAN or C-VLAN tag-classify.
       Either tag is accepted";
  }

  identity bandwidth-profile-type {
    description
      "Bandwidth Profile Types";
  }

  identity mef-10-bwp {
    base bandwidth-profile-type;
    description
      "MEF 10 Bandwidth Profile";
  }

  identity rfc-2697-bwp {
```

```
    base bandwidth-profile-type;
    description
        "RFC 2697 Bandwidth Profile";
}

identity rfc-2698-bwp {
    base bandwidth-profile-type;
    description
        "RFC 2698 Bandwidth Profile";
}

identity rfc-4115-bwp {
    base bandwidth-profile-type;
    description
        "RFC 4115 Bandwidth Profile";
}

identity service-type {
    description
        "Type of Ethernet service.";
}

identity p2p-svc {
    base service-type;
    description
        "Ethernet point-to-point service (EPL, EVPL).";
}

identity rmp-svc {
    base service-type;
    description
        "Ethernet rooted-multitpoint service (E-TREE, EP-TREE).";
}

identity mp2mp-svc {
    base service-type;
    description
        "Ethernet multipoint-to-multitpoint service (E-LAN, EP-LAN).";
}

identity lifecycle-status {
    description
        "Lifecycle Status.";
}

identity installed {
    base lifecycle-status;
    description
```

```
        "Installed.";
    }

    identity planned {
        base lifecycle-status;
        description
            "Planned.";
    }

    identity pending-removal {
        base lifecycle-status;
        description
            "Pending Removal.";
    }

    /*
     * Type Definitions
     */

    typedef eth-tag-type {
        type identityref {
            base eth-vlan-tag-type;
        }
        description
            "Identifies a specific ETH VLAN tag type.";
    }

    typedef eth-tag-classify {
        type identityref {
            base eth-vlan-tag-classify;
        }
        description
            "Identifies a specific VLAN tag classification.";
    }

    typedef vlanid {
        type uint16 {
            range "1..4094";
        }
        description
            "The 12-bit VLAN-ID used in the VLAN Tag header.";
    }

    typedef vid-range-type {
        type string {
            pattern "([1-9][0-9]{0,3}(-[1-9][0-9]{0,3})?" +
                "(,[1-9][0-9]{0,3}(-[1-9][0-9]{0,3})?)*)";
        }
    }
```

```
description
  "A list of VLAN Ids, or non overlapping VLAN ranges, in
  ascending order, between 1 and 4094.
  This type is used to match an ordered list of VLAN Ids, or
  contiguous ranges of VLAN Ids. Valid VLAN Ids must be in the
  range 1 to 4094, and included in the list in non overlapping
  ascending order.

  For example: 1,10-100,50,500-1000";
}

typedef bandwidth-profile-type {
  type identityref {
    base bandwidth-profile-type;
  }
  description
    "Identifies a specific Bandwidth Profile type.";
}

typedef service-type {
  type identityref {
    base service-type;
  }
  description
    "Identifies the type of Ethernet service.";
}

typedef lifecycle-status {
  type identityref {
    base lifecycle-status;
  }
  description
    "Identifies the Lifecycle Status .";
}

/*
 * Grouping Definitions
 */

grouping etht-bandwidth-profiles {
  description
    "Bandwidth profile configuration paramters.";

  leaf bandwidth-profile-type {
    type etht-types:bandwidth-profile-type;
    description
      "The type of bandwidth profile.";
  }
}
```

```
leaf CIR {
    type uint64;
    description
        "Committed Information Rate in Kbps";
}
leaf CBS {
    type uint64;
    description
        "Committed Burst Size in in KBytes";
}
leaf EIR {
    type uint64;
    /* Need to indicate that EIR is not supported by RFC 2697

    must
        ' ../bw-profile-type = "mef-10-bwp" or ' +
        ' ../bw-profile-type = "rfc-2698-bwp" or ' +
        ' ../bw-profile-type = "rfc-4115-bwp"'

    must
        ' ../bw-profile-type != "rfc-2697-bwp"'
    */
    description
        "Excess Information Rate in Kbps
        In case of RFC 2698, PIR = CIR + EIR";
}
leaf EBS {
    type uint64;
    description
        "Excess Burst Size in KBytes.
        In case of RFC 2698, PBS = CBS + EBS";
}
leaf color-aware {
    type boolean;
    description
        "Indicates weather the color-mode is color-aware or color-blind.";
}
leaf coupling-flag {
    type boolean;
    /* Need to indicate that Coupling Flag is defined only for MEF 10

    must
        ' ../bw-profile-type = "mef-10-bwp"'
    */
    description
        "Coupling Flag.";
}
}
```



