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G. Galimberti, Ed.
Cisco
R. Kunze
Deutsche Telekom
D. Hiremagalur, Ed.
G. Grammel, Ed.
Juniper
July 8, 2019

A YANG model to manage the optical interface parameters for an external
transponder in a WDM network
draft-ietf-ccamp-dwdm-if-param-yang-01

Abstract

This memo defines a Yang model related to the Optical Transceiver parameters characterising coherent 100G and above interfaces. 100G and above Transceivers support coherent modulation, multiple modulation formats, multiple FEC codes including some not yet specified (or by in phase of specification by) ITU-T G.698.2 [ITU.G698.2] or any other ITU-T recommendation. More context about the state of the Coherent transceivers is described in draft-many-coherent-DWDM-if-control. Use cases are described in RFC7698.

The Yang model defined in this memo can be used for Optical Parameters monitoring and/or configuration of the endpoints of a multi-vendor IaDI optical link. 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 and obsolete the SNMP mib module defined in draft-galikunze-ccamp-dwdm-if-snmp-mib for managing single channel optical interface parameters of DWDM applications, using the approach specified in G.698.2. This model supports parameters to characterize coherent transceivers found in current implementations to specify the mode of operation. As application identifiers like those specified in ITU-T G.874.1 [ITU.G874.1] are not available we use mode templates instead. A mode template describes transceiver characteristics in detail and can be identified by a mode-id.

This draft refers and supports the RFC7698 and draft-many-coherent-DWDM-if-control.

The YANG model describing and extending the optical parameters allows different vendors and operators to retrieve, provision and exchange information across the multi-vendor IaDI interfaces in an abstract manner.

The they concept introduced by this YANG model is the notion of a mode. A mode is a combination of parameters or parameter ranges that is supported by a transceiver. As an example, operating a device in QPSK mode may use a different FEC and requires less OSNR to reach the FEC limit than the same transceiver operating in QAM16 mode. Given the number of parameters and their possible combinations it is important for vendors to be able to qualify a set of combinations which is the basis to define a mode. The YANG model furthermore provides means to selecting one mode as current-mode from that pre-defined list of modes supported by the transceiver module. Once selected, current-opt-if-och-mode-params provide the means to configure specific parameters at run time and retrieve actual parameters from the module. For example, the frequency is a parameter that can be set within min/max boundaries set by the current mode. Laser Temperature however is a ro parameter available at run-time that can be checked against the mode boundaries and may trigger an event.

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].

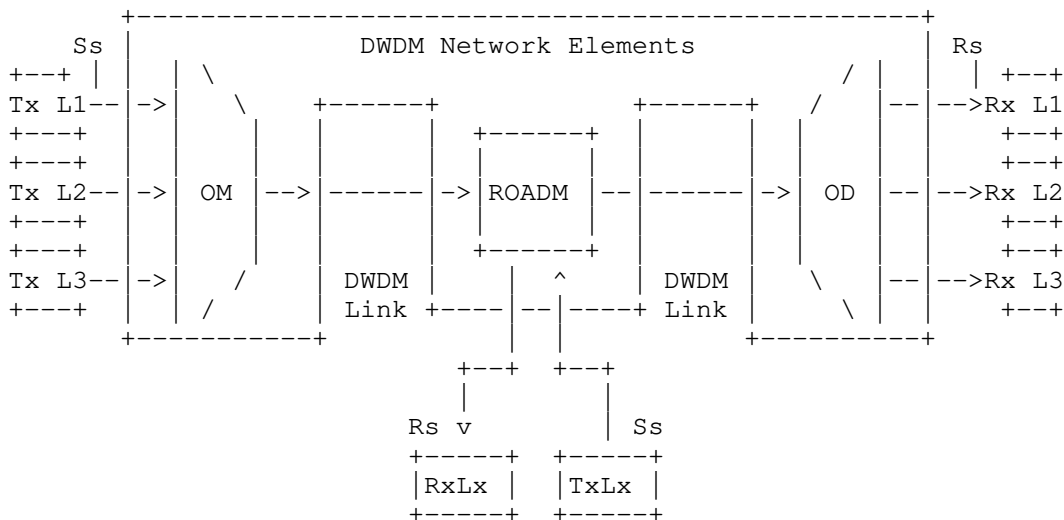
This memo specifies a Yang model for optical interfaces.

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. 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

4.1. 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.

Definitions of the optical parameters are provided below to increase the readability of the document.

4.1.1. Parameters at Ss

output-power:

The mean launched power at Ss is the average power (in dBm) of a pseudo-random data sequence coupled into the DWDM link.

central frequency:

This parameter indicates the Central frequency value that Ss and Rs will be set to work (in THz)

4.1.2. Interface at point Rs

input-power:

The average received power (in dBm) at point Rs.

Curr-OSNR:

Current Optical Signal to Noise Ratio (OSNR) estimated at Rx Transceiver port.

Curr-q-factor:

"Q" factor estimated at Rx Transceiver port.

4.2. Use Cases

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

4.3. Optical Interface for external transponder in a WDM network

The ietf-ext-xponder-wdm-if is an augment to the ietf-interface. It allows the user to set the operating mode of transceivers as well as other operational parameters. The module provides also threshold settings and notifications to supervise measured parameters and notify the client.

```
module: ietf-ext-xponder-wdm-if
  augment /if:interfaces/if:interface:
    +--rw optIfOChRsSs
    +--rw if-current-mode
```

```

+--ro mode-id? string
+--ro application-identifier? string
+--ro min-central-frequency? uint32
+--ro max-central-frequency? uint32
+--ro min-input-power? dbm-t
+--ro max-input-power? dbm-t
+--ro min-output-power? dbm-t
+--ro max-output-power? dbm-t
+--ro min-osnr-margin? int32
+--ro min-q-margin? int32
+--ro fec-info? string
+--ro fec-bitrate? string
+--ro fec-gain? string
+--ro fec-ber-mantissa-threshold? uint32
+--ro fec-ber-exponent-threshold? int32
+--ro number-of-lanes? uint32
+--ro min-laser-temperature? int32
+--ro max-laser-temperature? int32
+--ro max-total-rx-optical-power? dbm-t
+--ro max-chromatic-dispersion? int32
+--ro max-diff-group-delay? int32
+--ro modulation-format? string
+--ro bits-per-symbol? uint32
+--ro num-symbols-in-alphabet? uint32
+--ro symbols-index? uint32
+--ro if-supported-mode
+--ro number-of-modes-supported? uint32
+--ro mode-list* [mode-id]
+--ro mode-id? string
+--ro application-identifer? string
+--ro min-central-frequency? uint32
+--ro max-central-frequency? uint32
+--ro min-channel-input-power? dbm-t
+--ro max-channel-input-power? dbm-t
+--ro min-channel-output-power? dbm-t
+--ro max-channel-output-power? dbm-t
+--ro min-osnr-margin? int32
+--ro min-q-margin? int32
+--ro fec-info? string
+--ro fec-bitrate? string
+--ro fec-gain? string
+--ro pre-fec-ber-mantissa-threshold? uint32
+--ro pre-fec-ber-exponent-threshold? int32
+--ro number-of-lanes? uint32
+--ro min-laser-temperature? int32
+--ro max-laser-temperature? int32
+--ro max-total-rx-optical-power? dbm-t
+--ro max-chromatic-dispersion? int32

```

```

    |      +---ro max-diff-group-delay?      int32
    |      +---ro modulation-format?        string
    |      +---ro baud-rate?                 string
    |      +---ro bits-per-symbol?           uint32
    |      +---ro num-symbols-in-alphabet?   uint32
    |      +---ro symbols-index?             uint32
+---rw current-opt-if-och-mode-params
    |      +---rw mode-id?                   string
    |      +---rw central-frequency?         uint32
    |      +---rw channel-output-power?      int32
    |      +---ro channel-input-power?       int32
    |      +---ro total-input-power?         int32
    |      +---rw min-fec-ber-mantissa-threshold? uint32
    |      +---rw min-fec-ber-exponent-threshold? int32
    |      +---rw max-fec-ber-mantissa-threshold? uint32
    |      +---rw max-fec-ber-exponent-threshold? int32
    |      +---rw number-of-tcas-supported?   uint32
    |      +---rw mode-list* [tca-type]
    |      |      +---rw tca-type            opt-if-och-tca-types
    |      |      +---rw min-threshold?      int32
    |      |      +---rw max-threshold?      int32
    |      +---ro cur-osnr?                  int32
    |      +---ro cur-q-factor?              int32
    |      +---ro uncorrected-words?         uint64
    |      +---ro pre-fec-ber-mantissa?      uint32
    |      +---ro pre-fec-ber-exponent?      int32

```

notifications:

```

+---n opt-if-och-central-frequency-change
    |      +---ro if-name?    -> /if:interfaces/interface/name
    |      +---ro new-opt-if-och-central-frequency
    |      |      +---ro central-frequency?          uint32
+---n opt-if-och-mode-change
    |      +---ro if-name?    -> /if:interfaces/interface/name
    |      +---ro mode-id?           string
+---n opt-if-och-min-tca
    |      +---ro if-name?    -> /if:interfaces/interface/name
    |      +---ro tca-type?    opt-if-och-tca-types

```

5. Structure of the Yang Module

ietf-ext-xponder-wdm-if is a top level model for the support of this feature.

6. Yang Module

The ietf-ext-xponder-wdm-if is defined as an extension to ietf interfaces.

```
<CODE BEGINS> file "ietf-ext-xponder-wdm-if.yang"

module ietf-ext-xponder-wdm-if {
  namespace "urn:ietf:params:xml:ns:yang:ietf-ext-xponder-wdm-if";
  prefix ietf-ext-xponder-wdm-if;

  import ietf-interfaces {
    prefix if;
  }

  organization
    "IETF CCAMP
    Working Group";

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

    Editor:   Dharini Hiremagalur
              <mailto:dharithi@juniper.net>";

  description
    "This module contains a collection of YANG definitions for
    configuring Optical interfaces.

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

  revision "2019-07-08" {
    description
      "Revision 1.2";
    reference
      "";
  }
}
```



```
revision "2018-10-22" {
    description
        "Revision 1.2";
    reference
        "";
}

revision "2018-03-06" {
    description
        "Revision 1.1";
    reference
        "";
}

revision "2017-03-06" {
    description
        "Revision 1.0";
    reference
        "";
}

revision "2016-03-17" {
    description
        "Initial revision.";
    reference
        "";
}

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

typedef opt-if-och-tca-types {

    type enumeration {
        enum max-laser-linewdt {
            description " The maximum laser linewidth";
        }
        enum min-tx-power-tca {
            description " The min tx power tca";
        }
        enum max-tx-power-tca {
            description " The min tx power tca";
        }
    }
}
```

```
    }
    enum min-rx-power-tca{
        description " The min tx power tca";
    }
    enum max-rx-power-tca{
        description " The min tx power tca";
    }
    enum max-pol-power-diff-tca{
        description " The power diff. between polariz. tca";
    }
    enum max-pol-skew-diff-tca{
        description " The Skew between the two polariz. tca";
    }
    enum min-frequency-offset-tca{
        description " Min Frequency offset tca";
    }
    enum max-frequency-offset-tca{
        description " Max Frequency offset tca";
    }
    enum min-osnr-tca{
        description " Min OSNR tca";
    }
    enum max-osnr-tca{
        description " Max OSNR tca";
    }
    enum min-laser-temperature-tca{
        description " The min tx power tca";
    }
    enum max-laser-temperature-tca{
        description " Temperature tca";
    }
    enum min-fec-ber-tca{
        description " Min Pre Fec BER tca";
    }
    enum max-fec-ber-tca{
        description " Max Pre Fec BER tca";
    }
    enum min-q-tca{
        description "Min Q tca";
    }
    enum max-q-tca {
        description "Max Q tca";
    }
    }
    description " The different types of TCA's";
}
```

```
grouping opt-if-och-power {
  description "Interface optical Power";
  leaf channel-output-power {
    type int32;
    units ".01dbm";
    description "The output power for this interface
                  in .01 dBm.
                  The setting of the output power is
                  optional";
  }

  leaf channel-input-power {
    type int32;
    units ".01dbm";
    config false;
    description "The current channel input power of this
                  interface";
  }
  leaf total-input-power {
    type int32;
    units ".01dbm";
    config false;
    description "The total input power of this
                  interface";
  }
}

grouping opt-if-och-tca-thresholds {
  description "Thresholds for TCA's";
  leaf tca-type {
    type opt-if-och-tca-types;
    description "type of the TCA eg TX Power";
  }
  leaf min-threshold {
    type int32;
    description " A TCA is generated if the variable is
                  less than this value";

  }
  leaf max-threshold {
    type int32;
    description " A TCA is generated if the variable is
                  more than this value";
  }
}

grouping opt-if-och-fec {
  description "Fec info";
```

```
    leaf fec-info {
      type string {
        length "1..255";
      }
      config false;
      description
        "Fec Type - eg GFEC";
    }
    leaf fec-bitrate {
      type string {
        length "1..255";
      }
      config false;
      description
        "Fec Overhead rate ";
    }
    leaf fec-gain {
      type string {
        length "1..255";
      }
      config false;
      description
        "Fec Overhead rate ";
    }
    leaf pre-fec-ber-mantissa-threshold {
      type uint32;
      description " Mantissa of the FEC BER threshold";
    }
    leaf pre-fec-ber-exponent-threshold {
      type int32;
      description " Exponent of the FEC BER threshold";
    }
  }

  grouping opt-if-och-central-frequency {
    description "Interface Central Frequency";
    leaf central-frequency {
      type uint32;
      description " This parameter indicates the frequency
        of this interface ";
    }
  }

}

grouping opt-if-och-modulation-params {
```

```
description "Optical modulation parameters for the lane";
leaf modulation-format {
  type string {
    length "1..255";
  }
  config false;
  description
    "Modulation format for this mode";
}
leaf baud-rate {
  type uint32;
  description
    "Baud-rate or symbol rate";
}
leaf bits-per-symbol {
  type uint32;
  description " This parameter the bits per symbol for
    this mode.";
}
leaf num-symbols-in-alphabet {
  type uint32;
  description " This parameter the bits per symbol for
    this mode.";
}
leaf symbols-index {
  type uint32;
  description " This parameter is the symbol index this
    mode.";
}
}

grouping opt-if-och-lane-param {
  description "Optical parameters for the lane";
  leaf number-of-lanes {
    type uint32;
    config false;
    description
      "Number of optical lanes of this interface";
  }
  leaf min-laser-temperature {
    type int32;
    units ".01C";
    config false;
    description
      "Minimum Laser Temperature of this mode for
```

```
        this interface";
    }
    leaf max-laser-temperature {
        type int32;
        units ".01C";
        config false;
        description
            "Maximum Laser Temperature of this mode for
             this interface";
    }
    leaf max-total-rx-optical-power {
        type dbm-t;
        config false;
        description
            "Maximum rx optical power of this mode for
             this interface";
    }
    leaf max-chromatic-dispersion {
        type int32;
        config false;
        description
            "Maximum chromatic dispersion of this
             mode for this interface";
    }
    leaf max-diff-group-delay {
        type int32;
        config false;
        description
            "Maximum Differential group delay of this
             mode for this interface";
    }
    uses opt-if-och-modulation-params;
}

grouping opt-if-och-tca-list {
    description "List of TCA's.";
    leaf number-of-tcas-supported {
        type uint32;
        description "Number of tcas
                     supported by this interface";
    }
    list mode-list {
        key "tca-type";
        description "List of the tcas";
        uses opt-if-och-tca-thresholds;
    }
}
```

```
    }

    grouping opt-if-och-fec-tca-thresholds {
      description "Pre FEC BER Thresholds for TCA's";
      leaf min-fec-ber-mantissa-threshold {
        type uint32;
        description "Min Mantissa of the FEC BER threshold";

      }
      leaf min-fec-ber-exponent-threshold {
        type int32;
        description "Min Exponent of the FEC BER threshold";

      }
      leaf max-fec-ber-mantissa-threshold {
        type uint32;
        description "Max Mantissa of the FEC BER threshold";

      }
      leaf max-fec-ber-exponent-threshold {
        type int32;
        description "Max Exponent of the FEC BER threshold";

      }
    }
  }

  grouping opt-if-och-mode-params {
    description "OCh mode parameters.";
    leaf mode-id {
      type string {
        length "1..255";
      }
      description
        "Id for the OCh mode template";
    }
    leaf min-osnr-margin {
      type int32;
      units "dB";
      config false;
      description "OSNR margin to FEC threshold";
    }
    leaf q-margin {
      type int32;
      units "dB";
      config false;
      description "Q-Factor margin to FEC threshold";
    }
  }
}
```

```
    uses opt-if-och-central-frequency;
    uses opt-if-och-power;
    uses opt-if-och-fec-tca-thresholds;
    uses opt-if-och-tca-list;
}

grouping opt-if-och-statistics {
    description "OCh statistics.";
    leaf cur-osnr {
        type int32;
        units "dB";
        config false;
        description " OSNR margin to FEC threshold";
    }
    leaf cur-q-factor {
        type int32;
        units "dB";
        config false;
        description " Q-Factor of the interface";
    }
    leaf uncorrected-words {
        type uint64;
        config false;
        description " Post FEC errored words";
    }
    leaf pre-fec-ber-mantissa {
        type uint32;
        config false;
        description " Pre fec FEC errored words mantissa";
    }
    leaf pre-fec-ber-exponent {
        type int32;
        config false;
        description " Pre fec FEC errored words exponent";
    }
}

grouping opt-if-och-mode {
    description "OCh mode template.";
    leaf mode-id {
        type string {
            length "1..255";
        }
        config false;
        description
            "Id for the OCh mode template";
    }
}
```



```
leaf application-identifier {
    type uint32;
    config false;
    description "This parameter indicates the
                 application identifier according
                 to G.698.2";
}
leaf min-central-frequency {
    type uint32;
    config false;
    description "This parameter indicates the minimum
                 frequency for this template ";
}
leaf max-central-frequency {
    type uint32;
    config false;
    description "This parameter indicates the minimum
                 frequency for this template ";
}
leaf min-channel-input-power {
    type dbm-t;
    config false;
    description "The minimum input power of this
                 interface";
}
leaf max-channel-input-power {
    type dbm-t;
    config false;
    description "The maximum input power of this
                 interface";
}
leaf min-channel-output-power {
    type dbm-t;
    config false;
    description "The minimum output power of this
                 interface";
}
leaf max-channel-output-power {
    type dbm-t;
    config false;
    description "The maximum output power of this
                 interface";
}
leaf osnr-margin {
    type int32;
    units "dB";
    config false;
    description "OSNR margin to FEC threshold";
}
```

```
    }
    leaf q-margin {
        type int32;
        units "dB";
        config false;
        description "Q-Factor margin to FEC threshold";
    }
    uses opt-if-och-fec;
    uses opt-if-och-lane-param;
}

grouping opt-if-och-mode-list {
    description "List of Mode list group.";
    leaf number-of-modes-supported {
        type uint32;
        description "Number of modes
                    supported by this interface";
    }
    list mode-list {
        key "mode-id";
        description "List of the modes ";
        uses opt-if-och-mode;
    }
}

notification opt-if-och-central-frequency-change {
    description "A change of Central Frequency has been
                detected.";
    leaf "if-name" {
        type leafref {
            path "/if:interfaces/if:interface/if:name";
        }
        description "Interface name";
    }
    container new-opt-if-och-central-frequency {
        description "The new Central Frequency of the
                    interface";
        uses opt-if-och-central-frequency;
    }
}

notification opt-if-och-mode-change {
    description "A change of Mode Template has been
```

```

        detected.";
    leaf "if-name" {
        type leafref {
            path "/if:interfaces/if:interface/if:name";
        }
        description "Interface name";
    }
    leaf mode-id {
        type string {
            length "1..255";
        }
        description "Id for the OCh mode template";
    }
}

notification opt-if-och-min-tca {
    description "A min output TCA notification.";
    leaf "if-name" {
        type leafref {
            path "/if:interfaces/if:interface/if:name";
        }
        description "Interface name";
    }
    leaf tca-type {
        type opt-if-och-tca-types;
        description "Type of TCA for eg min tx power TCA";
    }
}

augment "/if:interfaces/if:interface" {
    description "Parameters for an optical interface";
    container optIfOChRsSs {
        description "RsSs path configuration for an interface";
        container if-current-mode {
            description "Current mode template of the
                interface";
            uses opt-if-och-mode;
        }

        container if-supported-mode {
            config false;
            description "Supported mode list of
                this interface";
            uses opt-if-och-mode-list;
        }
        container current-opt-if-och-mode-params {
            description "Current parameters of

```

```
        this interface";
        uses opt-if-och-mode-params;
        uses opt-if-och-statistics;
    }

}

}
```

<CODE ENDS>

7. 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.

8. 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

9. Acknowledgements

10. Contributors

Dean Bogdanovic
Westford
U.S.A.
email ivandean@gmail.com

Bernd Zeuner
Deutsche Telekom
Darmstadt
Germany
email B.Zeuner@telekom.de

Massimiliano Salsi
Juniper Networks
1133 Innovation Way
Sunnyvale, CA, 94089
U.S.A.
+1 408936847
email msalsi@google.com

Arnold Mattheus
Deutsche Telekom
Darmstadt
Germany
email a.mattheus@telekom.de

Manuel Paul
Deutsche Telekom
Berlin
Germany
email Manuel.Paul@telekom.de

Walid Wakim
Cisco
9501 Technology Blvd
ROSEMONT, ILLINOIS 60018
UNITED STATES
email wwakim@cisco.com

Kam Lam
Nokia
USA
+1 732 331 3476
kam.lam@nokia.com

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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

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

Authors' Addresses

Gabriele Galimberti (editor)
Cisco
Via Santa Maria Molgora, 48 c
20871 - Vimercate
Italy

Phone: +390392091462
Email: ggalimbe@cisco.com

Ruediger Kunze
Deutsche Telekom
Winterfeldtstr. 21-27
10781 Berlin
Germany

Phone: +491702275321
Email: RKunze@telekom.de

Dharini Hiremagalur (editor)
Juniper
1133 Innovation Way
Sunnyvale - 94089 California
USA

Email: dharinih@juniper.net

Gert Grammel (editor)
Juniper
Oskar-Schlemmer Str. 15
80807 Muenchen
Germany

Phone: +49 1725186386
Email: ggrammel@juniper.net

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Q. Wang, Ed.
ZTE
R. Valiveti, Ed.
Infinera Corp
H. Zheng, Ed.
Huawei
H. Helvoort
Hai Gaoming B.V
S. Belotti
Nokia
July 7, 2019

Applicability of GMPLS for B100G Optical Transport Network
draft-ietf-ccamp-gmpls-otn-b100g-applicability-01

Abstract

This document examines the applicability of using current existing GMPLS routing and signaling to set up ODUk/ODUflex over ODUcn link, as a result of the support of OTU/ODU links with rates larger than 100G in the 2016 version of G.709.

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1. Introduction

The current GMPLS routing [RFC7138] and signaling extensions [RFC7139] only includes coverage for the control of all the OTN capabilities that were defined in the 2012 version of G.709 [ITU-T_G709_2012].

While the 2016 version of G.709 [ITU-T_G709_2016] introduces support for new higher rate ODU signals, termed ODUCn (which have a nominal rate of $n \times 100$ Gbps), how to use GMPLS to configure ODUCn should be

taken into consideration. But it seems how to configure the ODUCn link needs more discussion, so this draft mainly focuses on the use of current GMPLS mechanisms to set up ODUk/ODUflex over an existing ODUCn link.

This document presents an overview of the changes introduced in [ITU-T_G709_2016] to motivate the present topic and then analyzes how the current GMPLS routing and signalling mechanisms can be utilized to setup ODUk/ODUflex connections over ODUCn links.

1.1. Scope

For the purposes of the B100G control plane discussion, the OTN should be considered as a combination of ODU and OTSi layers. Note that [ITU-T_G709_2016] is deprecating the use of the term "OCh" for B100G entities, and leaving it intact only for maintaining continuity in the description of the signals with bandwidth upto 100G. This document focuses on only the control of the ODU layer. The control of the OTSi layer is out of scope of this document. But in order to facilitate the description of the challenges brought by [ITU-T_G709_2016] to B100G GMPLS routing and signalling, some general description about OTSi will be included in this draft.

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].

2.2. OTN terminology used in this document

- a. OPUCn: Optical Payload Unit -Cn.
- b. ODUCn: Optical Data Unit - Cn.
- c. OTUCn: Fully standardized Optical Transport Unit - Cn.
- d. OTUCn-M: This signal is an extension of the OTUCn signal introduced above. This signal contains the same amount of overhead as the OTUCn signal, but contains a reduced amount of payload area. Specifically the payload area consists of M 5G tributary slots (where M is strictly less than 20*n).
- e. PSI: OPU Payload structure Indicator. This is a multi-frame message and describes the composition of the OPU signal. This

field is a concatenation of the Payload type (PT) and the Multiplex Structure Indicator (MSI) defined below.

- f. MSI: Multiplex Structure Indicator. This structure indicates the grouping of the tributary slots in an OPU payload area to realize a client signal that is multiplexed into an OPU. The individual clients multiplexed into the OPU payload area are distinguished by the Tributary Port number (TPN).
- g. GMP: Generic Mapping Procedure.
- h. OTSiG: see [ITU-T_G872]
- i. OTSiA: see [ITU-T_G872]

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

3. Overview of B100G in G.709

This section provides an overview of new features in [ITU-T_G709_2016].

3.1. OTUCn

In order to carry client signals with rates greater than 100Gbps, [ITU-T_G709_2016] takes a general and scalable approach that decouples the rates of OTU signals from the client rate evolution. The new OTU signal is called OTUCn; this signal is defined to have a rate of (approximately) $n \times 100\text{G}$. The following are the key characteristics of the OTUCn signal:

- a. The OTUCn signal contains one ODUCn. The OTUCn and ODUCn signals perform digital section roles only (see [ITU-T_G709_2016]:Section 6.1.1)
- b. The OTUCn signals can be viewed as being formed by interleaving n OTUC signals (where are labeled 1, 2, ..., n), each of which has the format of a standard OTUk signal without the FEC columns (per [ITU-T_G709_2016]Figure 7-1). The ODUCn have a similar structure, i.e. they can be seen as being formed by interleaving n instances of ODUC signals (respectively). The OTUC signal contains the ODUC signals, just as in the case of fixed rate OTUs defined in G.709 [ITU-T_G709_2016].
- c. Each of the OTUC "slices" have the same overhead (OH) as the standard OTUk signal in G.709 [ITU-T_G709_2016]. The combined signal OTUCn has n instances of OTUC OH, ODUC OH.

- d. The OTUC signal has a slightly higher rate compared to the OTU4 signal (without FEC); this is to ensure that the OPUC payload area can carry an ODU4 signal.

3.1.1. Carrying OTUCn between 3R points

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

The following scenarios of OTUCn transport need to be considered (see Figure 1):

- a. inter-domain interfaces: These types of interfaces are used for connecting OTN edge nodes to (a) client equipment (e.g. routers) or (b) hand-off points from other OTN networks. ITU-T has standardized the Flexible OTN (FlexO) interfaces to support these functions. Recommendation [ITU-T_G709.1] specifies a flexible interoperable short-reach OTN interface over which an OTUCn ($n \geq 1$) is transferred, using bonded FlexO interfaces which belong to a FlexO group. In its current form, Recommendation [ITU-T_G709.1] is limited to the case of transporting OTUCn signals using n 100G Ethernet PHY(s). When the PHY(s) for the emerging set of Ethernet signals, e.g. 200GbE and 400GbE, become available, new recommendations can define the required adaptations.
- b. intra-domain interfaces: In these cases, the OTUCn is transported using a proprietary (vendor specific) encapsulation, FEC etc. In future, it may be possible to transport OTUCn for intra-domain links using future variants of FlexO.