```
identity topology-role {
  description
    "The rold of underlay topology, e.g., hub, spoke, any-to-any. ";
}

identity resilience {
  description
    "Placeholder for resilience information in data plane, for future study. ";
}

identity access-role {
  description
    "Indicating whether the access is a working or protection access.";
}

identity performance {
  description
    "Placeholder for performace information, for future study.";
}

identity encaplate-type {
  description
    "Indicating how the service is encapsulated (to PW), e.g, raw or tag. ";
}

grouping pw-segement-bandwidth-profile-grouping {
  description
    "bandwidth profile grouping for PW segment. ";
  leaf bandwidth-profile-type {
    type eth-types:bandwidth-profile-type;
    description
      "The type of bandwidth profile.";
  }
  leaf CIR {
    type uint64;
    description
      "Committed Information Rate in Kbps";
  }
  leaf CBS {
    type uint64;
    description
      "Committed Burst Size in in KBytes";
  }
  leaf EIR {
    type uint64;
    /* Need to indicate that EIR is not supported by RFC 2697

    must
```

```
    '..../bw-profile-type = "mef-10-bwp" or ' +
    '..../bw-profile-type = "rfc-2698-bwp" or ' +
    '..../bw-profile-type = "rfc-4115-bwp"'

    must
      '..../bw-profile-type != "rfc-2697-bwp"'
    */
    description
      "Excess Information Rate in Kbps
      In case of RFC 2698, PIR = CIR + EIR";
  }
  leaf EBS {
    type uint64;
    description
      "Excess Burst Size in KBytes.
      In case of RFC 2698, PBS = CBS + EBS";
  }
}

grouping eth-bandwidth {
  description
    "Available bandwidth for ethernet.";
  leaf eth-bandwidth {
    type uint64 {
      range "0..100000000000";
    }
    units "Kbps";
    description
      "Available bandwidth value expressed in kilobits per second";
  }
}

grouping eth-label-restriction {
  description
    "Label Restriction for ethernet.";
  leaf tag-type {
    type eth-types:eth-tag-type;
    description "VLAN tag type.";
  }
  leaf priority {
    type uint8;
    description "priority.";
  }
}

grouping eth-label {
  description
    "Label for ethernet.";
  leaf vlanid {
```

```

        type etht-types:vlanid;
        description
            "VLAN tag id.";
    }
}

grouping eth-label-step {
    description "Label step for Ethernet VLAN";
    leaf eth-step {
        type uint16 {
            range "1..4095";
        }
        default 1;
        description
            "Label step which represent possible increments for
            an Ethernet VLAN tag.";
        reference
            "IEEE 802.1ad: Provider Bridges.";
    }
}
}
}

<CODE ENDS>

```

### 5.3. Other Transport Network client signal YANG Code

This module imports typedefs and modules from [RFC6991], [I-D.ietf-ccamp-otn-tunnel-model], [I-D.ietf-teas-yang-te-types].

```

<CODE BEGINS> file "ietf-trans-client-service.yang"
module ietf-trans-client-service {
    /* TODO: FIXME */
    //yang-version 1.1;

    namespace "urn:ietf:params:xml:ns:yang:ietf-trans-client-service";
    prefix "clntsvc";

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

    import ietf-otn-types {
        prefix "otn-types";
        //reference "RFC XXXX - OTN Tunnel YANG Model";
    }
}

```

```
import ietf-yang-types {
  prefix "yang";
  //reference "RFC 6991 - Common YANG Data Types";
}

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contact
  "
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      Giuseppe Fioccola (giuseppe.fioccola@huawei.com);
  ";

description
  "This module defines a YANG data model for describing
  transport client services.