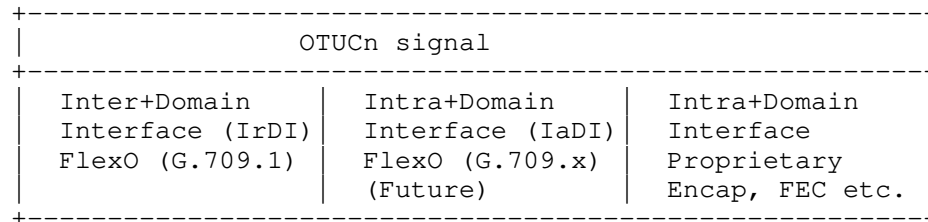


Figure 1: OTUCn transport possibilities

3.2. ODUcN

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

The ODUcN signals have a rate that is captured in Table 1.

| ODU Type | ODU Bit Rate |
|----------|---|
| ODUcN | $n \times 239/226 \times 99,532,800 \text{ kbit/s} = n \times 105,258,138.053 \text{ kbit/s}$ |

Table 1: ODUcN rates

The ODUcN is a multiplex section ODU signal, and is mapped into an OTUCn signal which provides the regenerator section layer. In some scenarios, the ODUcN, and OTUCn signals will be co-terminous, i.e. they will have identical source/sink locations. [ITU-T_G709_2016] and [ITU-T_G872] allow for the ODUcN signal to pass through a digital regenerator node which will terminate the OTUCn layer, but will pass the regenerated (but otherwise untouched) ODUcN towards a different OTUCn interface where a fresh OTUCn layer will be initiated (see Figure 2). In this case, the ODUcN is carried by 3 OTUCn segments.

Specifically, the OPUCn signal flows through these regenerators unchanged. That is, the set of client signals, their TPNs, trib-slot allocation remains unchanged. Note however that the ODUCn Overhead (OH) might be modified if TCM sub-layers are instantiated in order to monitor the performance of the repeater hops. In this sense, the ODUCn should not be seen as a general ODU which can be switched via an ODUk cross-connect.

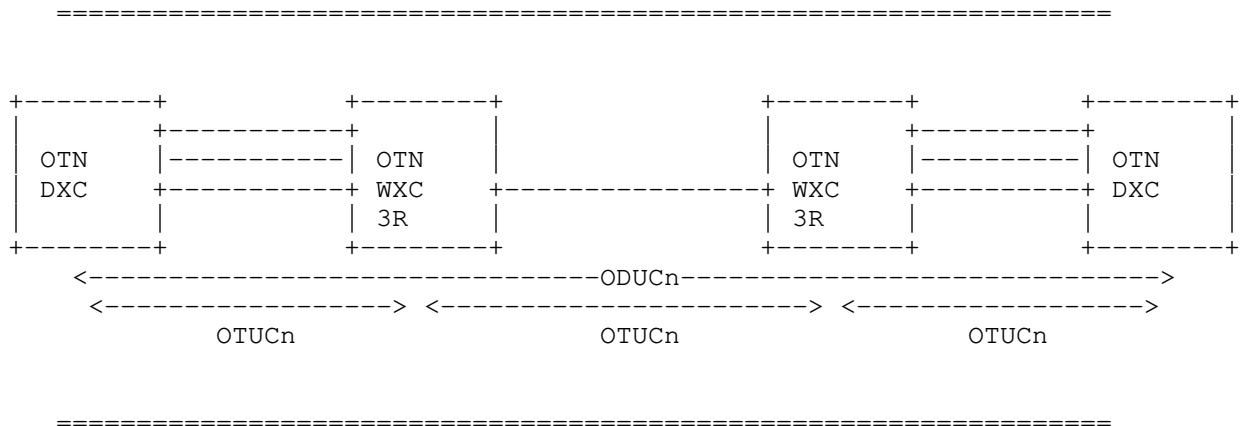


Figure 2: ODUCn signal

3.3. OTUCn-M

The standard OTUCn signal has the same rate as that of the ODUCn signal as captured in Table 1. This implies that the OTUCn signal can only be transported over wavelength groups which have a total capacity of multiples of (approximately) 100G. Modern DSPs support a variety of bit rates per wavelength, depending on the reach requirements for the optical link. In other words, it is possible to extend the reach of an optical link (i.e. increase the physical distance covered) by lowering the bitrate of the client signal that is modulated onto the carrier(s). By the very nature of the OTUCn signal, it is constrained to rates which are multiples of (approximately) 100G. If it so happens that the total rate of the LO-ODUs carried over the ODUCn is smaller than $n \times 100G$, it is possible to "crunch" the OTUCn to remove the unused capacity. With this in mind, ITU-T supports the notion of a reduced rate OTUCn signal, termed the OTUCn-M. The OTUCn-M signal is derived from the OTUCn signal by retaining all the n instances of overhead (one per OTUC slice) but only M tributary slots of capacity.

3.4. Time Slot Granularity

[ITU-T_G709_2012] introduced the support for 1.25G granular tributary slots in OPU2, OPU3, and OPU4 signals. With the introduction of higher rate signals, it is no longer practical for the optical networks (and the datapath hardware) to support a very large number of flows at such a fine granularity. ITU-T has defined the OPUC with a tributary slot granularity of 5G. This means that the ODUCn signal has $20 \times n$ tributary slots (of 5Gbps capacity). It is worthwhile considering that the range of tributary port number (TPN) is $10 \times n$, and not $20 \times n$ which would allow for a different client signal to be carried in each TS. As an example, it will not be possible to embed 15 5G ODUflex signals in a ODUC1.

3.5. Structure of OPUCn MSI with Payload type 0x22

As mentioned above, the OPUCn signal has $20 \times n$ 5G tributary slots. The OPUCn contains n PSI structures, one per OPUC instance. The PSI structure consists of the Payload Type (of 0x22), followed by a Reserved Field (1 byte), followed by the MSI. The OPUCn MSI field has a fixed length of $40 \times n$ bytes and indicates the availability of each TS. Two bytes are used for each of the $20 \times n$ tributary slots, and each such information structure has the following format ([ITU-T_G709_2016] G.709:Section 20.4.1):

- a. The TS availability bit 1 indicates if the tributary slot is available or unavailable
- b. The TS occupation bit 9 indicates if the tributary slot is allocated or unallocated
- c. b.c. The tributary port # in bits 2 to 8 and 10 to 16 indicates the port number of the client that is being carried in this specific TS; a flexible assignment of tributary port to tributary slots is possible. Numbering of tributary ports are is from 1 to $10n$.

3.6. Client Signal Mappings

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

- a. All client signals with rates less than 100G are mapped as specified in [ITU-T_G709_2016]:Clause 17. These mappings are identical to those specified in the earlier revision of G.709 [ITU-T_G709_2012]. Thus, for example, the 1000BASE-X/10GBASE-R signals are mapped to ODU0/ODU2e respectively (see Table 2 -- based on Table 7-2 in [ITU-T_G709_2016])

- b. Always map the new and emerging client signals to ODUflex signals of the appropriate rates (see Table 2 -- based on Table 7-2 in [ITU-T_G709_2016])
- c. Drop support for ODU Virtual Concatenation. This simplifies the network, and the supporting hardware since multiple different mappings for the same client are no longer necessary. Note that legacy implementations that transported sub-100G clients using ODU VCAT shall continue to be supported.
- d. ODUflex signals are low-order signals only. If the ODUflex entities have rates of 100G or less, they can be transported using either an ODUK (k=1..4) or an ODUCn server layer. On the other hand, ODUflex connections with rates greater than 100G will require the server layer to be ODUCn. The ODUCn signals must be adapted to an OTUCn signal. Figure 3 illustrates the hierarchy of the digital signals defined in [ITU-T_G709_2016].

| ODU Type | ODU Bit Rate |
|---|---|
| ODU0 | 1,244,160 Kbps |
| ODU1 | $239/238 \times 2,488,320$ Kbps |
| ODU2 | $239/237 \times 9,953,280$ Kbps |
| ODU2e | $239/237 \times 10,312,500$ Kbps |
| ODU3 | $239/236 \times 39,813,120$ Kbps |
| ODU4 | $239/227 \times 99,532,800$ Kbps |
| ODUflex for CBR client signals | $239/238 \times$ Client signal Bit rate |
| ODUflex for GFP-F mapped packet traffic | Configured bit rate |
| ODUflex for IMP mapped packet traffic | $s \times 239/238 \times 5\,156\,250$ kbit/s: $s=2,8,5*n, n \geq 1$ |
| ODUflex for FlexE aware transport | $103\,125\,000 \times 240/238 \times n/20$ kbit/s, where n is total number of available tributary slots among all PHYs which have been crunched and combined. |

Note that this table doesn't include ODUCn -- since it cannot be generated by mapping a non-OTN signal. An ODUCn is always formed by multiplexing multiple LO-ODUs.

Table 2: Types and rates of ODUs usable for client mappings

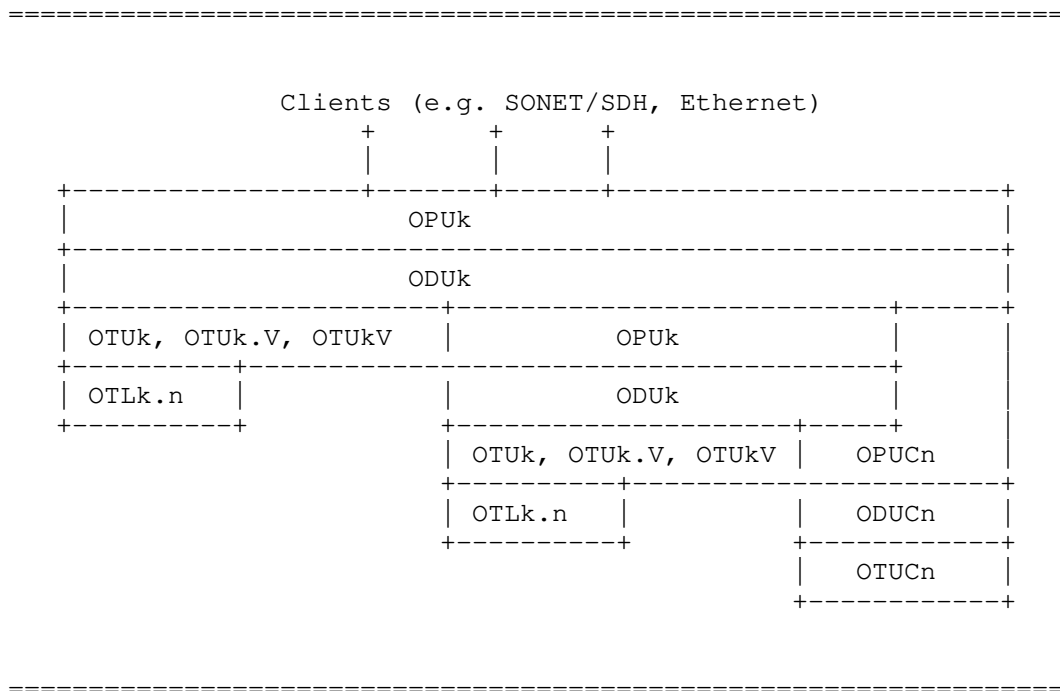


Figure 3: Digital Structure of OTN interfaces (from G.709:Figure 6-1)

4. Applicability and GMPLS Implications

4.1. Applicability and Challenges

Two typical scenarios are depicted in Appendix XIII of [ITU-T_G709_2016], which are also introduced into this document to help analyze the potential extension to GMPLS needed. Though these two scenarios are mainly introduced in G.709 to describe OTUCn sub rates application, they can also be used to describe general OTUCn application. One thing that should be note is these two scenarios are a little different from those described in [ITU-T_G709_2016], as the figure in this section include the OTSi(G) in to facilitate the description of the challenge brought by [ITU-T_G709_2016].

The first scenarios is depicted in Figure 4. This scenario deploys OTUCn/OTUCn-M between two line ports connecting two L1/L0 ODU cross connects (XC) within one optical transport network. One OTUCn is actually carried by one OTSi(G) or OTSiA.

As defined in [ITU-T_G872], OTSiG is used to represent one or more OTSi as a group to carry a single client signal (e.g., OTUCn). The

OTSiG may have non-associated overhead, the combination of the OTSiG and OTSiG-O is represented by the OTSiA management/control abstraction.

In this scenario, it is clear that the OTUCn and ODUCn link can be automatically established, after/together with the setup of OTSi(G) or OTSiA, as both OTUCn and ODUCn perform section layer only. One client OTUCn signal is carried by one single huge OTSi signal or a group of OTSi. There is a 1:1 mapping relationship between OTUCn and OTSi(G) or OTSiA.

For example, one 400G OTUCn signal can be carried by one single 400G OTSi signal or one 400G OTUCn signal can be split into 4 different OTUC instances, with each instances carried by one OTSi. Those four OTSi function as a group to carry a single 400G OTUCn signal.

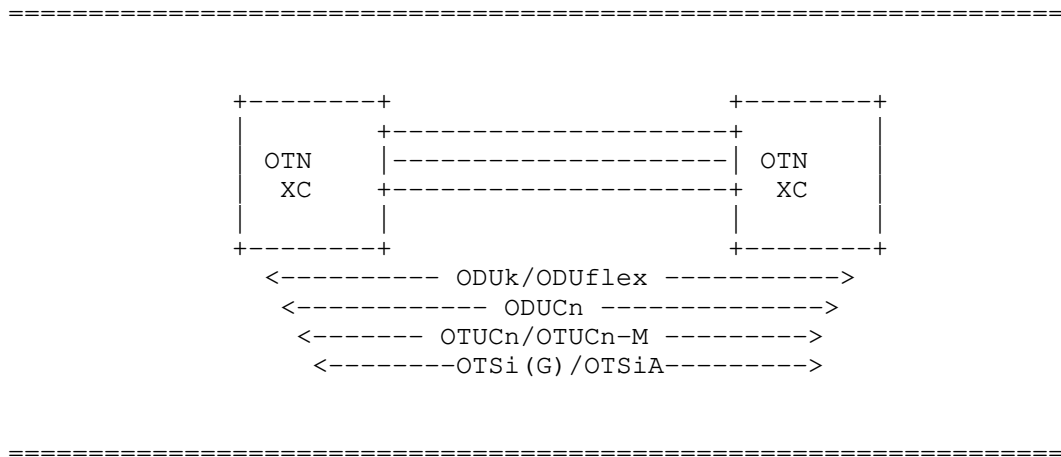


Figure 4: Scenario A

The second scenarios is depicted in Figure 4. This scenario deploys OTUCn/OTUCn-M between transponders which are in a different domain B, which are separated from the L1 ODU XCs in domain A and/or C. one end-to-end ODUCn is actually supported by three different OTUCn or OTUCn-M segments, which are in turn carried by OTSi(G) or OTSiA.

In the second scenario, OTUCn links will be established automatically after/together with the setup of OTSi(G) or OTSiA, while there are still some doubts about how the ODUCn link is established. In principle, it could/should be possible but it is not yet clear in details how the ODUCn link can be automatically setup.

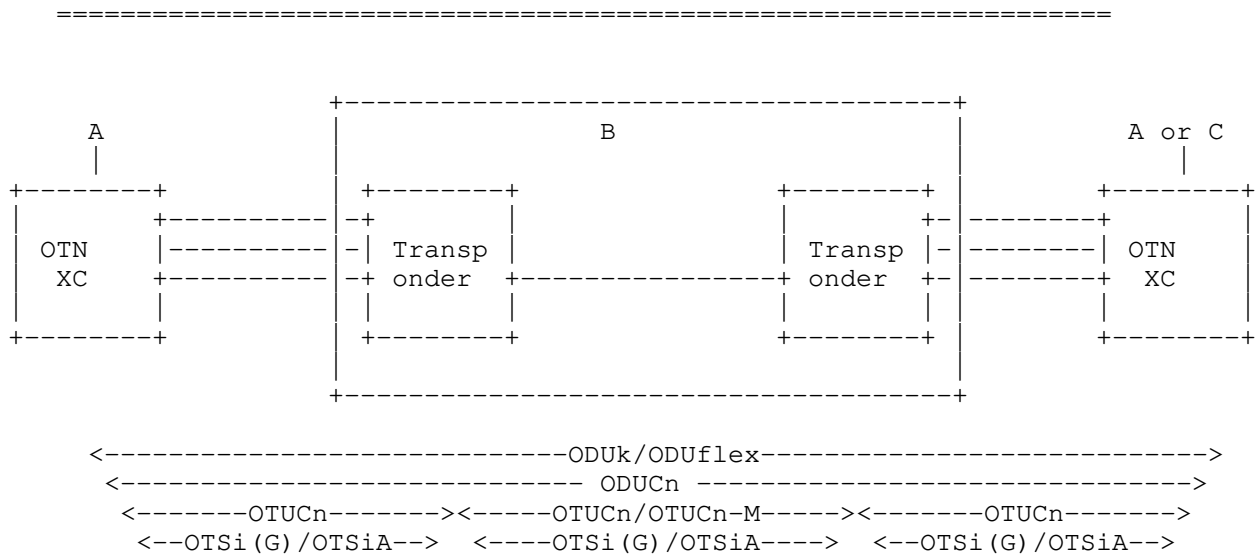


Figure 5: Scenario B

According to the above description, it can be concluded that some uncertainty about setup of ODUCn link still exist, and this uncertainty may have relationship with the progress in ITU-T. Based on the analysis, it is suggested that the scope of this draft should mainly focus on how to set up ODUk/ODUflex LSPs over ODUCn links, as also indicated in the figure above.

4.2. GMPLS Implications and Applicability

4.2.1. TE-Link Representation

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

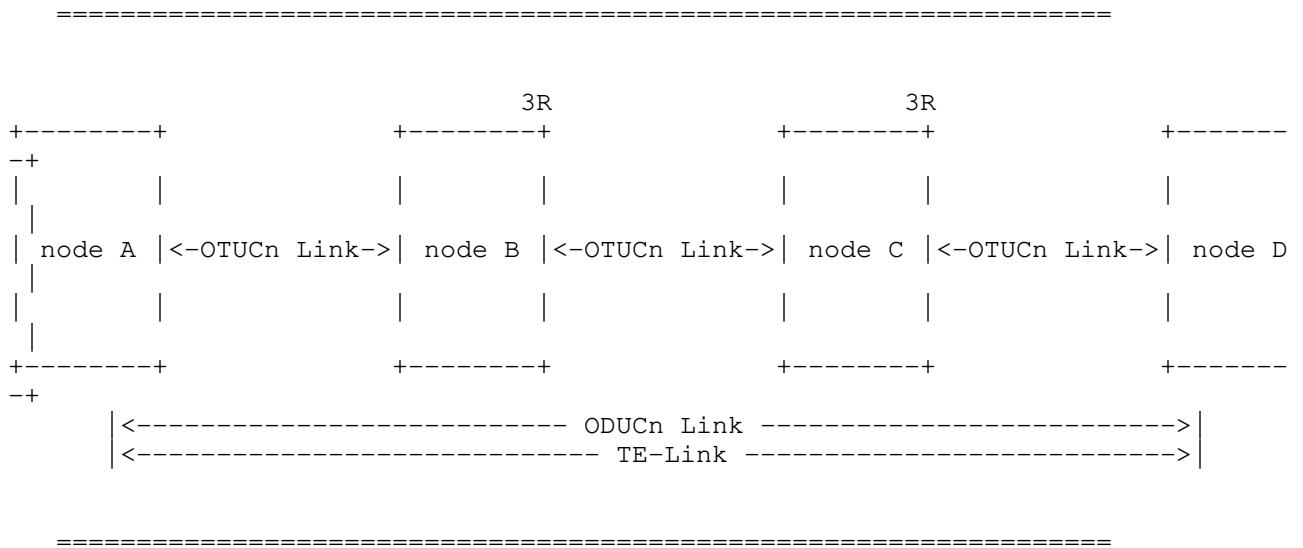


Figure 6: telink

Two ends of a TE-Link is able to know whether the TE-Link is supported by an ODUCn or an ODUk or an OTUk, as well as the resource related information (e.g., slot granularity, number of tributary slot available).

4.2.2. Implications and Applicability for GMPLS Signalling

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

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

An example is given below to illustrate the label format defined in RFC7139 for multiplexing ODU4 onto ODUC10. One ODUC10 has 200 5G slots, and twenty of them are allocated to the ODU4. Along with the

increase of "n", the label may become lengthy, an optimized label format may be needed.

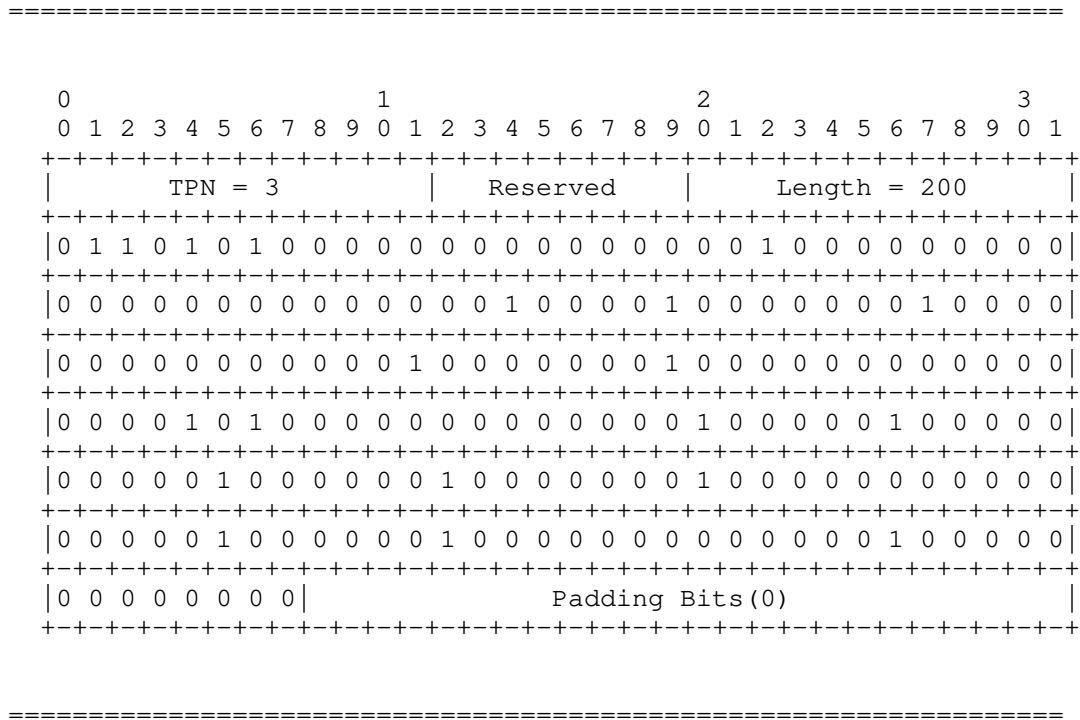


Figure 7: Label format

4.2.3. Implications and Applicability for GMPLS Routing

For routing, we think that no extension to current mechanisms defined in RFC7138 are needed. Because, once one ODUCn link is up, we need to advertise only the resources that can be used on this ODUCn link and the multiplexing hierarchy on this link. Considering ODUCn link is already configured, it's the ultimate hierarchy of this multiplexing, there is no need to explicitly extent the ODUCn signal type in the routing.

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

5. Acknowledgements

6. Authors (Full List)

Qilei Wang (editor)

ZTE

Nanjing, China

Email: wang.qilei@zte.com.cn

Radha Valiveti (editor)

Infinera Corp

Sunnyvale, CA, USA

Email: rvaliveti@infinera.com

Haomian Zheng (editor)

Huawei

CN

EMail: zhenghaomian@huawei.com

Huub van Helvoort

Hai Gaoming B.V

EMail: huubatwork@gmail.com

Sergio Belotti

Nokia

EMail: sergio.belotti@nokia.com

Iftekhar Hussain
Infinera Corp
Sunnyvale, CA, USA
Email: IHussain@infinera.com

Daniele Ceccarelli
Ericsson
Email: daniele.ceccarelli@ericsson.com

7. Contributors

Rajan Rao, Infinera Corp, Sunnyvale, USA, rrao@infinera.com
Fatai Zhang, Huawei, zhangfatai@huawei.com
Italo Busi, Huawei, italo.busi@huawei.com
Zheyu Fan, Individual, zheyu2008@gmail.com
Dieter Beller, Nokia, Dieter.Beller@nokia.com
Yuanbin Zhang, ZTE, Beijing, zhang.yuanbin@zte.com.cn
Zafar Ali, Cisco Systems, zali@cisco.com
Daniel King, d.king@lancaster.ac.uk
Manoj Kumar, Cisco Systems, manojk2@cisco.com
Antonello Bonfanti, Cisco Systems, abonfant@cisco.com
Akshaya Nadahalli, Individual, nadahalli@gmail.com

8. IANA Considerations

This memo includes no request to IANA.

9. Security Considerations

None.

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10.1. Normative References

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

10.2. Informative References

[I-D.izh-ccamp-flex-e-fwk]
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Authors' Addresses

Qilei Wang (editor)
ZTE
Nanjing
CN

Email: wang.qilei@zte.com.cn

Radha Valiveti (editor)
Infinera Corp
Sunnyvale
USA

Email: rvaliveti@infinera.com

Haomian Zheng (editor)
Huawei
CN

Email: zhenghaomian@huawei.com

Huub van Helvoort
Hai Gaoming B.V

Email: huubatwork@gmail.com

Sergio Belotti
Nokia

Email: sergio.belotti@nokia.com

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H. Zheng
I. Busi
Huawei Technologies
July 8, 2019

A YANG Data Model for Layer 1 Types
draft-ietf-ccamp-layer1-types-01

Abstract

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

Status of This Memo

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1. Introduction

This document introduces a collection of common data types which would be used in Layer 1 networks. The derived types and groupings are designed to be the common types applicable for modeling Traffic Engineering (TE) features for Layer 1 optical networks.

Typical L1 network, the Optical Transport Networking, was specified in [RFC7062]. Corresponding routing and signaling protocol have been specified in [RFC7138] and [RFC7139]. The types and groupings defined in this document is consistent to these document, and will be imported in other Layer 1 data models, including but not restrictive to, [I-D.ietf-ccamp-otn-topo-yang], [I-D.ietf-ccamp-otn-tunnel-model] and [I-D.ietf-ccamp-llcsm-yang].

The data model in this draft has only types defined including groupings, typedef and identities. There is no need to include configuration and state data according to the new Network Management Datastore Architecture [RFC8342]. The content in this draft is in consistent with [MEF63].

2. Terminology and Notations

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

3. Prefix in Data Node Names

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

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

4. Layer 1 Types Overview

4.1. Relationship with other Modules

This document defines one YANG module for common Layer 1 types: `ietf-layer1-types` for OTN specific types. The objective is to specifies common Layer 1 TE types that can be imported by layer 1 specific technology, for example OTN, in its technology-specific modules such as topology and tunnels. It is worth noting that the generic traffic-engineering (TE) types module is specified in [I-D.ietf-teas-yang-te-types] as `ietf-te-types`, and both the module `ietf-te-types` and `ietf-layer1-types` are needed to be imported when the OTN is configured.

4.2. Content in Layer 1 Type Module

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

`tributary-slot-granularity`:

This is to define the granularity for ODUk or ODUCn. Three granularities, 1.25G/2.5G/5G, have been specified.

`odu-type`:

This is to specify the type of ODUk.

`client-signal`:

This is to specify the client signal types of OTN networks. The initial input was the G-PID specified in [RFC7139]. Identities about a few categories of client signal types, including ETH, STM-n, OC and Fiber Channel have been specified.

otn-label-range-type:

The label range type of OTN has two different representations, tributary slots (TS) and tributary port number (TPN), according to [RFC7139]. Respective representation is specified under this same base type.

otn-link-bandwidth:

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

otn-path-bandwidth:

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

otn-label-restriction and otn-label-step:

These groupings are used for the augmentation of OTN label in a specific way.

otn-link-label and otn-path-label:

These groupings are used for the augmentation of label for OTN link and path respectively.

optical-interface-func:

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

service-performance-metric:

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

5. OTN Tunnel YANG Code

```
<CODE BEGINS>file "ietf-layer1-types@2019-07-08.yang"
module ietf-layer1-types {
  namespace "urn:ietf:params:xml:ns:yang:ietf-layer1-types";
  prefix "layer1-types";

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

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

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

  description
    "This module defines Layer 1 types.";

  revision "2019-07-07" {
    description
      "Initial Version";
    reference
      "RFC XXXX: A YANG Data Model for Layer 1 Types";
    // RFC Ed.: replace XXXX with actual RFC number, update date
    // information and remove this note
  }

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

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

  identity tsg-2.5G {
    base tributary-slot-granularity;
```

```
    description
      "2.5G tributary slot granularity";
  }

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

  identity odu-type {
    description
      "Base identity for protocol framing used by tributary signals.";
  }

  identity ODU0 {
    base odu-type;
    description
      "ODU0 protocol (1.24G), RFC7139/ITU-T G.709, standard track.";
  }

  identity ODU1 {
    base odu-type;
    description
      "ODU1 protocol (2.49G), RFC7139/ITU-T G.709, standard track.";
  }

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

  identity ODU2 {
    base odu-type;
    description
      "ODU2 protocol (10.03G), RFC7139/ITU-T G.709, standard track.";
  }

  identity ODU2e {
    base odu-type;
    description
      "ODU2e protocol (10.39G), RFC7139/ITU-T G.709, standard track.";
  }

  identity ODU3 {
    base odu-type;
    description
```

```
    "ODU3 protocol (40.31G), RFC7139/ITU-T G.709, standard track.";
}

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

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

identity ODU4 {
    base odu-type;
    description
        "ODU4 protocol (104.79G), RFC7139/ITU-T G.709, standard track.";
}

identity ODUFlex-cbr {
    base odu-type;
    description
        "ODU Flex CBR protocol for transporting constant bit rate
        signal";
}

identity ODUFlex-gfp {
    base odu-type;
    description
        "ODU Flex GFP protocol for transporting stream of packets
        using Generic Framing Procedure";
}

identity ODUCn {
    base odu-type;
    description
        "ODUCn protocol (beyond 100G)";
}

identity client-signal {
    description
        "Base identity from which specific client signals for the
        tunnel are derived";
}

// Editor Notes: may consider add the OTUk as client signal;
```

```
identity ETH-1Gb {
  base client-signal;
  description
    "Client signal type of 1GbE";
}

identity ETH-10Gb-LAN {
  base client-signal;
  description
    "Client signal type of 10GbE LAN";
}

identity ETH-10Gb-WAN {
  base client-signal;
  description
    "Client signal type of 10GbE WAN";
}

identity ETH-40Gb {
  base client-signal;
  description
    "Client signal type of 40GbE";
}

identity ETH-100Gb {
  base client-signal;
  description
    "Client signal type of 100GbE";
}

identity STM-1 {
  base client-signal;
  description
    "Client signal type of STM-1";
}

identity STM-4 {
  base client-signal;
  description
    "Client signal type of STM-4";
}

identity STM-16 {
  base client-signal;
  description
    "Client signal type of STM-16";
}
```

```
identity STM-64 {
  base client-signal;
  description
    "Client signal type of STM-64";
}

identity STM-256 {
  base client-signal;
  description
    "Client signal type of STM-256";
}
identity OC-3 {
  base client-signal;
  description
    "Client signal type of OC3";
}

identity OC-12 {
  base client-signal;
  description
    "Client signal type of OC12";
}

identity OC-48 {
  base client-signal;
  description
    "Client signal type of OC48";
}

identity OC-192 {
  base client-signal;
  description
    "Client signal type of OC192";
}

identity OC-768 {
  base client-signal;
  description
    "Client signal type of OC768";
}

identity FC-100 {
  base client-signal;
  description
    "Client signal type of Fibre Channel FC-100";
}

identity FC-200 {
```

```
    base client-signal;
    description
      "Client signal type of Fibre Channel FC-200";
  }

  identity FC-400 {
    base client-signal;
    description
      "Client signal type of Fibre Channel FC-400";
  }

  identity FC-800 {
    base client-signal;
    description
      "Client signal type of Fibre Channel FC-800";
  }

  identity FC-1200 {
    base client-signal;
    description
      "Client signal type of Fibre Channel FC-1200";
  }

  identity FC-1600 {
    base client-signal;
    description
      "Client signal type of Fibre Channel FC-1600";
  }

  identity FC-3200 {
    base client-signal;
    description
      "Client signal type of Fibre Channel FC-3200";
  }

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

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

  identity otn-label-range-type {
```

```
    description
      "Base identity from which specific OTN label
        range types derived";
  }

  identity label-range-trib-slot {
    base otn-label-range-type;
    description
      "Defines a range of OTN tributary slots";
  }

  identity label-range-trib-port {
    base otn-label-range-type;
    description
      "Defines a range of OTN tributary ports";
  }

  // Editor Notes: following grouping only used in otn topology model,
  // so suggest to move to ietf-otn-topology and remove from types.
  grouping otn-link-bandwidth {
    description "link bandwidth attributes for OTN";
    list odulist {
      key "odu-type";
      description
        "OTN bandwidth definition";
      leaf odu-type {
        type identityref {
          base layer1-types:odu-type;
        }
        description "ODU type";
      }
      leaf number {
        type uint16;
        description "Number of ODUs";
      }
    }
  }

  // Editor Notes: following groupings are used in both otn topology
  // and tunnel model, so suggest to be kept in the types.
  grouping otn-path-bandwidth {
    description "path bandwidth attributes for OTN";
    leaf odu-type {
      type identityref {
        base layer1-types:odu-type;
      }
      description "ODU type";
    }
  }
```

```
}
// Editor Notes: following groupings are used in both otn topology
// and tunnel model, so suggest to be kept in the types.
grouping otn-label-restriction {
  description "label restriction information for OTN";
  leaf range-type {
    type identityref {
      base layer1-types:otn-label-range-type;
    }
    description "type for range";
  }
  leaf tsg {
    type identityref {
      base layer1-types:tributary-slot-granularity;
    }
    description "Tributary slot granularity.";
    reference
      "G.709/Y.1331, February 2016: Interfaces for the
      Optical Transport Network (OTN)";
  }
  leaf priority {
    type uint8;
    description "priority.";
  }
}

// Editor Notes: following groupings are used in both otn topology
// and tunnel model, so suggest to be kept in the types.
grouping otn-link-label {
  description "link label information for OTN, for label-start/end";
  choice otn-label-type {
    description
      "OTN label range type, either TPN range or TS range";
    case tributary-port {
      leaf tpn {
        type uint16 {
          range "1..4095";
        }
        description
          "Tributary Port Number. Applicable for mux services.";
        reference
          "RFC7139: GMPLS Signaling Extensions for Control of Evolving
          G.709 Optical Transport Networks.";
      }
    }
    case tributary-slot {
      leaf ts {
        type uint16 {
```



```
        range "1..4095";
    }
    description
        "Tributary Slot Number. Applicable for mux services.";
    reference
        "RFC7139: GMPLS Signaling Extensions for Control of Evolving
        G.709 Optical Transport Networks.";
    }
}
}
}

// Editor Notes: following groupings are used in both otn topology
// and tunnel model, so suggest to be kept in the types.
grouping otn-path-label {
    description "label information for OTN, for label-hop";
    leaf tpn {
        type uint16 {
            range "1..4095";
        }
        description
            "Tributary Port Number. Applicable in case of mux services.";
        reference
            "RFC7139: GMPLS Signaling Extensions for Control of Evolving
            G.709 Optical Transport Networks.";
    }
    leaf tsg {
        type identityref {
            base layer1-types:tributary-slot-granularity;
        }
        description "Tributary slot granularity.";
        reference
            "G.709/Y.1331, February 2016: Interfaces for the
            Optical Transport Network (OTN)";
    }
    leaf ts-list {
        type string {
            pattern "([1-9][0-9]{0,3}(-[1-9][0-9]{0,3})?"
                + "(,[1-9][0-9]{0,3}(-[1-9][0-9]{0,3})?)*)";
        }
        description
            "A list of available tributary slots ranging
            between 1 and 9999.
            For example 1-20,25,50-1000";
        reference "RFC 7139: GMPLS Signaling Extensions for Control
            of Evolving G.709 Optical Transport Networks";
    }
}
}
```

```
// Editor Notes: following grouping only used in otn topology model,
// so suggest to move to ietf-otn-topology and remove from types.
grouping otn-label-step {
  description "Label step for OTN";
  choice otn-label-type {
    description
      "OTN label range type, either TPN range or TS range";
    case tributary-port {
      leaf tpn-step {
        type uint16 {
          range "1..80";
        }
        default 1;
        description
          "Label step which represents possible increments for
          Tributary Port Number.";
        reference
          "RFC7139: GMPLS Signaling Extensions for Control of Evolving
          G.709 Optical Transport Networks.";
      }
    }
    case tributary-slot {
      leaf ts {
        type uint16 {
          range "1..80";
        }
        default 1;
        description
          "Label step which represents possible increments for
          Tributary Slot Number.";
        reference
          "RFC7139: GMPLS Signaling Extensions for Control of Evolving
          G.709 Optical Transport Networks.";
      }
    }
  }
}

// Editor Notes: to be reviewed for the following coding functions.
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";
    }

// Editor Notes: To add the performance monitor parameters per L1CSM;
identity service-performance-metric {
    description "list of service-specific performance metric";
}

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

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

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

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

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

//Editor Notes: it's useful to separate network specific performance
//monitoring with service-specific
identity network-performance-metric {
    description "list of network-specific performance metric";
}

identity pm-placeholder {
    base "network-performance-metric";
    description "A placeholder for potential performance monitoring
        on L1 networks";
}
}
<CODE ENDS>
```

6. Security Considerations

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

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

The YANG module in this document defines layer 1 type definitions (i.e., typedef, identity and grouping statements) in YANG data modeling language to be imported and used by other layer 1 technology-specific modules. When imported and used, the resultant schema will have data nodes that can be writable, or readable. The access to such data nodes may be considered sensitive or vulnerable in some network environments. Write operations (e.g., edit-config) to these data nodes without proper protection can have a negative effect on network operations.

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

7. IANA Considerations

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

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

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

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

8. Acknowledgements

TBD.

9. Contributors

Dieter Beller
Nokia
Email: dieter.beller@nokia.com

Sergio Belotti
Nokia
Email: sergio.belotti@nokia.com

Yanlei Zheng
China Unicom
Email: zhengyl@dimpt.com

Aihua Guo
Huawei Technologies
Email: aihuaguo@huawei.com

Young Lee
Huawei Technologies
Email: leeyoung@huawei.com

Lei Wang
China Mobile
Email: wangleiyj@chinamobile.com

Oscar Gonzalez de Dios
Telefonica
Email: oscar.gonzalezdedios@telefonica.com

Xufeng Liu
Volta Networks
Email: xufeng.liu.ietf@gmail.com

Yunbin Xu
CAICT
Email: xuyunbin@rittt.com

Anurag Sharma
Google
Email: ansha@google.com

Rajan Rao
Infinera

Email: rrao@infinera.com

Victor Lopez
Telefonica
Email: victor.lopezalvarez@telefonica.com

Yunbo Li
China Mobile
Email: liyunbo@chinamobile.com

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Authors' Addresses

Haomian Zheng
Huawei Technologies
H1-1-A043S Huawei Industrial Base, Songshanhu
Dongguan, Guangdong 523808
China

Email: zhenghaomian@huawei.com

Italo Busi
Huawei Technologies
Milan
Italy

Email: Italo.Busi@huawei.com

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Expires: November 27, 2019

Y. Lee
Futurewei

V. Lopez
Telefonica

G. Galimberti
Cisco

Jean Luc Auge
Orange

D. Beller
Nokia

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A Yang Data Model for Optical Impairment-aware Topology

draft-ietf-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 Assignment (IA-RSA) for SSON.

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

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1. Introduction

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

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

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

This document augments the generic TE topology draft [TE-TOPO] where possible.

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

1.1. Terminology

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

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

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

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

- o configuration data
- o state data

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

1.2. Tree diagram

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

1.3. Prefixes in Data Node Names

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

| Prefix | YANG module | Reference |
|------------------|----------------------------------|------------|
| optical-imp-topo | ietf-optical-impairment-topology | [RFCXXXX] |
| layer0-types | ietf-layer0-types | [L0-Types] |
| 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.

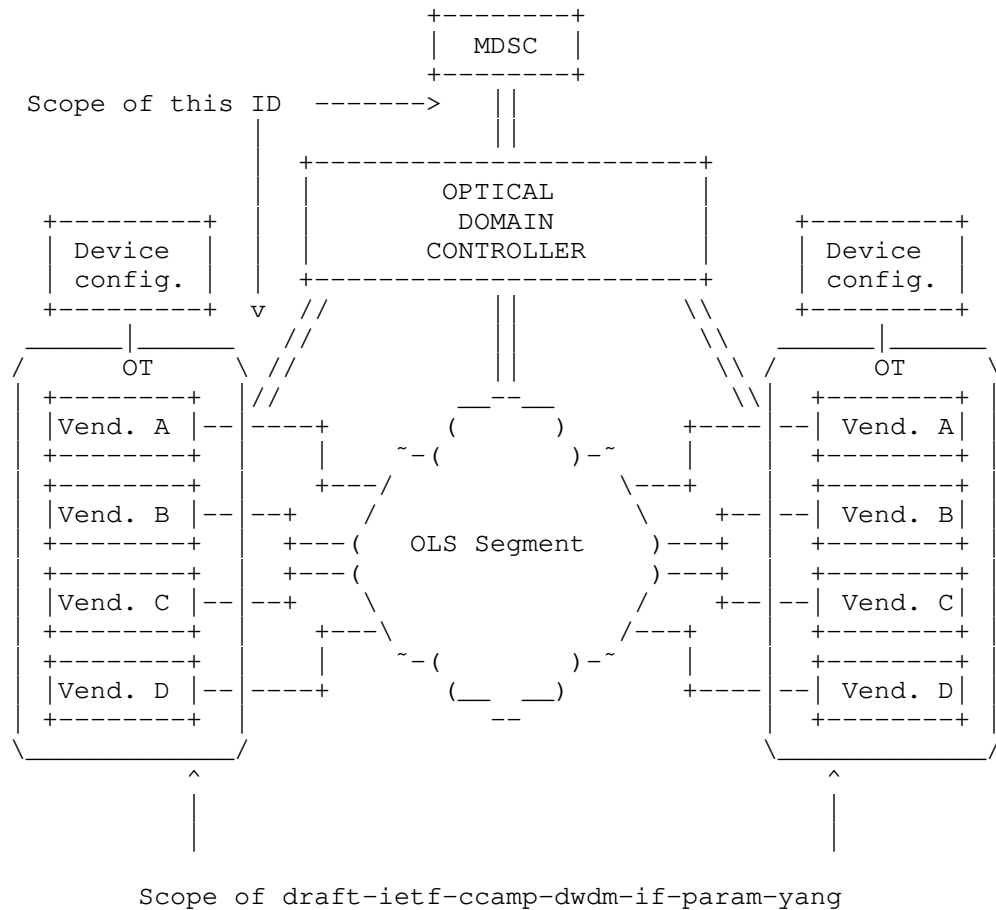


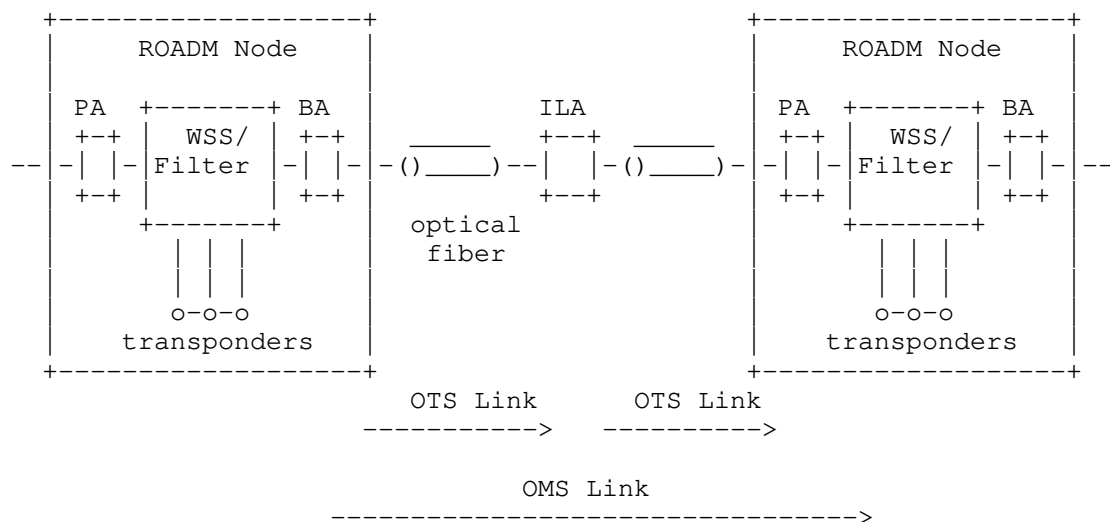
Figure 1. Control Plane Architecture

The models developed in this document is an abstracted Yang model that may be used in the interfaces between the MDSC and the Optical Domain Controller (aka MPI) and between the Optical Domain Controller and the Optical Device (aka SBI) in Figure 1. It is not intended to support detailed low-level DWDM interface model. DWDM interface 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 in a sequence of OTS links type (i), (ii), and (iii) as discussed above. OMS Media link would give an abstracted view of impairment data (e.g., power, OSNR, etc.) to the network controller.

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

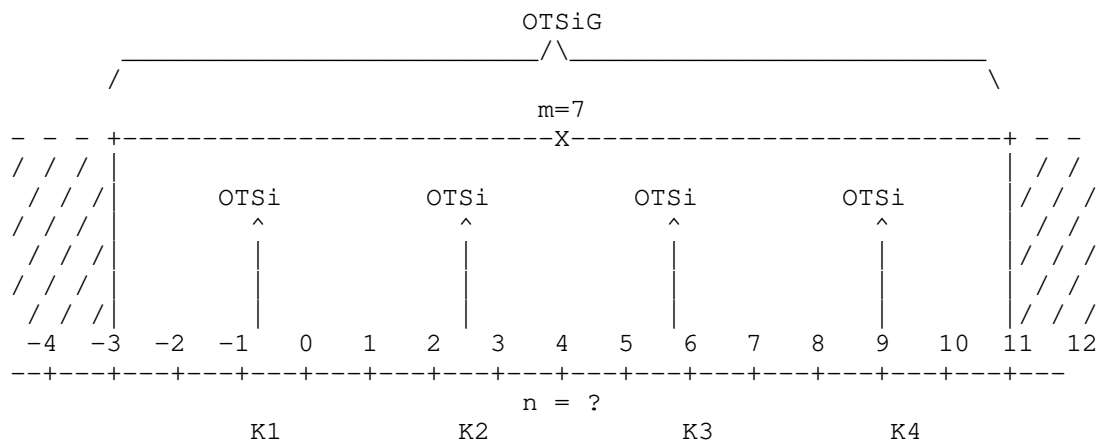
2.3.1. Optical Tributary Signal (OTSi)

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

2.3.2. Optical Tributary Signal Group (OTSiG)

The definition of the OTSiG is currently being moved from ITU-T Recommendation G.709 [G.709] to the new draft Recommendation G.807 (still work in progress) [G.807]. The OTSiG is an electrical signal

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

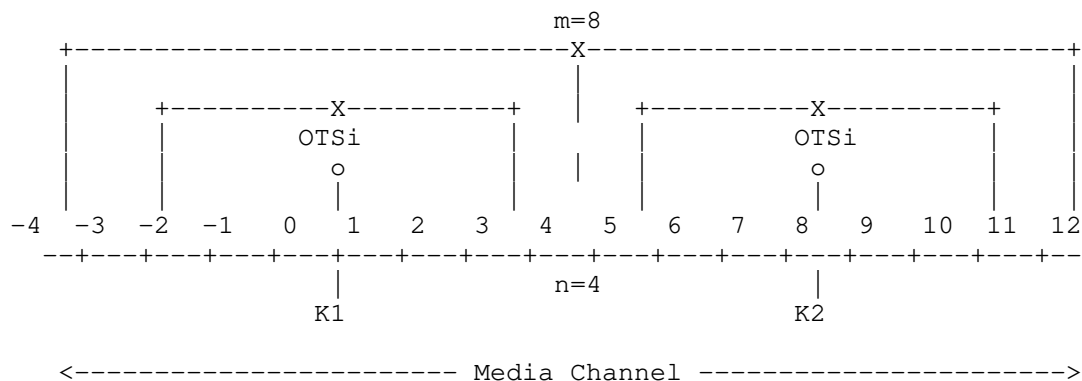


2.3.3 Media Channel (MC)

The definition of the MC is currently being moved from ITU-T Recommendation G.872 [G.872] to the new draft Recommendation G.807 (still work in progress) [G.807]. Section 3.2.2 defines the term MC and section 7.1.2 provides a more detailed description with some

examples. The definition of the MC is very generic (see ITU-T draft Recommendation G.807, Figure 7-1). In the YANG model below, the MC is used with the following semantics:

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

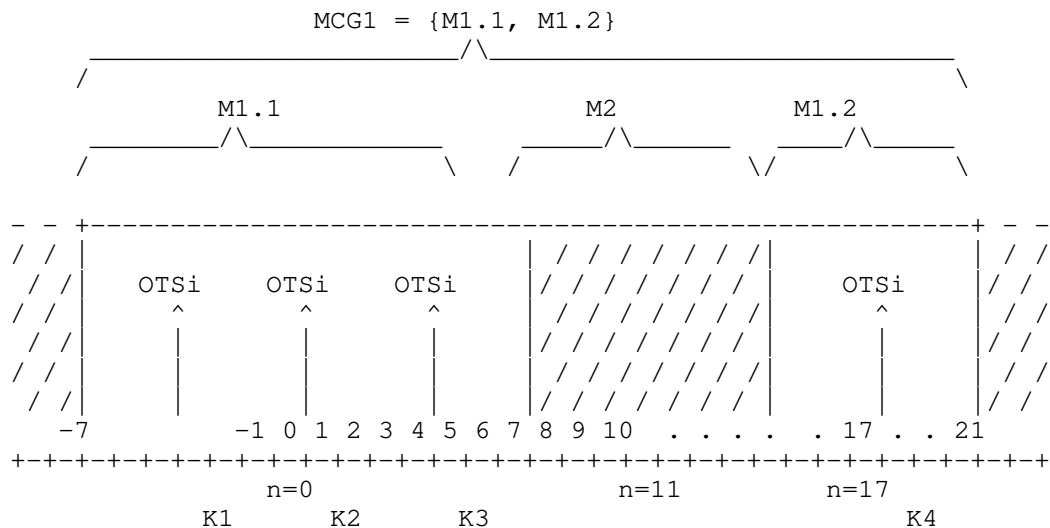


The frequency slot of the MC is defined by the n value defining the central frequency of the MC and the m value that defines the width of the MC following the flexible grid definition in ITU-T Recommendation G.694.1 [G.694.1]. In this model, the effective frequency slot as defined in ITU-T draft Recommendation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

2.3.3. Media Channel Group (MCG)

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

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



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

2.4. Amplifiers

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

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

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

2.5. Transponders

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.698.2 is one approach that only checks the code at both ends of the link. 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.

[Editor's Note: The current YANG model described in Section 3 with respect to the relationship between the transponder attributes and the OTSi will need to be investigated in the future revision]

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 media-channel-group* [i]
```

```

    +--ro i                               int16
    +--ro media-channels* [flexi-n]
      +--ro flexi-n                       uint16
      +--ro flexi-m?                     uint16
      +--ro OTSiG-ref?                   leafref
      +--ro OTSi-ref?                   leafref
+--ro OMS-elements* [elt-index]
  +--ro elt-index                       uint16
  +--ro uid?                           string
  +--ro type                           identityref
  +--ro element
    +--ro (element)?
      +--:(amplifier)
        +--ro amplifier
          +--ro type_variety             string
          +--ro operational
            +--ro actual-gain
              |                           decimal64
            +--ro tilt-target
              |                           decimal64
            +--ro out-voa
              |                           decimal64
            +--ro in-voa
              |                           decimal64
          +--ro (power-param)?
            +--:(channel-power)
              +--ro nominal-channel-power?
                |                           decimal64
            +--:(power-spectral-density)
              +--ro nominal-power-spectral-density?
                |                           decimal64
      +--:(fiber)
        +--ro fiber
          +--ro type_variety             string
          +--ro length                   decimal64
          +--ro loss_coef                 decimal64
          +--ro total_loss                decimal64
          +--ro pmd?                     decimal64
          +--ro conn_in?                  decimal64
          +--ro conn_out?                 decimal64
      +--:(concentratedloss)
        +--ro concentratedloss
          +--ro loss?                     decimal64
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point:
    +--ro OTSiG-element* [OTSiG-identifier]
      | +--ro OTSiG-identifier           int16

```

```

    +---ro OTSiG-container
      +---ro OTSi* [OTSi-carrier-id]
        +---ro OTSi-carrier-id          int16
        +---ro OTSi-carrier-frequency?   decimal64
        +---ro OTSi-signal-width?        decimal64
        +---ro channel-delta-power?      decimal64
+---ro transponders-list* [transponder-id]
  +---ro transponder-id                uint32
  +---ro (mode)?
    +---: (G.692.2)
      +---ro standard_mode?            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@2018-05-22.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 <younglee.tx@gmail.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:    Giovanni Martinelli <giomarti@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>
   Editor:    Dieter Beller <dieter.beller@nokia.com>
   Editor:    Sergio Belotti <Sergio.belotti@nokia.com>
   Editor:    Griseri Enrico <enrico.griseri@nokia.com>
   Editor:    Gert Grammel <ggrammel@juniper.net>";

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

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   authors of the code.  All rights reserved.