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  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).";

revision 2019-03-11 {
  description
    "version -06 as an I-D";
  reference
    "draft-zheng-ccamp-client-signal-yang";
}

/*
 * Groupings
 */
grouping client-svc-access-parameters {
  description
    "Transport client services access parameters";
```

```
leaf access-node-id {
  type te-types:te-node-id;
  description
    "The identifier of the access node in the underlying
    transport topology.";
}

leaf access-ltp-id {
  type te-types:te-tp-id;
  description
    "The TE link termination point identifier, used together with
    access-node-id to identify the access LTP.";
}

leaf client-signal {
  type identityref {
    base otn-types:client-signal;
  }
  description
    "Identifiies the client signal type associated with this port";
}

grouping client-svc-tunnel-parameters {
  description
    "Transport client services tunnel parameters";

  leaf tunnel-name {
    type string;
    description
      "TE service tunnel instance name.";
  }
}

grouping client-svc-instance_config {
  description
    "Configuraiton parameters for client services.";
  leaf client-svc-name {
    type string;
    description
      "Identifier of the p2p transport client service.";
  }

  leaf client-svc-id {
    type string;
    description
      "Name of the p2p transport client service.";
  }
}
```

```
leaf client-svc-descr {
    type string;
    description
        "Description of the transport client service.";
}

leaf client-svc-customer {
    type string;
    description
        "Customer of the transport client service.";
}

container resilience {
    description "";
}

uses te-types:te-topology-identifier;

leaf admin-status {
    type identityref {
        base te-types:tunnel-admin-state-type;
    }
    default te-types:tunnel-admin-state-up;
    description "Client service administrative state.";
}

container src-access-ports {
    description
        "Source access port of a client service.";
    uses client-svc-access-parameters;
}

    container dst-access-ports {
        description
            "Destination access port of a client service.";
        uses client-svc-access-parameters;
    }

    list svc-tunnels {
        key tunnel-name;
        description
            "List of the TE Tunnels supporting the client service.";
        uses client-svc-tunnel-parameters;
    }
}

grouping client-svc-instance_state {
    description
```

```
    "State parameters for client services.";
  leaf operational-state {
    type identityref {
      base te-types:tunnel-state-type;
    }
    config false;
    description "Client service operational state.";
  }
  leaf provisioning-state {
    type identityref {
      base te-types:lsp-state-type;
    }
    config false;
    description "Client service provisioning state.";
  }
  leaf creation-time {
    type yang:date-and-time;
    config false;
    description "The time of the service be created.";
  }
  leaf last-updated-time {
    type yang:date-and-time;
    config false;
    description "The time of the service's latest update.";
  }
}

/*
 * Data nodes
 */

container client-svc {
  description
    "Transport client services.";

  list client-svc-instances {
    key client-svc-name;
    description
      "The list of p2p transport client service instances";

    uses client-svc-instance_config;
    uses client-svc-instance_state;
  }
}

<CODE ENDS>
```

## 6. Considerations and Open Issue

Editor Notes: This section is used to note temporary discussion/conclusion that to be fixed in the future version, and will be removed before publication. We currently categorize all the client signal types into transparent and non-transparent, with separate models. There was consensus that no common model is needed for these two categories. Further Alignment with RFC8407 would be required before publication.

## 7. IANA Considerations

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

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

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

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

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

name: ietf-eth-tran-service  
namespace: urn:ietf:params:xml:ns:yang:ietf-eth-tran-service  
prefix: ethtsvc  
reference: RFC XXXX: A YANG Data Model for Transport Network Client Signal  
s

name: ietf-eth-tran-types  
namespace: urn:ietf:params:xml:ns:yang:ietf-eth-tran-types  
prefix: etht-types  
reference: RFC XXXX: A YANG Data Model for Transport Network Client Signal  
s

name: ietf-trans-client-service  
namespace: urn:ietf:params:xml:ns:yang:ietf-trans-client-service  
prefix: clntsvc  
reference: RFC XXXX: A YANG Data Model for Transport Network Client Signal  
s



## 8. Manageability Considerations

TBD.

## 9. Security Considerations

The data following the model defined in this document is exchanged via, for example, the interface between an orchestrator and a network domain controller.

The YANG module defined in this document can be accessed via the RESTCONF protocol defined in [RFC8040], or maybe via the NETCONF protocol [RFC6241].

There are a number of data nodes defined in the YANG module which 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., POST) to these data nodes without proper protection can have a negative effect on network operations.

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