   Redistribution and use in source and binary forms, with or
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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
   (http://trustee.ietf.org/license-info).";

revision 2019-05-22 {
  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 OTSiG {

```

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

```
container OTSiG-container {
  config false;
  description
    "the container contains the related list of OTSi.
    The list could also be of only 1 element";
  list OTSi {
    key "OTSi-carrier-id";
    description
      "list of OTSi's under OTSi-G";
    leaf OTSi-carrier-id {
      type int16;
      description "OTSi carrier-id";
    }
    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 media channel";
    }
  }
} // OTSiG container
} // OTSiG grouping
```

```

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

    list media-channels {
      key "flexi-n";
      description
        "list of media channels represented as (n,m)";
      uses layer0-types:flexi-grid-channel;
      leaf OTSiG-ref {
        type leafref {
          path "/nw:networks/nw:network/nw:node/tet:te" +
            "/tet:tunnel-termination-point/OTSiG-element/OTSiG-identifier" ;
        }
        description
          "Reference to the OTSiG list to get OTSiG identifier of the
            OSiG carried by this media channel that reports the transient stat
";
      }
      leaf OTSi-ref {
        type leafref {
          path "/nw:networks/nw:network/nw:node/tet:te" +
            "/tet:tunnel-termination-point/OTSiG-element[OTSiG-
identifier=current()/../OTSiG-ref]/"+
            "OTSiG-container/OTSi/OTSi-carrier-id" ;
        }
        description
          "Reference to the OTSi list supporting the related OTSiG" ;
      }
    }

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

grouping oms-element {
  description "OMS description";
  list OMS-elements {
    key "elt-index";
    description
      "defines the spans and the amplifier blocks of the amplified lines";
    leaf elt-index {

```



```

        type uint16;
        description
            "ordered list of Index of OMS element (whether it's a Fiber, an EDFA
or a
Concentratedloss)";
    }
    leaf uid {
        type string;
        description
            "unique id of the element if it exists";
    }
    leaf type {
        type identityref {
            base type-element;
        }
        mandatory true;
        description "element type";
    }

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

/* Data nodes */

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

```

```
}

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

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

  list OTSiG-element {
    key "OTSiG-identifier";
    config false;
    description
      "the list of possible OTSiG representing client digital stream";

    leaf OTSiG-identifier {
      type int16;
      description "index of OTSiG element";
    }
    uses OTSiG;
  }

  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
-----
```

prefix: optical-imp-topo
reference: RFC XXXX (TDB)

7. Acknowledgments

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

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9. Contributors

Jonas Martensson
RISE

Email: jonas.martensson@ri.se

Aihua Guo
Huawei Technologies

Email: aguo@futurewei.com

Authors' Addresses

Young Lee
Futurewei Technologies

Email: younglee.tx@gmail.com

Haomian Zheng
Huawei Technologies

Email: zhenghaomian@huawei.com

Italo Busi
Huawei Technologies

Email: Italo.Busi@huawei.com

Nicola Sambo
Scuola Superiore Sant'Anna

Email: nicosambo@gmail.com

Victor Lopez
Telefonica

Email: victor.lopezalvarez@telefonica.com

G. Galimberti
Cisco

Email: ggalimbe@cisco.com

Giovanni Martinelli
Cisco
Email: giomarti@cisco.com

AUGE Jean Luc
Orange

Email: jeanluc.auge@orange.com

LE ROUZIC Esther
Orange

Email: esther.lerouzic@orange.com

Julien Meuric
Orange

Email: julien.meuric@orange.com

Dieter Beller
Nokia

Email: dieter.beller@nokia.com

Sergio Belotti
Nokia

Email: Sergio.belotti@nokia.com

Griseri Enrico
Nokia

Email: enrico.griseri@nokia.com

Gert Grammel
Juniper

Email: ggrammel@juniper.net

CCAMP Working Group
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H. Zheng
A. Guo
I. Busi
Huawei Technologies
A. Sharma
Google
X. Liu
Volta Networks
S. Belotti
Nokia
Y. Xu
CAICT
L. Wang
China Mobile
O. Gonzalez de Dios
Telefonica
July 07, 2019

A YANG Data Model for Optical Transport Network Topology
draft-ietf-ccamp-otn-topo-yang-07

Abstract

This document describes a YANG data model to describe the topologies of an Optical Transport Network (OTN). It is independent of control plane protocols and captures topological and resource related information pertaining to OTN. This model enables clients, which interact with a transport domain controller, for OTN topology related operations such as obtaining the relevant topology resource information.

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 [RFC2119].

Status of This Memo

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1. Introduction

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. A transport network can be constructed of equipments utilizing any of a number of different transport technologies such as the Optical Transport Networks (OTN) or packet transport such as provided by the MPLS-Transport Profile (MPLS-TP).

This document defines a data model of an OTN network topology, using YANG [RFC7950]. The model can be used by an application exposing to a transport controller. Furthermore, it can be used by an application for the following purposes (but not limited to):

- o To obtain a whole view of the network topology information of its interest;
- o To receive notifications with regard to the information change of the OTN topology;
- o To enforce the establishment and update of a network topology with the characteristic specified in the data model, e.g., by a client controller;

The YANG model defined in this document is independent of control plane protocols and captures topology related information pertaining to an Optical Transport Networks (OTN) electrical layer, as the scope specified by [RFC7062] and [RFC7138]. Furthermore, it is not a stand-alone model, but augmenting from the TE topology YANG model defined in [I-D.ietf-teas-yang-te-topo]. Following TE topology YANG model, the YANG model defined in this document is interface independent. The model is included in [I-D.ietf-teas-actn-yang], which indicates the typical usage of IETF YANG models in ACTN architecture specified by [RFC8453]. More specifically, the usage of this model between transport controllers is described in [I-D.ietf-ccamp-transport-nbi-app-statement].

Optical network technologies, including fixed Dense Wavelength Switched Optical Network (WSON) and flexible optical networks (a.k.a., flexi-grid networks), are covered in [I-D.ietf-ccamp-wson-yang] and [I-D.ietf-ccamp-flexigrid-yang], respectively.

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.
- o Some of the key terms used in this document are listed as follow.
- o TS: Tributary Slot.
- o TSG: Tributary Slot Granularity.
- o TPN: Tributary Port Number.

3. YANG Data Model for OTN Topology

3.1. OTN Topology Data Model Overview

This document aims to describe the data model for OTN topology. As a classic Traffic-engineering (TE) technology, OTN provide TDM switching in transport network [ITU-T]. Therefore the YANG module presented in this document augments from a more generic Traffic Engineered (TE) network topology data model, i.e., the ietf-te-topology.yang, as specified in [I-D.ietf-teas-yang-te-topo]. In section 6 of [I-D.ietf-teas-yang-te-topo], the guideline for augmenting TE topology model was provided, and in this draft we respectively augment the OTN attributes, TE bandwidth and TE label. [RFC8345] should also be mentioned, which describe a network topology model and provide the fundamental model for [I-D.ietf-teas-yang-te-topo]. However, this work is not directly augmenting [RFC8345].

The entities and TE attributes, such as node, termination points and links, are still applicable for describing an OTN topology and the model presented in this document only specifies with technology-specific attributes/information. In OTN attributes augmentation, mainly OTN-specific parameters are included such as Tributary Slot Granularity (TSG), payload type and so on.

For different order of ODU in OTN technology, the te-bandwidth is augmented to allow specifying the type of ODU container and the number a link can support per priority level. For example, for a ODU3 link, it may advertise 32*ODU0, 16*ODU1, 4*ODU2 available, assuming only a single priority level is supported. If one of ODU2 resource is taken to establish a ODU path, then the availability of this ODU link is updated as 24*ODU0, 12*ODU1, 3*ODU2 available. If there are equipment hardware limitations, then a subset of potential

ODU type SHALL be advertised. For instance, an ODU3 link may only support 4*ODU2.

The types of OTN label can be divided into the tributary ports and the tributary slots, represented by TPN or TS list respectively. In the TE-label augmentation, two optional label formats are available for label representation. It is also worth noting that for the parameter "label-step" in TE topology models, the value is always set to 1 as the granularity of OTN resources is measured by 'tributary slot'. In this model we specify the 'otn-label-step', which is used to align with TE topology only.

Note the model in this document re-uses some attributes defined in ietf-otn-types.yang, which is specified in [I-D.ietf-ccamp-otn-tunnel-model].

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

3.2. YANG Tree for OTN topology

```
module: ietf-otn-topology
  augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
    +--rw otn-topology!
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes:
    +--rw tsg?          identityref
    +--rw distance?    uint32
  augment /nw:networks/nw:network/nw:node/nt:termination-point/tet:te:
    +--rw client-svc!
    +--rw client-facing?          boolean
    +--rw supported-client-signal* identityref
  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:
    +--:(otn)
    +--rw odu-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:
    +--:(otn)
    +--rw odulist* [odu-type]
    +--rw odu-type  identityref
    +--rw number?   uint16
  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:
```

```

+--:(otn)
  +--rw odulist* [odu-type]
    +--rw odu-type    identityref
    +--rw number?     uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
    /tet:path-constraints/tet:te-bandwidth/tet:technology:

+--:(otn)
  +--ro odulist* [odu-type]
    +--ro odu-type    identityref
    +--ro number?     uint16
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:

+--:(otn)
  +--ro odulist* [odu-type]
    +--ro odu-type    identityref
    +--ro number?     uint16
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:

+--:(otn)
  +--rw odulist* [odu-type]
    +--rw odu-type    identityref
    +--rw number?     uint16
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:

+--:(otn)
  +--rw odulist* [odu-type]
    +--rw odu-type    identityref
    +--rw number?     uint16
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:

+--:(otn)
  +--rw odulist* [odu-type]
    +--rw odu-type    identityref
    +--rw number?     uint16
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:

+--:(otn)
  +--rw odu-type?    identityref
augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes
  /tet:max-link-bandwidth/tet:te-bandwidth/tet:technology:

```



```

+--:(otn)
  +--rw odulist* [odu-type]
    +--rw odu-type    identityref
    +--rw number?     uint16
augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes
/tet:max-resv-link-bandwidth/tet:te-bandwidth/tet:technology:
+--:(otn)
  +--rw odulist* [odu-type]
    +--rw odu-type    identityref
    +--rw number?     uint16
augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes
/tet:unreserved-bandwidth/tet:te-bandwidth/tet:technology:
+--:(otn)
  +--rw odulist* [odu-type]
    +--rw odu-type    identityref
    +--rw number?     uint16
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:
+--:(otn)
  +--ro odu-type?     identityref
augment /nw:networks/nw:network/nt:link/tet:te
/tet:information-source-entry/tet:max-link-bandwidth
/tet:te-bandwidth/tet:technology:
+--:(otn)
  +--ro odulist* [odu-type]
    +--ro odu-type    identityref
    +--ro number?     uint16
augment /nw:networks/nw:network/nt:link/tet:te
/tet:information-source-entry/tet:max-resv-link-bandwidth
/tet:te-bandwidth/tet:technology:
+--:(otn)
  +--ro odulist* [odu-type]
    +--ro odu-type    identityref
    +--ro number?     uint16
augment /nw:networks/nw:network/nt:link/tet:te
/tet:information-source-entry/tet:unreserved-bandwidth
/tet:te-bandwidth/tet:technology:
+--:(otn)
  +--ro odulist* [odu-type]
    +--ro odu-type    identityref
    +--ro number?     uint16
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:
+--:(otn)
  +--rw odu-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:
+--:(otn)
  +--rw odulist* [odu-type]
    +--rw odu-type    identityref
    +--rw number?     uint16
augment /nw:networks/tet:te/tet:templates/tet:link-template
  /tet:te-link-attributes/tet:max-resv-link-bandwidth
  /tet:te-bandwidth/tet:technology:
+--:(otn)
  +--rw odulist* [odu-type]
    +--rw odu-type    identityref
    +--rw number?     uint16
augment /nw:networks/tet:te/tet:templates/tet:link-template
  /tet:te-link-attributes/tet:unreserved-bandwidth
  /tet:te-bandwidth/tet:technology:
+--:(otn)
  +--rw odulist* [odu-type]
    +--rw odu-type    identityref
    +--rw number?     uint16
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
  /tet:connectivity-matrices/tet:label-restrictions
  /tet:label-restriction:
  +--rw range-type?    identityref
  +--rw tsg?           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:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
    | +--rw tpn?    uint16
    +--:(tributary-slot)
    +--rw ts?      uint16
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
  /tet:connectivity-matrices/tet:label-restrictions
  /tet:label-restriction/tet:label-end/tet:te-label
  /tet:technology:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
    | +--rw tpn?    uint16
    +--:(tributary-slot)
    +--rw ts?      uint16
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
  /tet:connectivity-matrices/tet:label-restrictions

```

```

        /tet:label-restriction/tet:label-step/tet:technology:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
      | +--rw tpn-step?   uint16
    +--:(tributary-slot)
      +--rw ts?           uint16
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:
+--:(otn)
  +--rw tpn?             uint16
  +--rw tsg?             identityref
  +--rw ts-list?        string
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:
+--:(otn)
  +--rw tpn?             uint16
  +--rw tsg?             identityref
  +--rw ts-list?        string
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:
+--:(otn)
  +--rw tpn?             uint16
  +--rw tsg?             identityref
  +--rw ts-list?        string
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:
+--:(otn)
  +--rw tpn?             uint16
  +--rw tsg?             identityref
  +--rw ts-list?        string
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:
+--:(otn)

```

```

    +---ro tpn?          uint16
    +---ro tsg?          identityref
    +---ro ts-list?      string
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 range-type?   identityref
    +---rw tsg?          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:
+---:(otn)
    +---rw (otn-label-type)?
    +---:(tributary-port)
    |   +---rw tpn?      uint16
    +---:(tributary-slot)
    |   +---rw ts?       uint16
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
    /tet:connectivity-matrices/tet:connectivity-matrix/tet:from
    /tet:label-restrictions/tet:label-restriction/tet:label-end
    /tet:te-label/tet:technology:
+---:(otn)
    +---rw (otn-label-type)?
    +---:(tributary-port)
    |   +---rw tpn?      uint16
    +---:(tributary-slot)
    |   +---rw ts?       uint16
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
    /tet:connectivity-matrices/tet:connectivity-matrix/tet:from
    /tet:label-restrictions/tet:label-restriction/tet:label-step
    /tet:technology:
+---:(otn)
    +---rw (otn-label-type)?
    +---:(tributary-port)
    |   +---rw tpn-step?  uint16
    +---:(tributary-slot)
    |   +---rw ts?        uint16
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
    /tet:connectivity-matrices/tet:connectivity-matrix
    /tet:to/tet:label-restrictions/tet:label-restriction:
    +---rw range-type?   identityref
    +---rw tsg?          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:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
      | +--rw tpn?      uint16
    +--:(tributary-slot)
      +--rw ts?        uint16
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
  /tet:connectivity-matrices/tet:connectivity-matrix/tet:to
    /tet:label-restrictions/tet:label-restriction/tet:label-end
      /tet:te-label/tet:technology:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
      | +--rw tpn?      uint16
    +--:(tributary-slot)
      +--rw ts?        uint16
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
  /tet:connectivity-matrices/tet:connectivity-matrix/tet:to
    /tet:label-restrictions/tet:label-restriction/tet:label-step
      /tet:technology:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
      | +--rw tpn-step?  uint16
    +--:(tributary-slot)
      +--rw ts?          uint16
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:
+--:(otn)
  +--rw tpn?          uint16
  +--rw ts?           identityref
  +--rw ts-list?      string
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:
+--:(otn)
  +--rw tpn?          uint16
  +--rw ts?           identityref
  +--rw ts-list?      string
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:
+---: (otn)
  +---rw tpn?          uint16
  +---rw tsg?          identityref
  +---rw ts-list?      string
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:
+---: (otn)
  +---rw tpn?          uint16
  +---rw tsg?          identityref
  +---rw ts-list?      string
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:
+---: (otn)
  +---ro tpn?          uint16
  +---ro tsg?          identityref
  +---ro ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
    /tet:label-restrictions/tet:label-restriction:
  +---ro range-type?   identityref
  +---ro tsg?          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:
+---: (otn)
  +---ro (otn-label-type)?
    +---: (tributary-port)
      | +---ro tpn?    uint16
    +---: (tributary-slot)
      +---ro ts?      uint16
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:
+---: (otn)
  +---ro (otn-label-type)?
    +---: (tributary-port)
      | +---ro tpn?    uint16

```

```

        +---:(tributary-slot)
            +---ro ts?      uint16
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:
+---:(otn)
    +---ro (otn-label-type)?
        +---:(tributary-port)
            | +---ro tpn-step?    uint16
        +---:(tributary-slot)
            +---ro ts?            uint16
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:
+---:(otn)
    +---ro tpn?            uint16
    +---ro tsg?            identityref
    +---ro ts-list?       string
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:
+---:(otn)
    +---ro tpn?            uint16
    +---ro tsg?            identityref
    +---ro ts-list?       string
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:
+---:(otn)
    +---ro tpn?            uint16
    +---ro tsg?            identityref
    +---ro ts-list?       string
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:
+---:(otn)
    +---ro tpn?            uint16
    +---ro tsg?            identityref
    +---ro ts-list?       string

```

```

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:
  +--:(otn)
    +--ro tpn?          uint16
    +--ro tsg?          identityref
    +--ro ts-list?      string
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 range-type?    identityref
  +--ro tsg?            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:
  +--:(otn)
    +--ro (otn-label-type)?
      +--:(tributary-port)
        | +--ro tpn?    uint16
      +--:(tributary-slot)
        +--ro ts?      uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
    /tet:connectivity-matrix/tet:from/tet:label-restrictions
    /tet:label-restriction/tet:label-end/tet:te-label
    /tet:technology:
  +--:(otn)
    +--ro (otn-label-type)?
      +--:(tributary-port)
        | +--ro tpn?    uint16
      +--:(tributary-slot)
        +--ro ts?      uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
    /tet:connectivity-matrix/tet:from/tet:label-restrictions
    /tet:label-restriction/tet:label-step/tet:technology:
  +--:(otn)
    +--ro (otn-label-type)?
      +--:(tributary-port)
        | +--ro tpn-step?  uint16
      +--:(tributary-slot)
        +--ro ts?          uint16

```



```

augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
    /tet:connectivity-matrix/tet:to/tet:label-restrictions
      /tet:label-restriction:
        +--ro range-type?    identityref
        +--ro tsg?           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:
    +--:(otn)
      +--ro (otn-label-type)?
        +--:(tributary-port)
          | +--ro tpn?    uint16
        +--:(tributary-slot)
          +--ro ts?      uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
    /tet:connectivity-matrix/tet:to/tet:label-restrictions
      /tet:label-restriction/tet:label-end/tet:te-label
      /tet:technology:
    +--:(otn)
      +--ro (otn-label-type)?
        +--:(tributary-port)
          | +--ro tpn?    uint16
        +--:(tributary-slot)
          +--ro ts?      uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
    /tet:connectivity-matrix/tet:to/tet:label-restrictions
      /tet:label-restriction/tet:label-step/tet:technology:
    +--:(otn)
      +--ro (otn-label-type)?
        +--:(tributary-port)
          | +--ro tpn-step?  uint16
        +--:(tributary-slot)
          +--ro ts?          uint16
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:
  +--:(otn)
    +--ro tpn?      uint16
    +--ro tsg?      identityref
    +--ro ts-list?  string

```

```

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:
  +--:(otn)
    +--ro tpn?          uint16
    +--ro tsg?          identityref
    +--ro ts-list?      string
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:
  +--:(otn)
    +--ro tpn?          uint16
    +--ro tsg?          identityref
    +--ro ts-list?      string
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:
  +--:(otn)
    +--ro tpn?          uint16
    +--ro tsg?          identityref
    +--ro ts-list?      string
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:
  +--:(otn)
    +--ro tpn?          uint16
    +--ro tsg?          identityref
    +--ro ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point
    /tet:local-link-connectivities/tet:label-restrictions
    /tet:label-restriction:
  +--rw range-type?    identityref
  +--rw tsg?           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:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
      | +--rw tpn?      uint16
    +--:(tributary-slot)
      +--rw ts?        uint16
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:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
      | +--rw tpn?      uint16
    +--:(tributary-slot)
      +--rw ts?        uint16
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:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
      | +--rw tpn-step?  uint16
    +--:(tributary-slot)
      +--rw ts?          uint16
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:
+--:(otn)
  +--rw tpn?          uint16
  +--rw tsg?          identityref
  +--rw ts-list?      string
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:
+--:(otn)
  +--rw tpn?          uint16
  +--rw tsg?          identityref

```

```

    +--rw ts-list?    string
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:
+--:(otn)
    +--rw tpn?        uint16
    +--rw tsg?        identityref
    +--rw ts-list?    string
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:
+--:(otn)
    +--rw tpn?        uint16
    +--rw tsg?        identityref
    +--rw ts-list?    string
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:
+--:(otn)
    +--ro tpn?        uint16
    +--ro tsg?        identityref
    +--ro ts-list?    string
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 range-type? identityref
    +--rw tsg?        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:
+--:(otn)
    +--rw (otn-label-type)?
        +--:(tributary-port)
            | +--rw tpn?    uint16
            +--:(tributary-slot)

```

```

        +---rw ts?      uint16
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point/tet:local-link-connectivities
        /tet:local-link-connectivity/tet:label-restrictions
        /tet:label-restriction/tet:label-end/tet:te-label
        /tet:technology:
+---:(otn)
    +---rw (otn-label-type)?
        +---:(tributary-port)
            | +---rw tpn?      uint16
        +---:(tributary-slot)
            +---rw ts?      uint16
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point/tet:local-link-connectivities
        /tet:local-link-connectivity/tet:label-restrictions
        /tet:label-restriction/tet:label-step/tet:technology:
+---:(otn)
    +---rw (otn-label-type)?
        +---:(tributary-port)
            | +---rw tpn-step?  uint16
        +---:(tributary-slot)
            +---rw ts?      uint16
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:
+---:(otn)
    +---rw tpn?      uint16
    +---rw tsg?      identityref
    +---rw ts-list?  string
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:
+---:(otn)
    +---rw tpn?      uint16
    +---rw tsg?      identityref
    +---rw ts-list?  string
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point/tet:local-link-connectivities
        /tet:local-link-connectivity/tet:optimizations/tet:algorithm
        /tet:metric/tet:optimization-metric
        /tet:explicit-route-exclude-objects
        /tet:route-object-exclude-object/tet:type/tet:label
        /tet:label-hop/tet:te-label/tet:technology:
+---:(otn)

```

```

    +--rw tpn?          uint16
    +--rw tsg?          identityref
    +--rw ts-list?     string
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:
+--:(otn)
    +--rw tpn?          uint16
    +--rw tsg?          identityref
    +--rw ts-list?     string
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:
+--:(otn)
    +--ro tpn?          uint16
    +--ro tsg?          identityref
    +--ro ts-list?     string
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:
+--:(otn)
    +--rw tpn?          uint16
    +--rw tsg?          identityref
    +--rw ts-list?     string
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:
+--:(otn)
    +--rw tpn?          uint16
    +--rw tsg?          identityref
    +--rw ts-list?     string
augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes
    /tet:label-restrictions/tet:label-restriction:
    +--rw range-type?   identityref
    +--rw tsg?          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:
+--:(otn)
    +--rw (otn-label-type)?
        +--:(tributary-port)

```

```

        | +--rw tpn?    uint16
      +---:(tributary-slot)
        +--rw ts?     uint16
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:
+---:(otn)
  +--rw (otn-label-type)?
  +---:(tributary-port)
    | +--rw tpn?    uint16
  +---:(tributary-slot)
    +--rw ts?     uint16
augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes
/tet:label-restrictions/tet:label-restriction/tet:label-step
/tet:technology:
+---:(otn)
  +--rw (otn-label-type)?
  +---:(tributary-port)
    | +--rw tpn-step?  uint16
  +---:(tributary-slot)
    +--rw ts?         uint16
augment /nw:networks/nw:network/nt:link/tet:te
/tet:information-source-entry/tet:label-restrictions
/tet:label-restriction:
+--ro range-type?    identityref
+--ro tsg?           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:
+---:(otn)
  +--ro (otn-label-type)?
  +---:(tributary-port)
    | +--ro tpn?    uint16
  +---:(tributary-slot)
    +--ro ts?     uint16
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:
+---:(otn)
  +--ro (otn-label-type)?
  +---:(tributary-port)
    | +--ro tpn?    uint16
  +---:(tributary-slot)
    +--ro ts?     uint16
augment /nw:networks/nw:network/nt:link/tet:te

```

```

        /tet:information-source-entry/tet:label-restrictions
            /tet:label-restriction/tet:label-step/tet:technology:
+---:(otn)
  +---ro (otn-label-type)?
    +---:(tributary-port)
      | +---ro tpn-step?   uint16
    +---:(tributary-slot)
      +---ro ts?          uint16
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:
+---:(otn)
  +---rw tpn?            uint16
  +---rw tsg?            identityref
  +---rw ts-list?       string
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:
+---:(otn)
  +---rw tpn?            uint16
  +---rw tsg?            identityref
  +---rw ts-list?       string
augment /nw:networks/tet:te/tet:templates/tet:link-template
  /tet:te-link-attributes/tet:label-restrictions
    /tet:label-restriction:
  +---rw range-type?    identityref
  +---rw tsg?           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:
+---:(otn)
  +---rw (otn-label-type)?
    +---:(tributary-port)
      | +---rw tpn?      uint16
    +---:(tributary-slot)
      +---rw ts?         uint16
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:
+---:(otn)
  +---rw (otn-label-type)?
    +---:(tributary-port)
      | +---rw tpn?      uint16

```



```

    +---:(tributary-slot)
        +---rw ts?      uint16
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:
+---:(otn)
    +---rw (otn-label-type)?
        +---:(tributary-port)
            | +---rw tpn-step?      uint16
        +---:(tributary-slot)
            +---rw ts?              uint16

```

4. The YANG Code

```

<CODE BEGINS> file "ietf-otn-topology.yang"
module ietf-otn-topology {
  yang-version 1.1;

  namespace "urn:ietf:params:xml:ns:yang:ietf-otn-topology";
  prefix "otntopo";

  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
      "I-D.ietf-teas-yang-te-topo: YANG Data Model for
      Traffic Engineering (TE) Topologies";
  }

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

```

organization

"IETF CCAMP Working Group";

contact

"WG Web: <<http://tools.ietf.org/wg/ccamp/>>

WG List: <<mailto:ccamp@ietf.org>>

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

Editor: Aihua Guo
<<mailto:aihuaguo@huawei.com>>

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

Editor: Anurag Sharma
<<mailto:ansha@google.com>>

Editor: Xufeng Liu
<<mailto:xufeng.liu.ietf@gmail.com>>

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

Editor: Yunbin Xu
<<mailto:xuyunbin@ritt.cn>>

Editor: Lei Wang
<<mailto:wangleiyj@chinamobile.com>>

Editor: Oscar Gonzalez de Dios
<<mailto:oscar.gonzalezdedios@telefonica.com>>";

description

"This module defines a protocol independent Layer 1/ODU topology data model.

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

revision 2019-07-07 {

```
    description
      "Initial Revision";
    reference
      "RFC XXXX: A YANG Data Model for Optical Transport Network Topology";
      // RFC Ed.: replace XXXX with actual RFC number, update date
      // information and remove this note
  }

/*
 * Groupings
 */

grouping otn-link-attributes {
  description "link attributes for OTN";

  leaf tsg {
    type identityref {
      base layer1-types:tributary-slot-granularity;
    }
    description "Tributary slot granularity.";
    reference
      "G.709/Y.1331, February 2016: Interfaces for the
      Optical Transport Network (OTN)";
  }
  leaf distance {
    type uint32;
    description "distance in the unit of kilometers";
  }
}

/*
 * Open issue: move to otn-types to allow reuse in WSON and Flexi-grid topolog
y models?
 */
grouping otn-tp-attributes {
  description "tp attributes for OTN";

  container client-svc {
    presence "client-facing LTP.";
    description
      "OTN LTP Service attributes.";

    leaf client-facing {
      type boolean;
      default 'false';
      description
        "Indicates whether this LTP is a client-facing LTP.";
    }
    leaf-list supported-client-signal {
```

```

        type identityref {
            base layer1-types:client-signal;
        }
        description
            "List of client signal types supported by the LTP.";
    }
}

/*
 * Data nodes
 */
augment "/nw:networks/nw:network/nw:network-types/"
    + "tet:te-topology" {
    container otn-topology {
        presence "indicates a topology type of Optical Transport
            Network (OTN)-electrical layer.";
        description "otn topology type";
    }
    description "augment network types to include otn network";
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
    + "tet:te-link-attributes" {
    when "../..../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment only for otn network.";
    }
    description "Augment link configuration";
    uses otn-link-attributes;
}

augment "/nw:networks/nw:network/nw:node/nt:termination-point/"
    + "tet:te" {
    when "../..../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment only for otn network";
    }
    description "OTN TP attributes config in ODU topology.";
    uses otn-tp-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/"
+ "otntopo:otn-topology" {
description "Augment OTN TE bandwidth";
}
description "OTN bandwidth.";
case otn {
uses layer1-types:otn-path-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/"
+ "otntopo:otn-topology" {
description "Augment OTN TE bandwidth";
}
description "OTN bandwidth.";
case otn {
uses layer1-types:otn-link-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/"
+ "otntopo:otn-topology" {
description "Augment OTN TE bandwidth";
}
description "OTN bandwidth.";
case otn {
uses layer1-types:otn-link-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/"
+ "otntopo:otn-topology" {
description "Augment OTN TE bandwidth";

```

```

    }
    description "OTN bandwidth.";
    case otn {
        uses layer1-types:otn-link-bandwidth;
    }
}

/* Augment bandwidth path constraints of connectivity-matrix information-source
e */
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/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE bandwidth";
    }
    description "OTN bandwidth.";
    case otn {
        uses layer1-types:otn-link-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/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE bandwidth";
    }
    description "OTN bandwidth.";
    case otn {
        uses layer1-types:otn-link-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/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE bandwidth";
    }
    description "OTN bandwidth.";
    case otn {

```

```

    uses layer1-types:otn-link-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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE bandwidth";
  }
  description "OTN bandwidth.";
  case otn {
    uses layer1-types:otn-link-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/"
    + "otntopo:otn-topology" {
    description "OTN TE bandwidth.";
  }
  description "OTN bandwidth.";
  case otn {
    uses layer1-types:otn-path-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/"
    + "otntopo:otn-topology" {
    description "OTN TE bandwidth.";
  }
  description "OTN bandwidth.";
  case otn {
    uses layer1-types:otn-link-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/"
    + "otntopo:otn-topology" {
    description "OTN TE bandwidth.";
  }
  description "OTN bandwidth.";
  case otn {
    uses layer1-types:otn-link-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/"
    + "otntopo:otn-topology" {
    description "OTN TE bandwidth.";
  }
  description "OTN bandwidth.";
  case otn {
    uses layer1-types:otn-link-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/"
    + "otntopo:otn-topology" {
    description "OTN TE bandwidth.";
  }
  description "OTN bandwidth.";
  case otn {
    uses layer1-types:otn-path-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/"
  + "otntopo:otn-topology" {
  description "OTN TE bandwidth.";
}
description "OTN bandwidth.";
case otn {
  uses layer1-types:otn-link-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/"
  + "otntopo:otn-topology" {
  description "OTN TE bandwidth.";
}
description "OTN bandwidth.";
case otn {
  uses layer1-types:otn-link-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/"
  + "otntopo:otn-topology" {
  description "OTN TE bandwidth.";
}
description "OTN bandwidth.";
case otn {
  uses layer1-types:otn-link-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" {
/*
    when "../../../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "OTN TE bandwidth.";
    }
*/
    description "OTN bandwidth.";
    case otn {
        uses layer1-types:otn-path-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" {
/*
    when "../../../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "OTN TE bandwidth.";
    }
*/
    description "OTN bandwidth.";
    case otn {
        uses layer1-types:otn-link-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" {
/*
    when "../../../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "OTN TE bandwidth.";
    }
*/
    description "OTN bandwidth.";
    case otn {
        uses layer1-types:otn-link-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" {
/*
  when "../..../..../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "OTN TE bandwidth.";
  }
*/
  description "OTN bandwidth.";
  case otn {
    uses layer1-types:otn-link-bandwidth;
  }
}

/*
* Augment TE label.
*/

/* Augment label restrictions of connectivity-matrices */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label restriction.";
  uses layer1-types:otn-label-restriction;
}

/* Augment label restrictions start of connectivity-matrices */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses layer1-types:otn-link-label;
  }
}

```

```

/* Augment label restrictions end of connectivity-matrices */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses layer1-types:otn-link-label;
  }
}

/* Augment label restrictions step of connectivity-matrices */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses layer1-types:otn-label-step;
  }
}

/* Augment label hop of underlay primary path of connectivity-matrices */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses layer1-types:otn-path-label;
  }
}

/* Augment label hop of underlay backup path of connectivity-matrices */
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/"
    + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses layer1-types:otn-path-label;
}
}

/* Augment label hop of route-exclude of connectivity-matrices */
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/"
    + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses layer1-types:otn-path-label;
}
}

/* Augment label hop of route-include of connectivity-matrices (added) */
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/"
    + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }

```

```

    }
    description "OTN label.";
    case otn {
        uses layer1-types:otn-path-label;
    }
}

/* Augment label hop of path-route of connectivity-matrices */
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/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
        uses layer1-types:otn-path-label;
    }
}

/* Augment ingress label restrictions of connectivity-matrix */
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/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    uses layer1-types:otn-label-restriction;
}

/* Augment ingress label restrictions start of connectivity-matrix */
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/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
}

```

```

    description "OTN label.";
    case otn {
        uses layer1-types:otn-link-label;
    }
}

/* Augment ingress label restrictions end of connectivity-matrix */
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/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
        uses layer1-types:otn-link-label;
    }
}

/* Augment ingress label restrictions step of connectivity-matrix */
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/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
        uses layer1-types:otn-label-step;
    }
}

/* Augment egress label restrictions of connectivity-matrix */
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/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
}

```

```

}
description "OTN label.";
uses layer1-types:otn-label-restriction;
}

/* Augment egress label restrictions start of connectivity-matrix */
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/"
  + "otntopo:otn-topology" {
  description "Augment OTN TE label";
}
description "OTN label.";
case otn {
  uses layer1-types:otn-link-label;
}
}

/* Augment egress label restrictions end of connectivity-matrix */
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/"
  + "otntopo:otn-topology" {
  description "Augment OTN TE label";
}
description "OTN label.";
case otn {
  uses layer1-types:otn-link-label;
}
}

/* Augment egress label restrictions step of connectivity-matrix */
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/"
  + "otntopo:otn-topology" {

```



```

        description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
        uses layer1-types:otn-label-step;
    }
}

/* Augment label hop of underlay primary path of connectivity-matrix */
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/"
        + "otntopo:otn-topology" {
            description "Augment OTN TE label";
        }
    description "OTN label.";
    case otn {
        uses layer1-types:otn-path-label;
    }
}

/* Augment label hop of underlay backup path of connectivity-matrix */
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/"
        + "otntopo:otn-topology" {
            description "Augment OTN TE label";
        }
    description "OTN label.";
    case otn {
        uses layer1-types:otn-path-label;
    }
}

/* Augment label hop of route-exclude of connectivity-matrix */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/tet:optimizations/"

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    + "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/"
    + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses layer1-types:otn-path-label;
}
}

/* Augment label hop of route-include of connectivity-matrix */
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/"
    + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses layer1-types:otn-path-label;
}
}

/* Augment label hop of path-route of connectivity-matrix */
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/"
    + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
description "OTN label.";
case otn {

```

```

    uses layer1-types:otn-path-label;
  }
}

/* Augment label restrictions of connectivity-matrices information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/"
  + "tet:connectivity-matrices/tet:label-restrictions/tet:label-restriction"
n" {
  when "../..../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  uses layer1-types:otn-label-restriction;
}

/* Augment label restrictions start of connectivity-matrices information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/"
  + "tet:connectivity-matrices/tet:label-restrictions/tet:label-restriction"
n/"
  + "tet:label-start/tet:te-label/tet:technology" {
  when "../..../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses layer1-types:otn-link-label;
  }
}

/* Augment label restrictions end of connectivity-matrices information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/"
  + "tet:connectivity-matrices/tet:label-restrictions/tet:label-restriction"
n/"
  + "tet:label-end/tet:te-label/tet:technology" {
  when "../..../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses layer1-types:otn-link-label;
  }
}

```

```

/* Augment label restrictions step of connectivity-matrices information-source */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses layer1-types:otn-label-step;
  }
}

/* Augment label hop of underlay primary path of connectivity-matrices information-source */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses layer1-types:otn-path-label;
  }
}

/* Augment label hop of underlay backup path of connectivity-matrices information-source */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses layer1-types:otn-path-label;
  }
}

```

```

/* Augment label hop of route-exclude of connectivity-matrices information-source */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses layer1-types:otn-path-label;
  }
}

/* Augment label hop of route-include of connectivity-matrices information-source */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses layer1-types:otn-path-label;
  }
}

/* Augment label hop of path-route of connectivity-matrices information-source */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
}

```

```

    }
    description "OTN label.";
    case otn {
        uses layer1-types:otn-path-label;
    }
}

/* Augment ingress label restrictions 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:from/tet:label-restrictions/tet:label-restriction" {
    when "../..../..../..../..../..../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    uses layer1-types:otn-label-restriction;
}

/* Augment ingress label restrictions start 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:from/tet:label-restrictions/tet:label-restriction/"
    + "tet:label-start/tet:te-label/tet:technology" {
    when "../..../..../..../..../..../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
        uses layer1-types:otn-link-label;
    }
}

/* Augment ingress label restrictions end 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:from/tet:label-restrictions/tet:label-restriction/"
    + "tet:label-end/tet:te-label/tet:technology" {
    when "../..../..../..../..../..../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
}

```

```

    description "OTN label.";
    case otn {
        uses layer1-types:otn-link-label;
    }
}

/* Augment ingress label restrictions step 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:from/tet:label-restrictions/tet:label-restriction/"
    + "tet:label-step/tet:technology" {
    when "../.../.../.../.../.../.../.../..."
        + "nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
        uses layer1-types:otn-label-step;
    }
}

/* Augment egress label restrictions 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:to/tet:label-restrictions/tet:label-restriction" {
    when "../.../.../.../.../.../.../.../.../.../.../.../.../.../.../.../.../..."
        + "nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    uses layer1-types:otn-label-restriction;
}

/* Augment egress label restrictions start 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:to/tet:label-restrictions/tet:label-restriction/"
    + "tet:label-start/tet:te-label/tet:technology" {
    when "../.../.../.../.../.../.../.../.../.../.../.../.../.../.../..."
        + "nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
}

```

```

    case otn {
        uses layer1-types:otn-link-label;
    }
}

/* Augment egress label restrictions end 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:to/tet:label-restrictions/tet:label-restriction/"
    + "tet:label-end/tet:te-label/tet:technology" {
    when "../.../.../.../.../.../.../.../.../..."
        + "nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
        uses layer1-types:otn-link-label;
    }
}

/* Augment egress label restrictions step 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:to/tet:label-restrictions/tet:label-restriction/"
    + "tet:label-step/tet:technology" {
    when "../.../.../.../.../.../.../.../.../..."
        + "nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
        uses layer1-types:otn-label-step;
    }
}

/* Augment label hop of underlay primary path 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: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/"
        + "otntopo:otn-topology" {

```



```

        description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
        uses layer1-types:otn-path-label;
    }
}

/* Augment label hop of underlay backup path of connectivity-matrix informatio
n-source */
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/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
        uses layer1-types:otn-path-label;
    }
}

/* Augment label hop of route-exclude of connectivity-matrix information-sourc
e */
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/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
        uses layer1-types:otn-path-label;
    }
}

/* Augment label hop of route-include of connectivity-matrix information-sourc
e */
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/"
    + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses layer1-types:otn-path-label;
}
}

/* Augment label hop of path-route 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-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/"
    + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses layer1-types:otn-path-label;
}
}

/* Augment label restrictions of local-link-connectivities */
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/"
    + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
description "OTN label.";
uses layer1-types:otn-label-restriction;
}

/* Augment label restrictions start of local-link-connectivities */

```

```

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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses layer1-types:otn-link-label;
  }
}

/* Augment label restrictions end of local-link-connectivities */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses layer1-types:otn-link-label;
  }
}

/* Augment label restrictions step of local-link-connectivities */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses layer1-types:otn-label-step;
  }
}

/* Augment label hop of underlay primary path of local-link-connectivities */

```

```

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/"
+ "otntopo:otn-topology" {
description "Augment OTN TE label";
}
description "OTN label.";
case otn {
uses layer1-types:otn-path-label;
}
}

/* Augment label hop of underlay backup path of local-link-connectivities */
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/"
+ "otntopo:otn-topology" {
description "Augment OTN TE label";
}
description "OTN label.";
case otn {
uses layer1-types:otn-path-label;
}
}

/* Augment label hop of route-exclude of local-link-connectivities */
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/"
+ "otntopo:otn-topology" {
description "Augment OTN TE label";
}
description "OTN label.";
}

```

```

    case otn {
        uses layer1-types:otn-path-label;
    }
}

/* Augment label hop of route-include of local-link-connectivities */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
}
description "OTN label.";
case otn {
    uses layer1-types:otn-path-label;
}
}

/* Augment label hop of path-route of local-link-connectivities */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
}
description "OTN label.";
case otn {
    uses layer1-types:otn-path-label;
}
}

/* Augment label restrictions 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:label-restrictions/tet:label-restriction" {
when "../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
    }
description "OTN label.";
uses layer1-types:otn-label-restriction;
}

/* Augment label restrictions start 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:label-restrictions/tet:label-restriction/"
    + "tet:label-start/tet:te-label/tet:technology" {
when "../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses layer1-types:otn-link-label;
}
}

/* Augment label restrictions end 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:label-restrictions/tet:label-restriction/"
    + "tet:label-end/tet:te-label/tet:technology" {
when "../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses layer1-types:otn-link-label;
}
}

/* Augment label restrictions step 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:label-restrictions/tet:label-restriction/"
    + "tet:label-step/tet:technology" {
when "../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
        uses layer1-types:otn-label-step;
    }
}

/* Augment label hop of underlay primary path 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: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/"
    + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
        uses layer1-types:otn-path-label;
    }
}

/* Augment label hop of underlay backup path 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: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/"
    + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
        uses layer1-types:otn-path-label;
    }
}

```

```

}
}

/* Augment label hop of route-exclude 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: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/"
+ "otntopo:otn-topology" {
description "Augment OTN TE label";
}
description "OTN label.";
case otn {
uses layer1-types:otn-path-label;
}
}

/* Augment label hop of route-include 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: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/"
+ "otntopo:otn-topology" {
description "Augment OTN TE label";
}
description "OTN label.";
case otn {
uses layer1-types:otn-path-label;
}
}

/* Augment label hop of path-route 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-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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses layer1-types:otn-path-label;
}
}

/* Augment label hop of underlay primary path of TE link */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses layer1-types:otn-path-label;
}
}

/* Augment label hop of underlay backup path of TE link */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses layer1-types:otn-path-label;
}
}

```

```

/* Augment label restrictions of TE link */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  uses layer1-types:otn-label-restriction;
}

/* Augment label restrictions start of TE link */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses layer1-types:otn-link-label;
  }
}

/* Augment label restrictions end of TE link */
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/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses layer1-types:otn-link-label;
  }
}

/* Augment label restrictions step of TE link */
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/"

```

```
    + "otntopo:otn-topology" {
      description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
      uses layer1-types:otn-label-step;
    }
  }

/* Augment label restrictions of TE link information-source */
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/"
      + "otntopo:otn-topology" {
        description "Augment OTN TE label";
      }
    description "OTN label.";
    uses layer1-types:otn-label-restriction;
  }

/* Augment label restrictions start of TE link information-source */
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/"
      + "otntopo:otn-topology" {
        description "Augment OTN TE label";
      }
    description "OTN label.";
    case otn {
      uses layer1-types:otn-link-label;
    }
  }

/* Augment label restrictions end of TE link information-source */
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/"
      + "otntopo:otn-topology" {
        description "Augment OTN TE label";
      }
    description "OTN label.";
    case otn {
      uses layer1-types:otn-link-label;
    }
  }
```

```

}

/* Augment label restrictions step of TE link information-source */
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/"
    + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses layer1-types:otn-label-step;
}
}

/* Augment label hop of underlay primary path of TE link template */
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" {
/*
when "../../../../../../../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
*/
description "OTN label.";
case otn {
    uses layer1-types:otn-path-label;
}
}

/* Augment label hop of underlay backup path of TE link template */
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" {
/*
when "../../../../../../../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
*/
description "OTN label.";
case otn {

```

```

    uses layer1-types:otn-path-label;
  }
}

/* Augment label restrictions of TE link template */
augment "/nw:networks/tet:te/tet:templates/"
  + "tet:link-template/tet:te-link-attributes/"
  + "tet:label-restrictions/tet:label-restriction" {
/*
  when "../../../../../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
*/
  description "OTN label.";
  uses layer1-types:otn-label-restriction;
}

/* Augment label restrictions start of TE link template */
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" {
/*
  when "../../../../../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
*/
  description "OTN label.";
  case otn {
    uses layer1-types:otn-link-label;
  }
}

/* Augment label restrictions end of TE link template */
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" {
/*
  when "../../../../../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
*/
  description "OTN label.";
  case otn {

```

```

        uses layer1-types:otn-link-label;
    }
}

/* Augment label restrictions step of TE link template */
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" {
/*
    when "../..../..../..../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
*/
    description "OTN label.";
    case otn {
        uses layer1-types:otn-label-step;
    }
}
}

<CODE ENDS>

```

5. 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-otn-topology 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 [RFC7950]. name: ietf-otn-topology namespace: urn:ietf:params:xml:ns:yang:ietf-otn-topology prefix: otntopo reference: RFC XXXX

6. Security Considerations

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

The NETCONF access control model [RFC8341] provides the means to restrict access for particular NETCONF or RESTCONF users to a

preconfigured subset of all available NETCONF or RESTCONF protocol operations and content.

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/.../tet:te-bandwidth/tet:technology
/nw:networks/nw:network/nw:node/tet:te/.../tet:label-restriction
/nw:networks/nw:network/nw:node/.../tet:te-label/tet:technology
Editors note: we are using simplified description by folding similar
branches to avoid repetition.
```

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:

Editors note: Currently there is no such data nodes, temporarily kept for review.

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8. Contributors

Baoquan Rao
Huawei Technologies
Email: raobaoquan@huawei.com

Xian Zhang
Huawei Technologies
Email: zhang.xian@huawei.com

Huub van Helvoort
Hai Gaoming BV
the Netherlands
Email: huubatwork@gmail.com

Victor Lopez
Telefonica
Email: victor.lopezalvarez@telefonica.com

Yunbo Li
China Mobile
Email: liyunbo@chinamobile.com

Dieter Beller
Nokia
Email: dieter.beller@nokia.com

Yanlei Zheng
China Unicom
Email: zhengyl@dimpt.com

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Authors' Addresses

Haomian Zheng
Huawei Technologies
H1-1-A043S Huawei Industrial Base, Songshanhu
Dongguan, Guangdong 523808
China

Email: zhenghaomian@huawei.com

Aihua Guo
Huawei Technologies
12007 Sunrise Valley Drive, Suite 325
Reston, VA 20171
U.S.A

Email: aihuaguo@huawei.com

Italo Busi
Huawei Technologies
HUAWEI TECHNOLOGIES ITALIA Srl Centro Direzionale Milano 2
Milan, Milan 20090
Italy

Email: Italo.Busi@huawei.com

Anurag Sharma
Google
1600 Amphitheatre Parkway
Mountain View, CA 94043

Email: ansha@google.com

Xufeng Liu
Volta Networks

Email: xufeng.liu.ietf@gmail.com

Sergio Belotti
Nokia

Email: sergio.belotti@nokia.com

Yunbin Xu
CAICT

Email: xuyunbin@rictt.cn

Lei Wang
China Mobile

Email: wangleiyj@chinamobile.com

Oscar Gonzalez de Dios
Telefonica

Email: oscar.gonzalezdedios@telefonica.com

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H. Zheng
A. Guo
I. Busi
Huawei Technologies
A. Sharma
Google
R. Rao
Infinera
S. Belotti
Nokia
V. Lopez
Telefonica
Y. Li
China Mobile
Y. Xu
CAICT
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OTN Tunnel YANG Model
draft-ietf-ccamp-otn-tunnel-model-07

Abstract

This document describes the YANG data model for OTN Tunnels.

Status of This Memo

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1. Introduction

OTN transport networks, specified in [ITU-T], can carry various types of client services. In many cases, the client signal is carried over an OTN tunnel across connected domains in a multi-domain network. These OTN services can either be transported or switched in the OTN network. If an OTN tunnel is switched, then additional parameters need to be provided to create a Mux OTN service.

This document provides YANG model for creating OTN tunnel. The model augments the TE Tunnel model.

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 draft 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 More OTN specific terms can be found in [I-D.ietf-ccamp-otn-topo-yang].

3. OTN Tunnel Model Description

3.1. Overview of OTN Tunnel Model

The OTN tunnel model is using TE tunnel [I-D.ietf-teas-yang-te] as a basic model and augment to the TE tunnel with OTN-specific parameters, including the bandwidth information and label information. It is also worth noting that the OTN tunnel provisioning is usually based on the OTN topology. Therefore the OTN tunnel model is usually used together with OTN topology model specified in [I-D.ietf-ccamp-otn-topo-yang]. The OTN tunnel model also imports a few type modules, including ietf-otn-types, ietf-te-types and ietf-inet-types.

More scenarios and model applications can be found in [I-D.ietf-ccamp-transport-nbi-app-statement] and [I-D.ietf-teas-actn-yang]. The current model is following the YANG language specification as [RFC7950], and the corresponding protocol is recommended to be Netconf protocol in [RFC6241] or RESTconf protocol in [RFC8040].

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

3.2. OTN-specific Parameters in Tunnel Model

OTN specific parameters have been augmenting to the TE tunnel models. The attributes on both of the source and destination need to be configured when setting up the tunnel. Typical parameters, including client signal, TPN, TSG and corresponding tributary slot information,

are required in the OTN tunnel model. These parameters are consistent with the framework in [RFC7062], and the specification in [RFC7138] and [RFC7139].

The OTN bandwidth information has been augmenting to various sections of TE tunnel models, including tunnel bandwidth, primary path bandwidth and so on. The OTN label information has been augmenting to label hop of a group of routing objects and also LSPs.

3.3. OTN Path Compute RPC

Similarly with TE tunnel, a 'compute-only' mode of OTN tunnel model is also supported for stateful path computation. Given the OTN tunnel computed, the client may query and/or subscribe on the tunnel to be notified whenever it changes. In addition, also a stateless Remote Procedural Call (RPC) is specified. On receiving this RPC, the provider is expected to compute the available path subject to the constraints specified in RPC and feedback to the client without any changing of the OTN network or the OTN tunnels.

4. OTN Tunnel YANG Tree

```
module: ietf-otn-tunnel
  augment /te:te/te:tunnels/te:tunnel:
    +--rw src-client-signal?  identityref
    +--rw dst-client-signal?  identityref
  augment /te:te/te:globals/te:named-path-constraints
    /te:named-path-constraint/te:te-bandwidth/te:technology:
    +--:(otn)
      +--rw odu-type?  identityref
  augment /te:te/te:tunnels/te:tunnel/te:te-bandwidth/te:technology:
    +--:(otn)
      +--rw odu-type?  identityref
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
    /te:p2p-primary-path/te:te-bandwidth/te:technology:
    +--:(otn)
      +--rw odu-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:
    +--:(otn)
      +--rw odu-type?  identityref
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths
    /te:p2p-secondary-path/te:te-bandwidth/te:technology:
    +--:(otn)
      +--rw odu-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:
+--:(otn)
  +--rw tpn?          uint16
  +--rw tsg?          identityref
  +--rw ts-list?      string
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:
+--:(otn)
  +--rw tpn?          uint16
  +--rw tsg?          identityref
  +--rw ts-list?      string
augment /te:te/te:globals/te:named-path-constraints
        /te:named-path-constraint/te:path-in-segment
        /te:label-restrictions/te:label-restriction:
  +--rw range-type?   identityref
  +--rw tsg?          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:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
      | +--rw tpn?    uint16
    +--:(tributary-slot)
      +--rw ts?      uint16
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:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
      | +--rw tpn?    uint16
    +--:(tributary-slot)
      +--rw ts?      uint16
augment /te:te/te:globals/te:named-path-constraints
        /te:named-path-constraint/te:path-out-segment
        /te:label-restrictions/te:label-restriction:
  +--rw range-type?   identityref
  +--rw tsg?          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:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
      | +--rw tpn?      uint16
    +--:(tributary-slot)
      +--rw ts?        uint16
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:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
      | +--rw tpn?      uint16
    +--:(tributary-slot)
      +--rw ts?        uint16
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:
+--:(otn)
  +--rw tpn?            uint16
  +--rw tsg?            identityref
  +--rw ts-list?       string
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:
+--:(otn)
  +--rw tpn?            uint16
  +--rw tsg?            identityref
  +--rw ts-list?       string
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:
+--:(otn)
  +--rw tpn?            uint16
  +--rw tsg?            identityref
  +--rw ts-list?       string
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:
+--:(otn)
  +--rw tpn?          uint16
  +--rw tsg?          identityref
  +--rw ts-list?      string
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 range-type?   identityref
  +--rw tsg?          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:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
    | +--rw tpn?      uint16
    +--:(tributary-slot)
    | +--rw ts?       uint16
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:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
    | +--rw tpn?      uint16
    +--:(tributary-slot)
    | +--rw ts?       uint16
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 range-type?   identityref
  +--rw tsg?          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:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
    | +--rw tpn?      uint16
    +--:(tributary-slot)

```

```

        +--rw ts?      uint16
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:
+---:(otn)
    +--rw (otn-label-type)?
    +---:(tributary-port)
    |   +--rw tpn?      uint16
    +---:(tributary-slot)
    |   +--rw ts?      uint16
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:
+---:(otn)
    +--ro tpn?          uint16
    +--ro tsg?          identityref
    +--ro ts-list?      string
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:
+---:(otn)
    +--ro tpn?          uint16
    +--ro tsg?          identityref
    +--ro ts-list?      string
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:
+---:(otn)
    +--ro tpn?          uint16
    +--ro tsg?          identityref
    +--ro ts-list?      string
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:
+---:(otn)
    +--rw tpn?          uint16

```

```

    +--rw tsg?          identityref
    +--rw ts-list?      string
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:
+--:(otn)
    +--rw tpn?          uint16
    +--rw tsg?          identityref
    +--rw ts-list?      string
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:
+--:(otn)
    +--rw tpn?          uint16
    +--rw tsg?          identityref
    +--rw ts-list?      string
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:
+--:(otn)
    +--rw tpn?          uint16
    +--rw tsg?          identityref
    +--rw ts-list?      string
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 range-type?   identityref
    +--rw tsg?          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:
+--:(otn)
    +--rw (otn-label-type)?
    |   +--:(tributary-port)
    |   |   +--rw tpn?   uint16
    |   +--:(tributary-slot)

```

```

        +--rw ts?      uint16
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:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
      | +--rw tpn?      uint16
    +--:(tributary-slot)
      +--rw ts?      uint16
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 range-type?    identityref
  +--rw tsg?            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:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
      | +--rw tpn?      uint16
    +--:(tributary-slot)
      +--rw ts?      uint16
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:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
      | +--rw tpn?      uint16
    +--:(tributary-slot)
      +--rw ts?      uint16
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:

```

```

+--:(otn)
  +--ro tpn?          uint16
  +--ro tsg?          identityref
  +--ro ts-list?      string
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:

+--:(otn)
  +--ro tpn?          uint16
  +--ro tsg?          identityref
  +--ro ts-list?      string
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:

+--:(otn)
  +--ro tpn?          uint16
  +--ro tsg?          identityref
  +--ro ts-list?      string
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:

+--:(otn)
  +--rw tpn?          uint16
  +--rw tsg?          identityref
  +--rw ts-list?      string
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:

+--:(otn)
  +--rw tpn?          uint16
  +--rw tsg?          identityref
  +--rw ts-list?      string
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:

+--:(otn)
  +--rw tpn?          uint16

```

```

    +--rw tsg?          identityref
    +--rw ts-list?      string
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:

+--:(otn)
    +--rw tpn?          uint16
    +--rw tsg?          identityref
    +--rw ts-list?      string
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 range-type?   identityref
    +--rw tsg?          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:

+--:(otn)
    +--rw (otn-label-type)?
    +--:(tributary-port)
    |   +--rw tpn?      uint16
    +--:(tributary-slot)
    |   +--rw ts?       uint16
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:

+--:(otn)
    +--rw (otn-label-type)?
    +--:(tributary-port)
    |   +--rw tpn?      uint16
    +--:(tributary-slot)
    |   +--rw ts?       uint16
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 range-type?   identityref
    +--rw tsg?          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:

+--:(otn)
    +--rw (otn-label-type)?

```



```

    +---:(tributary-port)
    |   +---rw tpn?      uint16
    +---:(tributary-slot)
        +---rw ts?      uint16
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:
+---:(otn)
    +---rw (otn-label-type)?
    +---:(tributary-port)
    |   +---rw tpn?      uint16
    +---:(tributary-slot)
        +---rw ts?      uint16
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:
+---:(otn)
    +---ro tpn?          uint16
    +---ro tsg?          identityref
    +---ro ts-list?      string
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:
+---:(otn)
    +---ro tpn?          uint16
    +---ro tsg?          identityref
    +---ro ts-list?      string
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:
+---:(otn)
    +---ro tpn?          uint16
    +---ro tsg?          identityref
    +---ro ts-list?      string
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:
+---:(otn)
    +---ro tpn?          uint16
    +---ro tsg?          identityref
    +---ro ts-list?      string

```

5. OTN Tunnel YANG Code

```
<CODE BEGINS>file "ietf-otn-tunnel@2019-07-08.yang"
module ietf-otn-tunnel {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-otn-tunnel";
  prefix "otn-tunnel";

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

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

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

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

    Editor: Aihua Guo
           <mailto:aihuaguo@huawei.com>

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

    Editor: Anurag Sharma
           <mailto:ansha@google.com>

    Editor: Rajan Rao
           <mailto:rrao@infinera.com>

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

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

Editor: Yunbo Li
<mailto:liyunbo@chinamobile.com>

Editor: Yunbin Xu
<mailto:xuyunbin@ritt.cn>;

description

"This module defines a model for OTN Tunnel Services.

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

```
revision "2018-08-23" {
  description
    "Initial Revision";
  reference
    "RFC XXXX: OTN Tunnel YANG Model";
  // RFC Ed.: replace XXXX with actual RFC number, update date
  // information and remove this note
}

/*
 * Groupings
 */
```

```
grouping otn-tunnel-attributes {
  description "Parameters for OTN tunnel";

  leaf src-client-signal {
    type identityref {
      base layer1-types:client-signal;
    }
    description
      "Client signal at the source endpoint of the tunnel. ";
  }

  leaf dst-client-signal {
    type identityref {
      base layer1-types:client-signal;
    }
    description
```

```
        "Client signal at the destination endpoint of the tunnel";
    }

}

/*
 * Data nodes
 */

augment "/te:te/te:tunnels/te:tunnel" {
    description
        "Augment with additional parameters required for OTN service";
    uses otn-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 "OTN bandwidth.";
        case otn {
            uses layer1-types:otn-path-bandwidth;
        }
    }

/* Augment bandwidth of tunnel */
    augment "/te:te/te:tunnels/te:tunnel/"
        + "te:te-bandwidth/te:technology" {
        description "OTN bandwidth.";
        case otn {
            uses layer1-types:otn-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 "OTN bandwidth.";
        case otn {
            uses layer1-types:otn-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 "OTN bandwidth.";
  case otn {
    uses layer1-types:otn-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 "OTN bandwidth.";
  case otn {
    uses layer1-types:otn-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 "OTN label.";
  case otn {
    uses layer1-types:otn-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 "OTN label.";
  case otn {
    uses layer1-types:otn-path-label;
  }
}

/* Augment label restrictions for the forwarding direction of path-in-segment
of named-path-constraints */
```

```
augment "/te:te/te:globals/te:named-path-constraints/"
  + "te:named-path-constraint/te:path-in-segment/"
  + "te:label-restrictions/te:label-restriction" {
  description "OTN label.";
  uses layer1-types:otn-label-restriction;
}

/* Augment label restrictions start for the forwarding direction of path-in-segment of named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
  + "te:named-path-constraint/te:path-in-segment/"
  + "te:label-restrictions/"
  + "te:label-restriction/te:label-start/"
  + "te:te-label/te:technology" {
  description "OTN label.";
  case otn {
    uses layer1-types:otn-link-label;
  }
}

/* Augment label restrictions end for the forwarding direction of path-in-segment of named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
  + "te:named-path-constraint/te:path-in-segment/"
  + "te:label-restrictions/"
  + "te:label-restriction/te:label-end/"
  + "te:te-label/te:technology" {
  description "OTN label.";
  case otn {
    uses layer1-types:otn-link-label;
  }
}

/* Augment label restrictions for the forwarding direction of path-out-segment of named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
  + "te:named-path-constraint/te:path-out-segment/"
  + "te:label-restrictions/"
  + "te:label-restriction" {
  description "OTN label.";
  uses layer1-types:otn-label-restriction;
}

/* Augment label restrictions start for the forwarding direction of path-out-segment of named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
  + "te:named-path-constraint/te:path-out-segment/"
  + "te:label-restrictions/"
  + "te:label-restriction/te:label-start/"
  + "te:te-label/te:technology" {
  description "OTN label.";
  case otn {
    uses layer1-types:otn-link-label;
  }
}
```

```
    }
  }

  /* Augment label restrictions end for the forwarding direction of path-out-segment of named-path-constraints */
  augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/te:path-out-segment/"
    + "te:label-restrictions/"
    + "te:label-restriction/te:label-end/"
    + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
      uses layer1-types:otn-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 "OTN label.";
    case otn {
      uses layer1-types:otn-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 "OTN label.";
    case otn {
      uses layer1-types:otn-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 "OTN label.";
```

```
    case otn {
        uses layer1-types:otn-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 "OTN label.";
    case otn {
        uses layer1-types:otn-path-label;
    }
}

/* Augment label restrictions for the forwarding direction of path-in-segment
of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:path-in-segment/te:label-restrictions/"
    + "te:label-restriction" {
    description "OTN label.";
    uses layer1-types:otn-label-restriction;
}

/* Augment label restrictions start for the forwarding direction of path-in-segment
of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:path-in-segment/te:label-restrictions/"
    + "te:label-restriction/te:label-start/"
    + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
        uses layer1-types:otn-link-label;
    }
}

/* Augment label restrictions end for the forwarding direction of path-in-segment
of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:path-in-segment/te:label-restrictions/"
    + "te:label-restriction/te:label-end/"
    + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
        uses layer1-types:otn-link-label;
    }
}
```



```

    }
  }

  /* Augment label restrictions for the forwarding direction of path-out-segment
  of primary path */
  augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:path-out-segment/te:label-restrictions/"
    + "te:label-restriction" {
    description "OTN label.";
    uses layer1-types:otn-label-restriction;
  }

  /* Augment label restrictions start for the forwarding direction of path-out-s
  egment 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 "OTN label.";
    case otn {
      uses layer1-types:otn-link-label;
    }
  }

  /* Augment label restrictions end for the forwarding direction of path-out-seg
  ment 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 "OTN label.";
    case otn {
      uses layer1-types:otn-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 "OTN label.";
    case otn {
      uses layer1-types:otn-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 "OTN label.";
  case otn {
    uses layer1-types:otn-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 "OTN label.";
  case otn {
    uses layer1-types:otn-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 "OTN label.";
  case otn {
    uses layer1-types:otn-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 "OTN label.";
    case otn {
        uses layer1-types:otn-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 "OTN label.";
    case otn {
        uses layer1-types:otn-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 "OTN label.";
    case otn {
        uses layer1-types:otn-path-label;
    }
}

/* Augment label restrictions for the forwarding direction of path-in-segment
of reverse primary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:p2p-primary-reverse-path/"
    + "te:path-in-segment/te:label-restrictions/"
    + "te:label-restriction" {
    description "OTN label.";
    uses layer1-types:otn-label-restriction;
}

/* Augment label restrictions start for the forwarding direction of path-in-segment
of reverse primary path */
augment "/te:te/te:tunnels/te:tunnel/"

```

```
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:p2p-primary-reverse-path/"
    + "te:path-in-segment/te:label-restrictions/"
    + "te:label-restriction/te:label-start/"
    + "te:te-label/te:technology" {
description "OTN label.";
case otn {
    uses layer1-types:otn-link-label;
}
}

/* Augment label restrictions end for the forwarding direction of path-in-segment of reverse primary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:p2p-primary-reverse-path/"
    + "te:path-in-segment/te:label-restrictions/"
    + "te:label-restriction/te:label-end/"
    + "te:te-label/te:technology" {
description "OTN label.";
case otn {
    uses layer1-types:otn-link-label;
}
}

/* Augment label restrictions for the forwarding direction of path-out-segment of reverse primary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:p2p-primary-reverse-path/"
    + "te:path-out-segment/te:label-restrictions/"
    + "te:label-restriction" {
description "OTN label.";
uses layer1-types:otn-label-restriction;
}

/* Augment label restrictions start for the forwarding direction of path-out-segment of reverse primary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:p2p-primary-reverse-path/"
    + "te:path-out-segment/te:label-restrictions/"
    + "te:label-restriction/te:label-start/"
    + "te:te-label/te:technology" {
description "OTN label.";
case otn {
    uses layer1-types:otn-link-label;
}
}

/* Augment label restrictions end for the forwarding direction of path-out-segment of reverse primary path */
```

```
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:p2p-primary-reverse-path/"
  + "te:path-out-segment/te:label-restrictions/"
  + "te:label-restriction/te:label-end/"
  + "te:te-label/te:technology" {
  description "OTN label.";
  case otn {
    uses layer1-types:otn-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 "OTN label.";
  case otn {
    uses layer1-types:otn-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 "OTN label.";
  case otn {
    uses layer1-types:otn-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 "OTN label.";
    case otn {
        uses layer1-types:otn-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 "OTN label.";
    case otn {
        uses layer1-types:otn-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 "OTN label.";
    case otn {
        uses layer1-types:otn-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 "OTN label.";
    case otn {
        uses layer1-types:otn-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 "OTN label.";
case otn {
    uses layer1-types:otn-path-label;
}
}

/* Augment label restrictions for the forwarding direction of path-in-segment
of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:path-in-segment/te:label-restrictions/"
    + "te:label-restriction" {

description "OTN label.";
uses layer1-types:otn-label-restriction;
}

/* Augment label restrictions start for the forwarding direction of path-in-segment
of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:path-in-segment/te:label-restrictions/"
    + "te:label-restriction/te:label-start/"
    + "te:te-label/te:technology" {
description "OTN label.";
case otn {
    uses layer1-types:otn-link-label;
}
}

/* Augment label restrictions end for the forwarding direction of path-in-segment
of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:path-in-segment/te:label-restrictions/"
    + "te:label-restriction/te:label-end/"
    + "te:te-label/te:technology" {
description "OTN label.";
case otn {
    uses layer1-types:otn-link-label;
}
}

/* Augment label restrictions for the forwarding direction of path-out-segment
of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:path-out-segment/te:label-restrictions/"
    + "te:label-restriction" {

```

```

    description "OTN label.";
    uses layer1-types:otn-label-restriction;
}

/* Augment label restrictions start for the forwarding direction of path-out-segment of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:path-out-segment/te:label-restrictions/"
    + "te:label-restriction/te:label-start/"
    + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
        uses layer1-types:otn-link-label;
    }
}

/* Augment label restrictions end for the forwarding direction of path-out-segment of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:path-out-segment/te:label-restrictions/"
    + "te:label-restriction/te:label-end/"
    + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
        uses layer1-types:otn-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 "OTN label.";
    case otn {
        uses layer1-types:otn-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 "OTN label.";
    case otn {
        uses layer1-types:otn-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 "OTN label.";
    case otn {
        uses layer1-types:otn-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 "OTN label.";
    case otn {
        uses layer1-types:otn-path-label;
    }
}
/*
grouping p2p-path-ero {
    description
        "TE tunnel ERO configuration grouping";

    leaf te-default-metric {
        type uint32;
        description
            "Traffic engineering metric.";
    }
    leaf te-delay-metric {
        type uint32;
        description
            "Traffic engineering delay metric.";
    }
    leaf te-hop-metric {
        type uint32;
        description
            "Traffic engineering hop metric.";
```

```
    }
    container explicit-route-objects-always {
      description "Explicit route objects container";
      list route-object-include-exclude {
        key "index";
        description
          "List of explicit route objects";
        leaf explicit-route-usage {
          type identityref {
            base te-types:route-usage-type;
          }
          description "An explicit-route hop action.";
        }
        uses te-types:explicit-route-hop {
          augment "type/label/label-hop/te-label/technology" {
            description "OTN label.";
            case otn {
              uses layer1-types:otn-path-label;
            }
          }
        }
      }
    }
  }
}
*/
/*
rpc otn-te-tunnel-path-compute {
  description "OTN TE tunnel path computation";
  input {
    list request {
      key "id";
      description "A list of path computation requests.";

      leaf id {
        type uint8;
        description
          "Request ID.";
      }
      leaf type {
        type identityref {
          base te-types:te-tunnel-type;
        }
        description "TE tunnel type.";
      }
      leaf source {
        type inet:ip-address;
        description
          "TE tunnel source address.";
      }
    }
  }
}
```

```
    }

    leaf destination {
      type inet:ip-address;
      description
        "TE tunnel destination address";
    }
    leaf src-tp-id {
      type binary;
      description
        "TE tunnel source termination point identifier.";
    }
    leaf dst-tp-id {
      type binary;
      description
        "TE tunnel destination termination point identifier.";
    }
    leaf switching-layer {
      type identityref {
        base te-types:switching-capabilities;
      }
      description
        "Switching layer where the requests are computed.";
    }
    leaf encoding {
      type identityref {
        base te-types:lsp-encoding-types;
      }
      description "LSP encoding type";
    }
    leaf protection-type {
      type identityref {
        base te-types:lsp-protection-type;
      }
      description "LSP protection type";
    }
    leaf restoration-type {
      type identityref {
        base te-types:lsp-restoration-type;
      }
      description "LSP restoration type";
    }
    leaf provider-id {
      type te-types:te-global-id;
      description
        "An identifier to uniquely identify a provider.";
    }
    leaf client-id {
```

```
    type te-types:te-global-id;
    description

        "An identifier to uniquely identify a client.";
}
leaf te-topology-id {
    type te-types:te-topology-id;
    description
        "It is presumed that a datastore will contain many
        topologies. To distinguish between topologies it is
        vital to have UNIQUE topology identifiers.";
}
leaf setup-priority {
    type uint8 {
        range "0..7";
    }
    description
        "TE LSP setup priority";
}
leaf hold-priority {
    type uint8 {
        range "0..7";
    }
    description
        "TE LSP hold priority";
}
leaf te-path-metric-type {
    type identityref {
        base te-types:path-metric-type;
    }
    default te-types:path-metric-te;
    description
        "The tunnel path metric type.";
}

leaf odu-type {
    type identityref{
        base layer1-types:odu-type;
    }
    description "Type of ODU";
}
container p2p-primary-paths {
    description "Set of P2P primary paths container";
    list p2p-primary-path {
        key "name";
        description
            "List of primary paths for this tunnel.";
        leaf name {
```

```
        type string;
        description "TE path name";
    }

    uses p2p-path-ero;
}

container p2p-secondary-paths {
    description "Set of P2P secondary paths container";
    list p2p-secondary-path {
        key "name";
        description
            "List of secondary paths for this tunnel.";
        leaf name {
            type string;
            description "TE path name";
        }
        uses p2p-path-ero;
    }
}

uses otn-tunnel-attributes;
}

output {
    leaf return-code {
        type enumeration {
            enum success {
                description "success";
            }
            enum aborted {
                description "aborted";
            }
            enum destination-not-found {
                description "destination-not-found";
            }
            enum invalid-argument {
                description "invalid-argument";
            }
            enum no-memory {
                description "no-memory";
            }
            enum no-path-found {
                description "no-path-found";
            }
            enum other-error {
                description "other-error";
            }
            enum some-path-not-found {
```

```
        description "some-path-not-found";
    }
    enum source-not-found {
        description "source-not-found";

    }
    enum topology-error {
        description "topology-error";
    }
}
description
    "Return code";
}
list result {
    key "id";
    description
        "A list of results for all requests.";

    leaf id {
        type uint8;
        description
            "Request ID";
    }
    container p2p-primary-paths {
        description "Set of P2P primary paths container";
        list p2p-primary-path {
            key "name";
            description
                "List of resultant primary paths for this tunnel.";
            leaf name {
                type string;
                description "TE path name";
            }
            uses p2p-path-ero;
        }
    }
    container p2p-secondary-paths {
        description "Set of P2P secondary paths container";
        list p2p-secondary-path {
            key "name";
            description
                "List of resultant secondary paths for this tunnel.";
            leaf name {
                type string;
                description "TE path name";
            }
            uses p2p-path-ero;
        }
    }
}
```

```

    }
  }
}
}*/
}

<CODE ENDS>

```

6. Security Considerations

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

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

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:

```

/te:te/te:tunnels/te:tunnel /te:te/./te:te-bandwidth/te:technology
/te:te/./te:type/te:label/te:label-hop/te:te-label/te:technology
/te:te/./te:label-restrictions/te:label-restriction/te:label-start/
te:te-label/te:technology /te:te/./te:label-restrictions/te:label-
restriction/te:label-end/te:te-label/te:technology
/te:te/./te:label-restrictions/te:label-restriction/ Editors note:
we are using simplified description by folding similar branches to
avoid repetition.

```

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:

/te:te/../../te:type/te:label/te:label-hop/te:te-label/te:technology
Editors note: we are using simplified description by folding similar branches to avoid repetition.

Some of the RPC operations in this YANG module may be considered sensitive or vulnerable in some network environments. It is thus important to control access to these operations. These are the operations and their sensitivity/vulnerability:

+---x otn-te-tunnel-path-compute This path compute RPC provides a mechanism to enable the client to query and/or subscribe on the tunnel to be notified whenever it changes. Thus path computation is only for the client reference, with no real deploy or resource reservation.

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

URI: urn:ietf:params:xml:ns:yang:ietf-otn-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-otn-tunnel |
| namespace: | urn:ietf:params:xml:ns:yang:ietf-otn-tunnel |
| prefix: | otn-tunnel |
| reference: | RFC XXXX |

| | |
|------------|--|
| name: | ietf-otn-types |
| namespace: | urn:ietf:params:xml:ns:yang:ietf-otn-types |
| prefix: | otn-types |
| reference: | RFC XXXX |

8. Acknowledgements

TBD.

9. Contributors

Dieter Beller
Nokia
Email: dieter.beller@nokia.com

Yanlei Zheng
China Unicom
Email: zhengyl@dimpt.com

Xian Zhang
Huawei Technologies
Email: zhang.xian@huawei.com

Lei Wang
China Mobile
Email: wangleiyj@chinamobile.com

Oscar Gonzalez de Dios
Telefonica
Email: oscar.gonzalezdedios@telefonica.com

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Authors' Addresses

Haomian Zheng
Huawei Technologies
H1-1-A043S Huawei Industrial Base, Songshanhu
Dongguan, Guangdong 523808
China

Email: zhenghaomian@huawei.com

Aihua Guo
Huawei Technologies
12007 Sunrise Valley Drive, Suite 325
Reston, VA 20171
U.S.A

Email: aihuaguo@huawei.com

Italo Busi
Huawei Technologies
HUAWEI TECHNOLOGIES ITALIA Srl Centro Direzionale Milano 2
Milan, Milan 20090
Italy

Email: Italo.Busi@huawei.com

Anurag Sharma
Google
1600 Amphitheatre Parkway
Mountain View, CA 94043
USA

Email: ansha@google.com

Rajan Rao
Infinera
169 Java Drive
Sunnyvale, CA 94089
USA

Email: rrao@infinera.com

Sergio Belotti
Nokia

Email: sergio.belotti@nokia.com

Victor Lopez
Telefonica

Email: victor.lopezalvarez@telefonica.com

Yunbo Li
China Mobile

Email: liyunbo@chinamobile.com

Yunbin Xu
CAICT

Email: xuyunbin@rict.cn

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I. Hussain
R. Valiveti
Infinera Corp
Q. Wang
ZTE
L. Andersson
M. Chen
H. Zheng
Huawei
February 13, 2019

GMPLS Routing and Signaling Framework for Flexible Ethernet (FlexE)
draft-izh-ccamp-flex-e-fwk-07

Abstract

This document specifies the GMPLS control plane requirements, framework, and architecture for the FlexE technology. The document also discusses interoperation between the GMPLS control plane for FlexE and the control plane of any networking layer using the FlexE technology as a server layer.

As different from earlier Ethernet data planes FlexE allows for decoupling of the Ethernet Physical layer (PHY) and Media Access Control layer (MAC) rates.

Study Group 15 (SG15) of the ITU-T has endorsed the FlexE Implementation Agreement from Optical Internetworking Forum (OIF) and included it, by reference, in some of their Recommendations.

Status of This Memo

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1. Introduction

This document specifies the GMPLS control plane requirements, framework, and architecture for the FlexE technology. The FlexE control plane requirements are found in an appendix.

Prior to FlexE Ethernet MAC rates were until constrained to match the rates of the Ethernet PHY(s). FlexE, specified by the OIF, allows MAC rates to be different from PHY rates. An OIF implementation agreement [OIFFLEXE1] allows for complete decoupling of the MAC and PHY rates. This has been further extended in [OIFFLEXE2].

SG15 in ITU-T has endorsed the OIF FlexE data plane and parts of [G.872], [G.709], [G.798] and [G.8021]. The Recommendations depends on or are based on the FlexE data plane.

The FlexE implementation agreement includes support for:

- a. MAC rates which are greater than the rate of a single PHY; multiple PHYs are bonded to achieve this
- b. MAC rates which are less than the rate of a PHY (sub-rate)
- c. support for channelization within a single PHY, or over a group of bonded PHYs.

The capabilities supported by the FlexE data plane are:

- a. Support a large rate Ethernet MAC over bonded Ethernet PHYs, e.g. supporting a 200G MAC over 2 bonded 100GBASE-R PHY(s)
- b. Support a sub-rate Ethernet MAC over a single Ethernet PHY, e.g. supporting a 50G MAC over a 100GBASE-R PHY

- c. Support a collection of flexible Ethernet clients over a single Ethernet PHY, e.g. supporting two MACs with the rates 25Gbps, and one with rate 50G over a single 100GBASE-R PHY
- d. Support a sub-rate Ethernet MAC over bonded PHYs, e.g. supporting a 150G Ethernet client over 2 bonded 100GBASE-R PHY(s)
- e. Support a collection of Ethernet MAC clients over bonded Ethernet PHYs, e.g. supporting a 50G and 150G MAC over 2 bonded 100GBASE-R PHY(s)

FlexE networks feature FlexE Ethernet interfaces, for more details see Section 4.1.

From a control plane perspective, the FlexE Groups may be viewed as logical links and FlexE Clients as logical sub-interfaces (or channelized interfaces).

These logical point-to-point links may be realized in at least two different ways:

- a. direct point-to-point links with no intervening transport network.
- b. direct point-to-point links across a transport network transport network.
- c. Ethernet PHY(s) may be transparently transported via an Optical Transport Network (OTN), as defined by ITU-T in [G.709] and [G.798].

The OTN set of client mappings has been extended to support the use cases identified in the OIF FlexE implementation agreement.

This document is a framework for the network control plane signaling and routing extensions required to establish FlexE links (FlexE Groups (PHY) and FlexE Clients (MAC)). FlexE Links may interconnect customer edge devices (CE to CE), CE to provider edge devices (PE), PE to PE, or devices at the edge to devices in the core (PE to P) or devices in the core (P to P).

Any pair of neighbouring L2 and L3 device that support FlexE interfaces may be interconnected P2P using a FlexE link (PHY and MAC). Further a device that terminates a FlexE link MUST be able to extract either the L2 or L3 payload and switch on the appropriate level, i.e. Ethernet, MPLS or IP. It should be noted that any type of switching is outside of scope for the FlexE specification.

FlexE CE devices may typically be L3 routers or other devices that use FlexE at layers 1 and 2 to provide point-to-point connectivity between each other.

Thus this draft considers the cases in which the two peer FlexE devices are:

- o interconnecting two parts of a customer network (CE to CE).
- o at the edge of the customer network (CE) and the close edge of the provider network (PE to CE).
- o opposite edges of the FlexE capable network (PE to PE).
- o at the edge of the FlexE network PE interconnected to a provider device (PE to P).
- o interconnecting two provider devices (P to P).

This list of deployment cases will help identify the GMPLS control plane (i.e. routing and signaling) extensions that may be required to support establishment of FlexE services.

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. Updates in the version

This section will be removed before posting.

1. Following a suggestion from Daniele the FlexE Control Plane Requirements has been moved to an appendix.
2. There are still some of the comments from Daniele that might need to be addressed, but we have had a pretty large overlap in comments, so the intention is that all should be addressed.
3. The terms Ethernet Interface and Ethernet sub-Interface has been re-introduced in relation to FlexE Group and FlexE Client respectively.

4. Except for some spelling corrections Section 5 to Section 7 are virtually untouched, though it is likely that some of the changes in the earlier parts of the document will have to be reflected into those sections also.

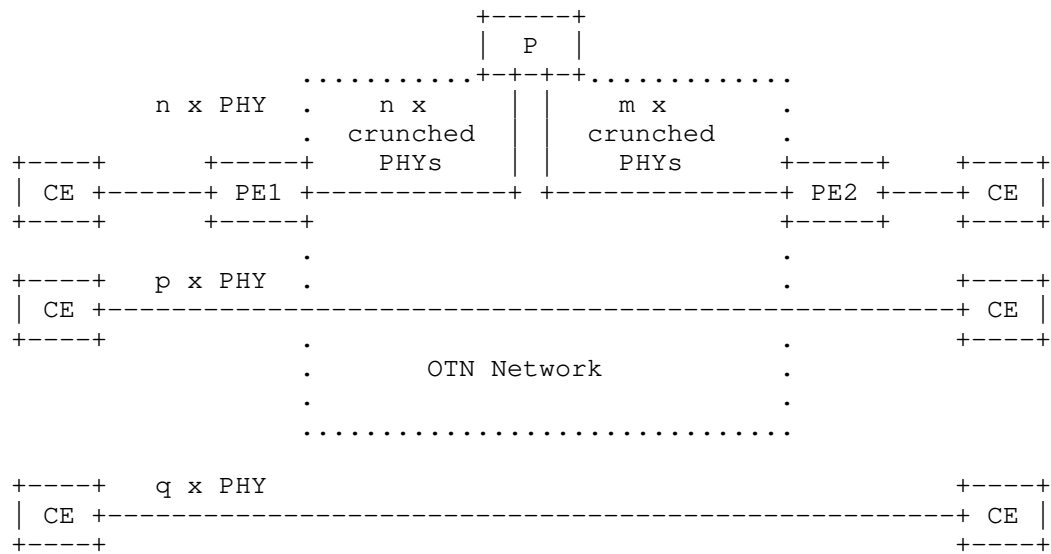
2. Terminology

- a. CE (Customer Edge): the group of functions that support the termination/origination of data received from or sent to the network. Sometimes the term CE device is used.
- b. controller: a joint term for any entity that may set up a LSP, FlexE Group or FlexE Client, e.g. a control plane, centralized controller, YANG model or management system.
- c. crunch: the term crunch in the context of OTN networks and FlexE links is used when e.g. unavailable calendar slots are not transported across the OTN network, but are removed at the ingress and recreated at the egress.
- d. Ethernet PHY: an entity representing Physical Coding Sublayer (PCS), Physical Media Attachment (PMA), and Physical Media Dependent (PMD) layers.
- e. FlexE Calendar: The total capacity of a FlexE Group is represented as a collection of slots which have a granularity of 5Gbps. 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, 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).
- f. FlexE Channelized sub-Interface, the channelized Ethernet sub-interface realized by the FlexE Client.
- g. FlexE Client: An Ethernet flow based on a MAC data rate that may or may not correspond to any Ethernet PHY rate.
- h. FlexE Group: A FlexE Group is composed of from 1 to n Ethernet PHYs. In the first version of FlexE each PHY is identified by a number in the range {1-254}.
- i. FlexE Interface, the Ethernet interface realized the FlexE Group
- j. FlexE Shim: the layer that maps or demaps the FlexE Client flows carried over a FlexE Group.

- k. LMP: Link Management Protocol
- l. LSP: Label Switched Path
- m. OIF: Optical Internetworking Forum
- n. OTN: Optical Transport Network
- o. PE: Provider Edge (device) the term is used for the functions needed at the edge of a provider network or the device to which these functions are allocated.
- p. P: Provider (device), the term is used for the functions needed in the core of a provider network or the device to which these functions are allocated.
- q. SG15: ITU-T Study Group 15 (Transport, Access and Home).
- r. TE: Traffic Engineering
- s. TED: Traffic Engineering Database

3. FlexE Reference Model

The figure below gives a simplified FlexE reference model.



Legend: m, n, p and q indicate how many PHYs there are in a FlexE Group

Figure 1: FlexE Reference Model

The services offered by Flexible Ethernet are essentially the same as for traditional Ethernet, connection less Ethernet transport. In essence the FlexE interfaces and links may be viewed as any other Ethernet interfaces or links. However, it is possible to capture additional TE information in the Traffic Engineering Data Base showing unique characteristics of FlexE channelized interfaces and links. This makes it possible for the control plane to strategically use FlexE networks to support advanced TE.

4. GMPLS Controlled FlexE

The high level goals for using a GMPLS control plane for FlexE can be summarized as:

- o Set up a FlexE Group
- o Set up a FlexE Client
- o Advertise the TE information of FlexE Groups and FlexE Clients

- o Set up of a higher layer LSPs that require to be (or would have significant benefits to) be run over a FlexE infrastructure.
- o Decoupling PHY and MAC bandwidth opens up some interesting features for networks that features FlexE links. By establishing several FlexE Clients with bandwidth that are part of the bandwidth of the FlexE Group, it is possible to create channels between to nodes.
- o By controlling the mapping a user packets (or frames) to these channels it is possible to create bandwidth that are dedicated for special purposes, and that can't be infringed on by packets (or frames) that does not satisfy this mapping.

4.1. Interfaces in a FlexE network

FlexE Ethernet interfaces are realized by the means of a basic building block. The same building block is used for a single PHY and when the PHY's are bonded. The building block consists of two FlexE Shim functions (see Section 5.2.2.2) and a logical point to point link. The FlexE Shim functions are located at each end of the logical point to point link. This link carries the Ethernet PHY signals between the two FlexE Shim Functions.

4.2. Mapping of traffic in the data plane

An example of which data plane mappings takes place when an upper layer, e.g. IP or MPLS, send packets over a FlexE interfaces is shown in Figure 2.

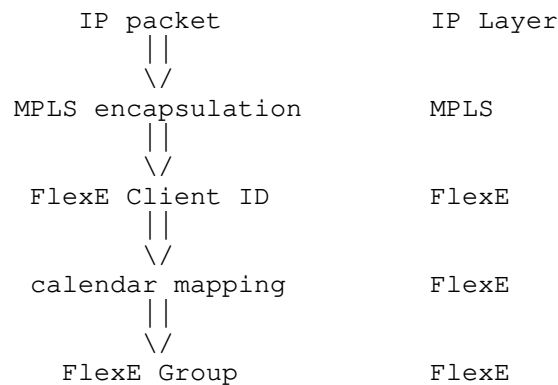


Figure 2: Traffic Mapping

In the mapping steps indicated in Figure 2 only one step in the mapping is visible by each layer.

- o the MPLS layer knows from the IP address, which MPLS label stack to encapsulate the IP packet in
- o the MPLS layer also know which MPLS label(s) that maps to which FlexE Client
- o the FlexE layer also knows from the FlexE Client Identifier, which calendar slots the packet will be transferred over
- o the FlexE layer knows which FlexE Group a certain set of calendar slots belongs too

4.3. The GMPLS Control Plane and the FlexE identifiers

This section lists some of the procedures and actions on FlexE Interface Identifiers that a GMPLS Control plane need to perform. Also, a centralized controller, YANG model or a management system that are used to establish interfaces and links need to perform the same actions.

The FlexE Group Identifier and the FlexE Client Identifier, included in the overhead of each frame sent over a FlexE Interface or sub-Interface, indicates a particular Group or Client.

When the Control Plane, a centralized controller, a YANG model or a management system sets up a FlexE Interface at least the bandwidth

has to be included in the setup message. The FlexE system returns the FlexE Group Identifier in the response message.

When a channelized sub-interface is set up, the party that initiates the setup includes the Interface (FlexE Group) Identifier over which the sub-Interface will be established, and the bandwidth requested for the sub-interface. The FlexE system returns the FlexE Client Identifier.

The identifiers received by the party that initiates a setup of an FlexE Interface are used, by a controller, to set up FlexE sub-interfaces.

The identifiers received by the party that initiates a setup of an FlexE sub-Interface are used, e.g. to map an MPLS label to the correct FlexE sub-interfaces.

4.4. Operational concerns

When operating a link in a FlexE network it is likely that an operator would like to split the FlexE Interface in sub-Interfaces used for best effort traffic and sub-Interfaces for dedicated for special purposes. An example would be when there is a 100 Gbit/s FlexE interface split into five 10 Gbit/s sub-interfaces and one 50 Gbit/s sub-interface. The 50 Gbit/s sub-interface could be used for best effort traffic, the five 10 Gbit/s could be used for dedicated traffic.

In such cases it is conceivable that packets/frames that have a matching key will be put on a specific sub-Interface, while traffic that does not have a matching key will be put on the best effort sub-interface.

4.5. Pre-configured vs. Control Plane established LSPs in a FlexE capable network

The FlexE infrastructure may be established in three different ways

- o The FlexE Groups and FlexE Client may be pre-configured
- o Only the FlexE Groups may be pre-configured, while the setup of the FlexE Client is triggered by the request to setup a MPLS LSP.
- o The setup of both FlexE Group and FlexE Client may be triggered by the request to setup an MPLS LSP.

In the case the FlexE Groups and FlexE Clients are preconfigured the FlexE capable nodes need to have the ability to announce the preconfigured FlexE Client and/or FlexE Groups as if they were LSPs.

4.6. Signaling Channel

In the type of equipment for which FlexE was first specified an out of band signaling channel is not commonly available. If that is the case, and the GMPLS FlexE control plane will be used, the FlexE Group will have to setup by e.g. a management system and a FlexE Client on that FlexE Group (also configured) will have to allocated as a signaling channel.

Further details of the setup of the FlexE Groups, FlexE Clients and MPLS LSPs over a FlexE infrastructure will be found in Section 6.2.

4.7. MPLS LSP over the FlexE Data Plane

FlexE is a true link layer technology, i.e. it is not switched, this means that the FlexE Groups and FlexE Clients are terminated on the next-hop node, and that the switching needs to take place on a higher layer.

The FlexE technology can be used to establish link layer connectivity with high and deterministic bandwidth. However, there is no way described in the FlexE specification to, in a deterministic way, allocate certain traffic to a specific FlexE Client. Control of the FlexE link layer by a GMPLS control plane can achieve this.

A GMPLS controlled FlexE capable node may be thought of using the traditional model of a node with a separation between control and data plane.

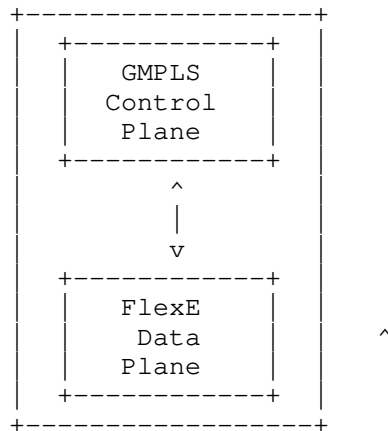


Figure 3: GMPLS controlled FlexE Node

The GMPLS control plane will speak extended standard GMPLS protocols with its neighbours and peers.

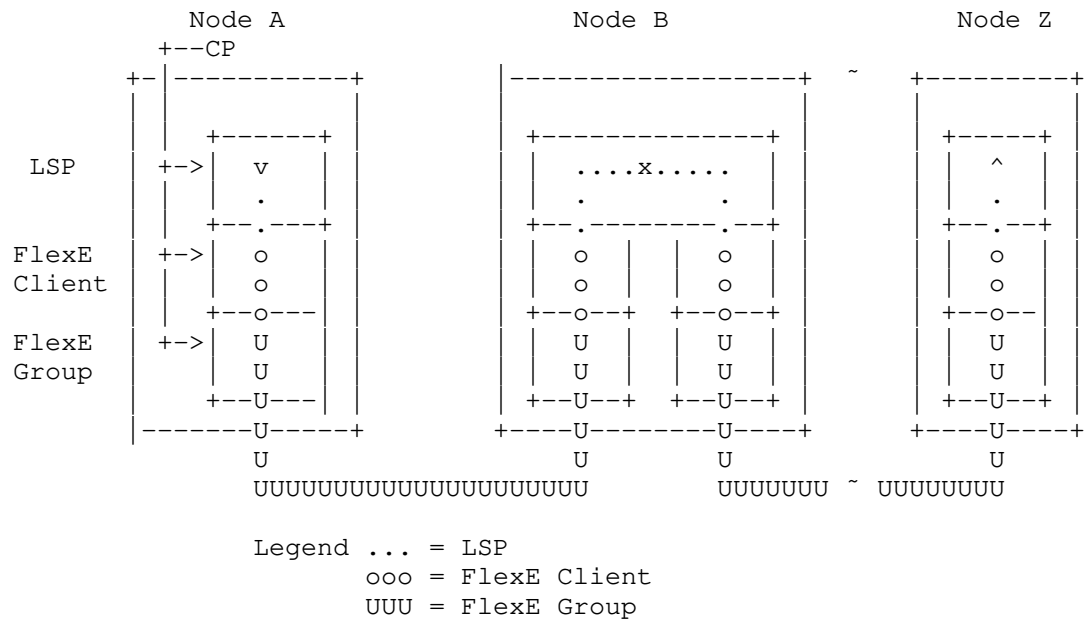


Figure 4: GMPLS controlled network with FlexE infrastructure

Figure 4 describes how an MPLS LSP is mapped over a FlexE Client and FlexE Group.

4.8. Configuring the data plane in FlexE capable nodes

In Figure 4 we show an LSP, a FlexE Client and a FlexE Group, the LSP is there because while the FlexE Channel and Group are not switched, switching in our example takes place on the LSP level. This section will discuss establishment of FlexE Clients and Groups, and mapping of the LSP onto a FlexE Client.

The establishment of a LSP over a FlexE system is very similar to how this is done in any other system. Building on information gathered through the routing system and using the GMPLS signaling to establish the LSP.

4.8.1. Configure/Establish a FlexE Group/Link

Consider the setup of a FlexE Group between node A and B, corresponding to the row of U's from node A to B in Figure 4. The FlexE Group is considered to consist of n PHYs, but does not have any FlexE Clients defined from start.

When this is done by the GMPLS control plane, two conditions need to be fulfilled (1) there need to be a data channel defined between node A and B; and (2) a FlexE capable IGP-TE protocol needs to be running in the network.

Node A will send an RSVP-TE message to node B with the information describing the FlexE Group to be setup. This information might be thought of as the "FlexE Group Label" (or part of the FlexE label). It will contain at least the following information:

- o A FlexE Group Identifier (FGid).
- o The number of active FlexE Channels (numFC), where 0 indicates that zero clients are active.
- o Number of PHYs that the FlexE Group is composed of, for each PHY
 - * PHY identifier
 - * PHY bandwidth
 - * slot granularity/number of slots
 - * available and unavailable slots

When node B receives the RSVP-TE message it checks that it can setup the requested FlexE Group. If the check turns positive, node send an acknowledgment to node A and the FlexE Group is setup.

A more detailed description of how to setup a FlexE Group, will be included in the draft dealing with signaling in detail.

4.8.2. Configure/Establish a FlexE Client

Consider the situation where a FlexE Group is already established (as described in Section 4.8.1) and an m G FlexE Client is needed. Similar to the establishment of the FlexE Group, node A will send a RSV-TE message to node B.

This RSVP-TE message include at least the following information:

- o FlexE Group Identifier
- o FlexE Client Identifier
- o from which PHYs the slots will allocated, i.e. slots might come from more than one PHY.
- o Information per PHY
 - * PHY bandwidth
 - * slot granularity
 - * available/unavailable slots
 - * allocated slots

A more detailed description of how to setup a FlexE Channel, will be included in the draft dealing with signaling in detail.

4.8.3. Advertise FlexE Groups and FlexE Clients

Once the FlexE Group and FlexE Clients are configured they can be advertised into the routing system as normal routing adjacencies, including the FlexE specific TE information.

5. Framework and Architecture

This section discusses FlexE framework and architecture. Framework is taken to mean how FlexE interoperates with other parts of the data communication system. Architecture is taken to mean how functional groups and elements within FlexE work together to deliver the

expected FlexE services. Framework is taken to mean how FlexE interacts with its environment.

5.1. FlexE Framework

The service offered by Flexible Ethernet is a transport service very similar (or even identical) to the service offered by Ethernet.

There are two major additions supported by FlexE:

- o FlexE is intended to support high bandwidth and FlexE can offer granular bandwidth from 5Gbits/s and a bandwidth as high as the FlexE Group allows.
- o As FlexE Groups and clients are setup as a configuration activity, by a centralized controller or by a GMPLS control plane the service is connection oriented.

5.2. FlexE Architecture

5.2.1. Architecture Components

This section discusses the different parts of FlexE signaling and routing and how these parts interoperate.

The FlexE routing mechanism is used to provide resource available information for setup of higher layer LSPs, like Ethernet PHYs' information, partial-rate support information. Based on the resource available information advertised by routing protocol, an end-to-end FlexE connection is computed, and then the signaling protocol is used to set up the end-to-end connection.

FlexE signaling mechanism is used to setup LSPs.

MPLS forwarding over a FlexE infrastructure is different from forwarding over other infrastructures. When MPLS runs over a FlexE infrastructure it is possible that there are more than FlexE Client that meet the next-hop requirements, often it is possible to use any suitable FlexE Client for a hop between two nodes. If the mapping between a MPLS encapsulated packet and the FlexE Client, this mapping need to be explicit when the LSP is set up, and the MPLS label will be used to find the correct FlexE Client.

5.2.2. FlexE Layer Model

The FlexE layer model is similar Ethernet model, the Ethernet PHY layer corresponds to the "FlexE Group", and the MAC layer corresponds to the "FlexE Client".

As different from earlier Ethernet the combination of FlexE Group and Client allows for a huge freedom when it comes to define the bandwidth of an Ethernet connectivity.

5.2.2.1. FlexE Group structure

The FlexE Group might be supported by virtually any transport network, including the Ethernet PHY. While the Ethernet PHY offers a fixed bandwidth the FlexE Group has been structured into 5 Gbit/s slots. This means that the FlexE Group can support FlexE Clients of a variety of bandwidths.

The first version is defined for 20 slots of 5 Gbit/s over a 100 Gbit/s PHY. The 100 Gbit/s PHYs can be bonded to give higher bandwidth.

5.2.2.2. FlexE Client mapping

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 Shim is the layer that maps or demaps the FlexE Client flows carried over a FlexE Group. As defined in [OIFFLEXE1], MAC rates of 10, 40, and any multiple of 25 Gbit/s are supported. This means that if there is a 100 Gbit/s FlexE Group between A and B, a FlexE Client of 10, 25, 40, 50, 75 and 100 Gbit/s can be created.

However, by bonding, for example 5 PHYs of 100 Gbit/s to a single FlexE Group, FlexE Clients of 500 Gbit/s can be supported.

6. Control Plane

This section discusses the procedures and extensions needed to the GMPLS Control Plane to establish FlexE LSPs.

There are several ways to establish FlexE Groups, allocate slots for FlexE Clients, and setup higher layer LSPs. A configuration tool, a centralized controller or the GMPLS control plane can all be used.

To create the FlexE GMPLS control plane Groups, FlexE Clients and higher layer LSPs, extensions to the following protocols may be needed:

- o "RSVP-TE: Extensions to RSVP for LSP Tunnels" (RSVP-TE) [RFC3209]
- o "Link Management Protocol" (LMP) [RFC4204]
- o "Path Computation Element (PCE) Communication Protocol" (PCEP) [RFC5440]

- o IS-IS Extensions for Traffic Engineering (ISIS-TE) [RFC5305]
- o "OSPF Extensions in Support of Generalized Multi-Protocol Label Switching (GMPLS)" (OSPF-TE) [RFC4203]
- o "North-Bound Distribution of Link-State and Traffic Engineering (TE) Information Using BGP" (BGP-LS) [RFC7752]

A FlexE control plane YANG model will also be needed.

Section 6.2 and Section 6.1 discusses the role of the GMPLS control plane when primarily setting up LSPs.

When discussing the signaling and routing procedures we assume that the FlexE Group has been established prior to executing the procedures needed to establish an LSP. Technically it is possible to establish FlexE Group, allocate FlexE Client slots and LSP with a single exchange of GMPLS signaling messages.

6.1. GMPLS Routing

To establish an LSP the Traffic Engineering (TE) information is the most critical information, e.g. resource utilization on interfaces and link, including the availability of slots on the FlexE Groups. The GMPLS routing protocols needs to be extended to handle this information. The Traffic Engineering Database (TED) will keep an updated version of this information.

The FlexE capable nodes will be identified by IP-addresses, and the routing and traffic engineering information will be flooded to all nodes within the routing domain using TCP/IP.

When an LSP over the FlexE infrastructure is about to be setup, e.g. R1 - R4 - R5 in Figure 5 the information in the TED is used verify that resources are available. When it is conformed that the LSP is established the TED is updated, marking the resources used for the new LSP as used. Similarly, when a LSP is taken down the resources are marked as free.

6.2. GMPLS Signaling

As described in Section 4 the state of the FlexE infrastructure may effect the actions needed to setup an LSP in a FlexE capable network. The FlexE infrastructure maybe be:

1. fully pre-configured

2. partially pre-configured, i.e. the FlexE Group may be pre-configured, but not the FlexE Clients
3. not pre-configured, i.e. the setup of FlexE Group and FlexE Client will be triggered because of the request to setup an LSP.

Figure 5 will be used to illustrate the different cases.

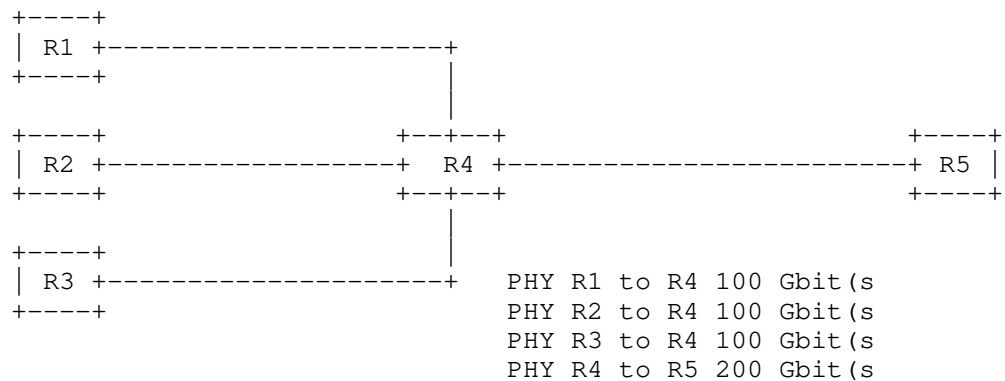


Figure 5: FlexE LSP Example

The text in Section 6.2 is not a specification of the GMPLS signaling extensions for FlexE capable network, it is a description to illustrate the expected features of such a protocol. Nor do we discuss failure scenarios.

6.2.1. LSP setup with pre-configured FlexE infrastructure

In this first example, referencing Figure 5, one 100 Gbit/s FlexE Group is configured between R1 and R4, between R2 and R4, and between R3 and R4. Between R4 and R5 there is a 200 Gbit/s FlexE Group.

Over each 100 Gbit/s FlexE Group there are four 5 Gbit/s, two 20 Gbit/s and one 40 Gbit/s FlexE Clients configured. Over the 200 Gbit/s FlexE Group there are eight 5 Gbit/s, four 20 Gbit/s and two 40 Gbit/s FlexE Clients configured.

One of the 5 Gbit/s FlexE Clients on each FlexE Groups are used as signaling channel.

To establish the for example a 200 Mbit/s MPLS LSP the normal GMPLS request/response procedures are followed. R1 sends the request to R4, R4 allocate resources on one of the FlexE Clients, forward the request to R5. R5 responds to R4 indicating the label and the FlexE Client the traffic should be sent over, R4 does the same for R1.

The only difference between the standard signaling and what happens here is that there the assigned label will be used to find the right FlexE Client.

6.2.2. LSP setup with partially configured FlexE infrastructure

In the second example, also referencing Figure 5, the FlexE Groups are setup in the same way as in the first example, however only one 5 Gbit/s FlexE Client per FlexE Group are established by configuration. This FlexE Client will be used for signaling.

When preparing to send the request that a 5 Gbit/s MPLS LSP shall be set up R1 discovers that there are no feasible FlexE Client between R1 and R4. R1 therefore sends the request to establish such a FlexE Client, when receiving the request R4 allocates resources for the FlexE Client on the FlexE Group. There may be different strategies for allocating the bandwidth for this FlexE Client. Such strategies are out of scope for this document. R1 then sends the information about the FlexE Client to R1, and both ends establish the FlexE Client.

When the FlexE Client between R1 and R4 is established, R1 proceeds to send the request for an MPLS LSP to R4. R4 will discover that a feasible FlexE Client is missing between R4 and R5. The same procedure s for setting up the FlexE Client between R1 and R4 is repeated for R4 and R5. When there is a feasible FlexE Client available the signaling to set up the MPLS LSP continues as normal.

The label allocated for the MPLS LSP will be used to find the correct FlexE Client.

When a FlexE Clients is set up in this way they can be announced into the routing system in two different ways. First, they can be made generally available, i.e. it will be free to use for anyone that want to set up LSPs over the FlexE Group between R1 and R4 and between R4 and R5. Second, the use of the FlexE Clients may be restricted to the application that initially did set up the FlexE Client.

6.2.3. LSP setup with non-configured FlexE infrastructure

This example also refers to Figure 5 as different from the earlier example no FlexE Group or FlexE Client configuration is done prior to the first request for an MPLS LSP over the FlexE infrastructure.

To make the set up of LSPs in a FlexE network where no FlexE Groups or FlexE Clients have been configured two conditions need to be fulfilled. First an out of band signaling channel must be available. Second the FlexE Capabilities must be announced in to the IGP and/or centralized controller.

If these two conditions are fulfilled, the set up of an MPLS LSP progress pretty much as in the partially configured network. The difference is that the set up of both the FlexE Group and FlexE Client are triggered by the request to set up an MPLS LSP.

As in the partially configured case FlexE Clients can be announced into the routing system in two different modes, either they are generally available. It or they are reserved for the applications that first established them.

6.2.4. Packet Label Switching Data Plane

This section discusses how the FlexE LSP data plane works. In general it can be said that the interface offered by the FlexE Shim and the FlexE Client is equivalent to the interface offered by the Ethernet MAC.

Figure 6 below illustrates the FlexE packet switching data plane procedures.

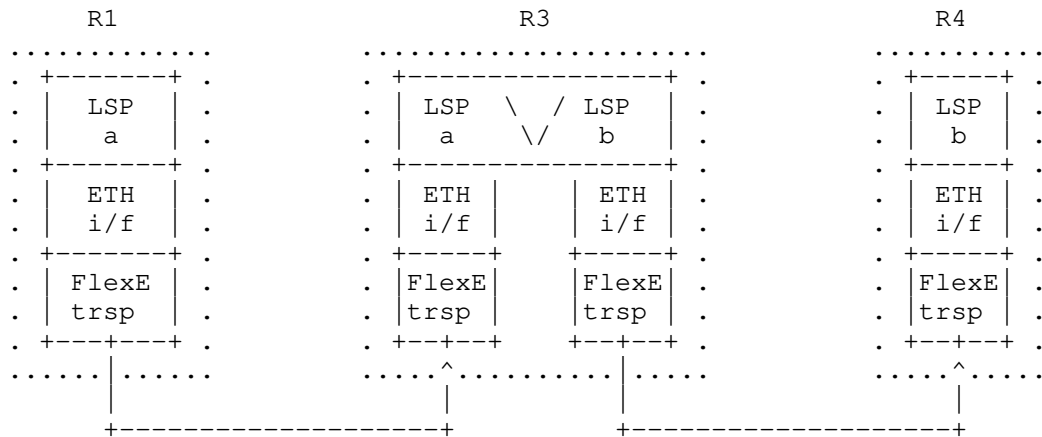


Figure 6: LSP over FlexE Data Plane

The data plane processes packets like this:

- o The LSP encapsulating and forwarding function in node R1 receives a packet that needs to be encapsulated as an MPLS packet with the label "a". The label "a" is used to figure out which FlexE emulated Ethernet interfaces the label encapsulated packet need to be forwarded over.
- o The Ethernet interfaces, by means of FlexE transport, forwards the packet to node R3. Node R3 swaps the label "a" to label "b" and uses "b" to decide over which interface to send the packet.
- o Node R3 forwards the packet to node R, which terminates the LSP.

Sending MPLS encapsulated packets over a FlexE Client is similar to send them over an Ethernet 802.1 interface. The critical differences are:

- o FlexE channelized sub-interfaces guarantee a deterministic bandwidth for an LSP.
- o When a application that originally establish a FlexE Client reserve it for use by that application only, it is possible to create unfringeable bandwidth end-to-end for an MPLS LSP.
- o FlexE infrastructure allows for creating very large end to end bandwidth

7. Operations, Administration, and Maintenance (OAM)

To be added in a later version.

8. Acknowledgements

9. IANA Considerations

This memo includes no request to IANA.

Note to the RFC Editor: This section should be removed before publishing.

10. Security Considerations

To be added in a later version.

11. Contributors

Khuzema Pithewan, Infinera Corp, kpithewan@infinera.com

Fatai Zhang, Huawei, zhangfatai@huawei.com

Jie Dong, Huawei, jie.dong@huawei.com

Zongpeng Du, Huawei, duzongpeng@huawei.com

Xian Zhang, Huawei, zhang.xian@huawei.com

James Huang, Huawei, james.huang@huawei.com

Qiwon Zhong, Huawei, zhongqiwen@huawei.com

Yongqing Zhu China Telecom zhuyq@gsta.com

Huanan Chen China Telecom chenhuanan@gsta.com

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Appendix A. Requirements

This section summarizes the signaling and routing requirements for a FlexE control plane, with respect to establishing FlexE Groups, FlexE Clients and MPLS LSPs that require support from an FlexE infrastructure.

Req-1 The FlexE control plane SHALL support the creation of FlexE Groups.

- * A FlexE Groups consist one or more 100GE Ethernet PHY(s). In the first version of FlexE the number of PHYs are in the range of 1 to 254.
- * This requirement can be met by several methods, e.g. routing and signaling protocols, a centralized controller or a management system.

Any such method need to have network access to the FlexE shims at each of the Ethernet PHY(s) termination points.

Req-2 The FlexE control plane SHALL have the ability to delete a FlexE Group.

Req-3 The FlexE control plane SHALL have the ability to initiate an administratively lock or unlock of a FlexE Group.

- * This ability is needed e.g. for executing the next requirement.

Req-4 When a FlexE Group has been administratively looked is SHALL be possible to add PHYs to an operational FlexE Group.

Req-5 When a FlexE Group has been administratively looked is SHALL be possible to remove PHYs from an operational FlexE Group.

Req-6 The FlexE control plane SHALL support the ability to collect, advertise and discover information about FlexE capable nodes, including the TE information the FlexE Groups and FlexE Clients the nodes support.

Note: In essence correct, but something is backward. Need to think.

Req-7 The FlexE control plane SHALL allow the addition (or removal) of one or more FlexE clients to a FlexE Group. The addition (or removal) of a FlexE Client flow SHALL NOT affect the services of the other FlexE Client signals.

Req-8 The FlexE control plane SHALL, though this MAY not be possible in all network scenarios, support FlexE Client flow resizing without affecting any existing FlexE Clients within the same FlexE Group.

Req-9 The FlexE control plane SHALL support establishment of MPLS LSPs that requires the support of a FlexE infrastructure.

Authors' Addresses

Iftekhar Hussain
Infinera Corp
169 Java Drive
Sunnyvale, CA 94089
USA

Email: IHussain@infinera.com

Radha Valiveti
Infinera Corp
169 Java Drive
Sunnyvale, CA 94089
USA

Email: rvaliveti@infinera.com

Qilei Wang
ZTE
Nanjing
CN

Email: wang.qilei@zte.com.cn

Loa Andersson
Huawei
Stockholm
Sweden

Email: loa@pi.nu

Mach Chen
Huawei
CN

Email: mach.chen@huawei.com

Haomian Zheng
Huawei
CN

Email: zhenghaomian@huawei.com

Internet Working Group
Internet Draft
Intended status: Standards Track

Y. Jiang
X. He
Huawei
W. Cheng
China Mobile
J. Wang
Y. Han
Fiberhome
July 8, 2019

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YANG Data Model for FlexE Interface Management
draft-jiang-ccamp-flex-e-yang-01

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. Besides 100GBASE-R PHYs, FlexE 2.0 further supports the bonding of 200GBASE-R PHYs or 400GBASE-R PHYs respectively.

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 in a FlexE group. 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 slot 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 PHYs is represented in each PHY as an array of slots (e.g., each representing 5Gbps of bandwidth).

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 management interface for configuration of a FlexE group.
- flexe-phy-list specifies a list of PHYs in a Flex Group.
- 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 calendar-slot-list per PHY is modeled which represents all the slots in a PHY (i.e., all sub-calendars of the FlexE instances in this PHY), and calendar is actually a conglomerate of all the slots in calendar slot lists for 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-phy-list* [phy-number]
        +--rw phy-number          uint8
        +--rw flexe-phy-if?        if:interface-ref
        +--ro phy-status?          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 flexe-client-if?      if:interface-ref
        +--rw mapped-slot-list* [mapped-slot-id]
          +--rw mapped-slot-id      uint8
          +--rw mapped-phy-number?   uint8
        +--ro flexe-client-status?  uint8

```

```
    +--ro flexe-group-status?    uint8
```

A tree diagram of the module for FlexE client interface is depicted as the following:

```
module: ietf-interfaces-flexe-client
  augment /if:interfaces/if:interface:
    +--rw flexe-client
      +--ro mac-address
      +--rw group-number?          uint32
```

3. YANG Module for FlexE interface

This module imports iana-if-type [RFC7224] and ietf-interfaces [RFC8343].

```
<CODE BEGINS> file "ietf-flexex@2019-07-05.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 "2019-07-05" {
    description "Initial version";
    reference
      "draft-jiang-ccamp-flexex-yang-01: YANG Data Model for FlexE
      Interface Management ";
  }

  identity flexEthernet {
    base ianaift:iana-interface-type;
    description
      "Flex Ethernet.";
  }
}
```

```
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";
}

augment "/if:interfaces/if:interface" {

  when "if:type = 'ianaift:flexEthernet'" {
    description "Applies to Flex bonded Ethernet interfaces";
  }

  description
    "Augment interface model with OIF Flex Ethernet interface
    specific configuration nodes. Each flexEthernet 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-enumeration;
  default "slot-5g";
  description
    "The granularity of a slot in a FlexE group.";
}

leaf flexe-phy-type {
  type flexe-phy-enumeration;
  default "PHY-100GBASE-R";
  description
    "The type of PHYs bonded in 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].";
  }

  leaf flexe-phy-if {
    type if:interface-ref;
    description
      "Reference to a Flexe PHY interface.";
```

```
    }
    leaf phy-status {
        type uint8;
        config false;
        description
            "Fault status for a FlexE PHY. Status includes:
             OK, Local Fault, Remote Fault and etc.";
    }

    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 PHY. Max elements of
             slot-list for a FlexE PHY is dependent on the PHY
             bandwidth (X)G and the slot granularity (Y)G, i.e.,
             X/Y. For example, for a 400GBASE-R PHY:
             If slot-granularity=slot-5g, max-elements is 80.
             If slot-granularity=slot-25g, max-elements is 16.";

        leaf flexe-slot-status {
            type slot-status-enumeration;
            default unused;
            description
                "Slot status of a slot in an instance.";
        }
    } //calendar-slot-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 flexe-client-if {
        type if:interface-ref;
        description
            "The type of a flexe client interface must be
```

```
        'flexeClient'.";
    }

    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.";
        }
    } // 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
leaf flexe-group-status {
    type uint8;
    config false;
    description
        "Fault status for a FlexE Group. If any PHY is in fault,
        the FlexE Group status is indicated in fault. Status
        includes:
            OK, Local Fault, Remote Fault and etc.";
}
} //flexe-group
} //augment
}

<CODE ENDS>
```

4. YANG Module for FlexE client interface

The following YANG data module augments the interface container defined in RFC 8343 for FlexE client interfaces.

```
<CODE BEGINS> file "ietf-interfaces-flexec-client@2019-07-05.yang"
module iETF-interfaces-flexec-client {
  yang-version 1.1;

  namespace
    "urn:ietf:params:xml:ns:yang:ietf-interfaces-flexec-client";

  prefix flexcl;

  import iETF-interfaces {
    prefix if;
  }

  import iETF-yang-types {
    prefix yang;
  }

  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>
    Author:   Yuanlong Jiang
              <mailto:jiangyuanlong@huawei.com>
    Author:   Xiang He
              <mailto:hexiang@huawei.com>
    Author:   Weiqiang Cheng
              <mailto:chengweiqiang@chinamobile.com>";

  description
    "This module contains YANG definitions for configuration of
    'FlexE client' interfaces.  FlexE Client is defined in
    OIF Flexible Ethernet 2.0 Implementation Agreement.";

  revision 2019-07-05 {
    description "Initial revision";
```

```
    reference
      "Internet draft: draft-jiang-ccamp-flexe-yang-01";
  }

  identity flexeClient {
    base ianaift:iana-interface-type;
    description
      "FlexE Client.";
  }

  /*
   * Configuration parameters for FlexE client interfaces.
   */
  augment "/if:interfaces/if:interface" {
    when "derived-from-or-self(if:type, 'ianaift:flexeClient')" {
      description "Applies to FlexE client interfaces";
    }
    description
      "Augment the interface model with parameters for
       FlexE client interfaces";

    container flexe-client {
      description
        "Contains parameters for FlexE client interfaces
         which expose an Ethernet MAC layer.";
      leaf mac-address {
        type yang:mac-address;
        config false;
        description
          "The MAC address of the FlexE client.";
      }
      leaf group-number {
        type uint32 {
          range "1..1048574";
        }
        description
          "FlexE Group Number of the FlexE group binding this
           client.";
      }
      // statistics can further be defined for the MAC layer
    }
  }
}
<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 [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/flexe-phy-list specifies a list of FlexE PHYs.

/flexe/flexe-group/flexe-client-list specifies a list of FlexE Client, and each client is mapped to some slots in a FlexE PHY.

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.

6. 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].

It is proposed that IANA register a new IANAifType TBD for the interface type of Flex client in the "IANA Interface Type YANG Module" [RFC7224].

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Authors' Addresses

Yuanlong Jiang
Huawei Technologies Co., Ltd.
Bantian, Longgang district
Shenzhen 518129, China
Email: jiangyuanlong@huawei.com

Xiang He
Huawei Technologies Co., Ltd.
Huawei Campus, No. 156 Beiqing Rd.
Beijing 100095
Email: hexiang9@huawei.com

Weiqiang Cheng
China Mobile
No.32 Xuanwumen West Street
Beijing 100053, China
Email: chengweiqiang@chinamobile.com

Junfang Wang
Fiberhome
Email: wjf@fiberhome.com

Yalei Han
Fiberhome
Email: ylhan@fiberhome.com

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Q. Wang, Ed.
X. Niu, Ed.
ZTE Corporation
Y. Xu
CAICT
July 8, 2019

Analysis for FlexE control
draft-wang-ccamp-flex-e-control-analysis-02

Abstract

This document gives some analysis about the control of FlexE.

Status of This Memo

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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 requirements, which can be found in section 2. What kind of model should we employed when configuring FlexE capable equipments, how to configure the FlexE group and FlexE client, and what kind of parameters do we need to take into consideration when configuring FlexE group and FlexE client. The analysis is based on the description in section 7 and 8 of [ITU-T G.8023] and FlexE IA 2.0.

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 with multiple FlexE client ports could be 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, with each MAC flow mapped into one FlexE client.

3.1.1. FlexE Group

A FlexE Group is consisted of from 1 to n 100G FlexE instances, which are carried over from 1 to m 100G, 200G or 400G Ethernet PHYs. All PHYs in the group must operate at the same rate.

FlexE group is consisted of a number of FlexE instances, and each instance 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 in ITU-T terminology). Currently, only RPF (Remote PHY Fault) indication is used to report the state of FlexE group.

The FlexE group exists between two FlexE shim, there is no slot switching defined in FlexE. Only one fault indication is defined, there is no other OAM function developed yet. Based on these analysis, we should be able to understand that FlexE is just an interface technology, and once a FlexE group is configured, it only functions as one Ethernet link, similar to 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 10Gb/s, 40Gb/s, or $m \times 25\text{Gb/s}$. The FlexE Client MAC rates supported by FlexE Groups may support all, or only a subset of these FlexE Client rates. Each FlexE Client is presented to the FlexE Shim as a 64B/66B encoded bit stream according to clause 82 of [IEEE 802.3]. FlexE clients have the semantics of an Ethernet PHY. There is no new layer network. Both FlexE group and FlexE client are processed at Ethernet PHY layer. From the network management perspective, the FlexE client can be created and the calendar slots information of one FlexE group can be allocated to one FlexE client. The FlexE client could be generated internally within a system, or created from a traditional Ethernet PHY. What kind of FlexE clients will be created depends on the operator's needs.

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, modelling FlexE client as a network layer is not correct.

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, slots allocated for a specific FlexE client 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. If

200G and 400G are used, the 100G FlexE instance should be used in the case of PHYMAP, as current version of [ITU-T G.8023] only cover the scope of 100G PHY.

The built-in function multiplexer performs the action of assigning the individual FlexE Client to specific calendar slots of the FlexE group according to the input management information.

At the destination side, the Demultiplexer function could use activate the FlexE Client and assigns the calendar slots of the FlexE group payload area to the individual FlexE client according to external configuration or the client calendar information carried in the overhead. Expected group ID, PHYMAP and calendar allocation information are needed sometimes to help verify the correctness of FlexE configuration.

3.1.4. MAC Frame

Defined in IEEE.

3.1.5. Adaptation between MAC frames and FlexE Client

The external management information commands used as input to the adaptation function are defined by [IEEE 802.3], according to the description in [ITU-T G.8023]. 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 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 during this process. Therefore, configuration for mapping MAC frames into FlexE client from external management system is not needed.

Based on the above analysis, two high-level requirements for control/management of FlexE are considered in this draft.

Configuration mode

Configuration of FlexE group

Creation of FlexE client and allocation of one or more FlexE group calendar slot resources to a FlexE client.

3.2.1. Configuration Mode for FlexE client

There are two different configuration modes for bring one FlexE client into service. The first one is static model, which is to use external management system to configure the FlexE client and resources allocated for the FlexE client at source and destination FlexE shims. In this case, the CR/CA mechanism does not work. Verification of configuration consistency at FlexE source and destination site by comparing the inband FlexE overhead with the configuration at FlexE destination are needed; The other one is MASTER/SLAVE mode, which is to use the FlexE overhead to coordinate the resource configuration between FlexE source and destination, the external resource configuration information is only sent the source node.

3.2.2. 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 could be 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 for both ends, and the initial configuration must be the same for both direction. The group is configured to be 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). A PHY number may correspond to the physical port ordering on equipment, but the FlexE Shim at each end of the group must identify each PHY in the group using the same PHY number, and each 100G FlexE Instance with the same 100G FlexE Instance number. In certain cases, it may be desirable not to populate all 100G FlexE instances on a 200G or 400G PHY, and these so-called unequipped FlexE instance should also be configured. Unequipped instances must always be the highest numbered instance(s) on a PHY of the FlexE Group, and there must always be at least one equipped 100G FlexE Instance on every PHY.

If aware case is needed to be considered, unavailable slot information should be configured at FlexE aware node to discard unavailable slot first, so as to put the rest of available slots onto the lower rate physical port.

3.2.3. Allocate Resources for FlexE Client

The FlexE client MAC flows are encapsulated in one or more FlexE calendar slots.

According to the analysis in section 3.2.1, there are two different configuration modes. For the first one, static mode, after the FlexE group is configured, the FlexE client resource allocation information are sent both to FlexE source and destination to help create the FlexE client. A number of expected configuration parameters are sent to FlexE destination to help verify the correctness of configuration at both sides. Information sent can be found in [draft-xiaobn-ccamp-flexe-yang-mod]. For the Master/slave mode, the FlexE client resource allocation information are only sent to the FlexE source site. The FlexE source site first create the FlexE clients, and then the built-in multiplexer at the FlexE source site allocates the calendar slots to a specific FlexE client according to the input from external management system, and insert these configuration information into the FlexE overhead. When these overheads arrives at the destination site, the demultiplexer function at the destination site extracts FlexE overhead first and get the information of calendar slot allocation information. Based on these information, the FlexE destination site finish the configuration of FlexE clients. In order to verify the correctness of the resource configuration, the expected FlexE group ID, PHY number and instance number information, FlexE client number and slot allocation information for a specific FlexE client should also be configured to FlexE destination site.

The FlexE client 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 be used by the upper layer (e.g., MPLS-TP) flow correctly.

3.3. Control Requirements Derived

- a. Using external control/management system to configure FlexE group, which may include the configuration of group number, PHY number and instance number, as well as correlation between logical PHY number and physical port number. A number of expected configuration parameters are also needed to help verify the consisten between FlexE source and destination.
- b. Using external control/management system to create the FlexE client, which include the FlexE client number, FlexE client type and slots allocation information. Different configuration mode for FlexE client are needed.

- c. External control command could 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 unequipped instance, unavailable slots, which include the number of unequipped instance and number of unavailable slots on each instances

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 and FlexE client. Once a FlexE group is configured and the FlexE client ports is created, slots allocation is configured, 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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Authors' Addresses

Qilei Wang (editor)
ZTE Corporation
Nanjing
CN

Email: wang.qilei@zte.com.cn

Xiaobing Niu (editor)
ZTE Corporation
Beijing
CN

Email: niu.xiaobing@zte.com.cn

Yunbin Xu
CAICT
Beijing
CN

Email: xuyunbin@caict.ac.cn

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X. Niu, Ed.
Q. Wang, Ed.
ZTE
Y. Xu
CAICT
S. Munagapati
Cisco
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A YANG Data Model for Flex Ethernet (FlexE)
draft-xiaobn-ccamp-flex-e-yang-mod-02

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 1.1 [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.

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

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 v1.1, 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-flex-e-yang
  +--rw flex-e-configuration
    +--rw flex-e-groups
      +--rw flex-e-group* [group-number]
        +--rw group-number          uint32
        +--rw group-attributes
          +--rw flex-e-gp-avb-bw?    rt-types:bandwidth-ieee-float32
          +--rw cal-slot-gran?      flex-e-tp:cal-slot-gran
          +--rw flex-e-phy-type?     flex-e-tp:flex-e-phy-type
          +--rw bonded-phys
            +--rw flex-e-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 flex-e-instances
            +--rw flex-e-instance* [flex-e-inst-num]
              +--rw flex-e-inst-num      uint8
              +--rw unavb-sub-cal-slot-list* [sub-cal-slot-id]
                +--rw sub-cal-slot-id    uint8

```

```

|         |   +--rw unequipped-flexe-instance* [flexe-inst-num]
|         |       +--rw flexe-inst-num      uint8
+--rw expected-group-number?   uint32
+--rw expected-phy-map?        string
+--rw expected-cal-cfg?        flexe-tp:calendar-AorB
+--rw tx-calendar?             flexe-tp:calendar-AorB
+--rw rx-calendar?             flexe-tp: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 flexe-group-number?   uint32
+--rw alloc-slots
|   +--rw tx-alloc-A-slots
|       |   +--rw instance-slots* [flexe-inst-num slot-id]
|       |       +--rw flexe-inst-num      uint8
|       |       +--rw slot-id             uint8
+--rw tx-alloc-B-slots
|   |   +--rw instance-slots* [flexe-inst-num slot-id]
|   |       +--rw flexe-inst-num      uint8
|   |       +--rw slot-id             uint8
+--rw (tx-calendar-neg)?
|   +--:(STATIC-MODE)
|       |   +--rw rx-alloc-slots
|       |       |   +--rw instance-slots* [flexe-inst-num slot-id]
|       |       |       +--rw flexe-inst-num      uint8
|       |       |       +--rw slot-id             uint8
|       |       +--rw rx-expected-A-slots
|       |       |   +--rw instance-slots* [flexe-inst-num slot-id]
|       |       |       +--rw flexe-inst-num      uint8
|       |       |       +--rw slot-id             uint8
|       |       +--rw rx-expected-B-slots
|       |       |   +--rw instance-slots* [flexe-inst-num slot-id]
|       |       |       +--rw flexe-inst-num      uint8
|       |       |       +--rw slot-id             uint8
|       +--:(MASTER-SLAVE)
+--rw client-interface?      if:interface-ref

```

Figure 1

6. FlexE types Module

```
<CODE BEGINS> file "ietf-flexex-types@2019-06-06.yang"
module ietf-flexex-types {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-flexex-types";
  prefix "flexex-tp";
  import ietf-routing-types {
    prefix rt-types;
    description "Import ietf-routing-types module.";
  }
  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 types used in FlexE YANG modules.

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

    This version of this YANG module is part of RFC TBD; see
    the RFC itself for full legal notices.";
  revision 2019-06-06{
    description
      "Version 01.";
    reference
      "draft-xiaobn-ccamp-flexex-yang-mod-02.txt";
  }
  revision 2019-03-11{
    description
      "Initial version.";
    reference
      "draft-xiaobn-ccamp-flexex-yang-mod-00.txt";
  }

  /* typedefs */
  typedef cal-slot-gran {
    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@2019-06-06.yang"
module ietf-flex-e-yang {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-flex-e-yang";
  prefix "flex-e";
  import ietf-routing-types {
    prefix rt-types;
    description "Import ietf-routing-types module.";
    reference "RFC8294";
  }
  import ietf-interfaces {
    prefix if;
    description "Import ietf-interfaces module.";
    reference "RFC7223";
  }
  import ietf-flex-e-types {
    prefix flex-e-tp;
    description "Import ietf-flex-e-types module.";
  }
  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);
     Editor: Sivakumar Munagapati (smunagap@cisco.com)";
  description
    "This module defines a YANG data model for FlexE.
```

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

```
revision 2019-06-06 {
  description
    "Version 02.";
  reference
    "draft-xiaobn-ccamp-flex-e-yang-mod-02.txt";
}
revision 2019-05-17 {
  description
    "Version 01.";
  reference
    "draft-xiaobn-ccamp-flex-e-yang-mod-01.txt";
}
revision 2019-03-11 {
  description
    "Initial version.";
  reference
    "draft-xiaobn-ccamp-flex-e-yang-mod-00.txt";
}

grouping slot-list
{
  description
    "Calendar slots in FlexE instances.";
  list instance-slots {
    key "flex-e-inst-num slot-id";
    description
      "List of slots for the FlexE client.";
    leaf flex-e-inst-num {
      type uint8 ;
      description
        "It refers to the FlexE instance of a calendar slot.
        Clause 6.1 FlexE Group in FlexE IA 2.0";
    }
    leaf slot-id {
      type uint8;
      description
        "Id number of a sub-calendar slot in a FlexE instance.
        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. ";
    }
  }
}
```

```

}

/* 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-gp-avb-bw{
        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 rates,
          it's recommended to confine the bandwidth allocated for a
          FlexE group into a integer compound from litimited types
          of MAC rateds.";
      }
      leaf cal-slot-gran{
        type flexe-tp:cal-slot-gran;
        description
          "The granularity of calendar slot is 5G or 25G";
        reference
          "OIF FlexE IA 2.0";
      }
      leaf flexe-phy-type{
        type flexe-tp: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 FlexE PHY num and the 100G
                FlexE instance num are the same and in the range
                [1-254]; For 200GBASE-R, each PHY num is in the
                range [1-126]. For 400GBASE-R, each PHY num 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 group.";
            }
            leaf remote-phy-interface {
                type if:interface-ref;
                description
                    "Remote PHY interface related to the current PHY in
                    a FlexE group.";
            }
        }
    }

    container flexe-instances {
        description
            "FlexE instances in a FlexE Group";
        list flexe-instance {
            key flexe-inst-num;
            description
                "List of a FlexE instance in a FlexE Group. Not including
                those unequipped instances in the bonded PHYs.";
            leaf flexe-inst-num {
                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 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 six bits, and 0,1,2, or 3 in the two
lower order bits. ";
}
list unavb-sub-cal-slot-list {
  key sub-cal-slot-id;
  description
    "List of sub-calendar slots unavailable in a FlexE
    Instance.";
  leaf sub-cal-slot-id {
    type uint8;
    description
      "Identification number of a sub-calendar slot in a
      FlexE instance.
      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-inst-num;
  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-inst-num{
    type uint8 ;
    description
      "Clause 6.1 FlexE Group in FlexE IA 2.0";
  }
}
}
leaf expected-group-number {
  type uint32 {
    range 1..1048574 ;
  }
}
description
  "The expected FlexE group number is configured at the FlexE
  demux. Its vaule is in the range 1~0xFFFFFE."

```

```
    Refer to ExGID in G.8023.";
}
leaf expected-phy-map {
    type string {
        length "256";
        pattern "[0-1]*";
    }
    description
        "The expected FlexE PHY MAP is configured at the FlexE
        demux. The length of PHY MAP is 8*32=256. If a FlexE PHY
        ( for FlexE IA V1.1) or FlexE instance( for FlexE IA V2.0)
        is configured in the FlexE Group, the corresponding bit is
        set to 1.
        Refer to ExPHYMAP in G.8023.";
}
leaf expected-cal-cfg {
    type flexe-tp:calendar-AorB;
    description
        "The expected calendar configuration( ExCC in ITU-T G.8023)
        is configured on FlexE demux.
        Refer to ExCC in G.8023.";
}
leaf tx-calendar {
    type flexe-tp:calendar-AorB;
    description
        "Calendar configuration in the transmit direction.
        Refer to TxCC in G.8023. ";
}
leaf rx-calendar {
    type flexe-tp:calendar-AorB;
    description
        "Calendar configuration in the receive direction";
}
leaf tx-calendar-neg {
    type enumeration {
        enum STATIC-MODE {
            value 1 ;
            description
                "STATIC mode. In this mode, calendar slots on mux and
                demux need to be configured";
        }
        enum MASTER-SLAVE {
            value 2 ;
            description
                "MASTER-SLAVE mode. In this mode, calendar slots only
                need to be configured on mux";
        }
    }
}
```

```
        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.";
            reference
                "FlexE IA 2.0.";
        }
    }
}
```

```
container bandwidth {
  description "Client bandwidth";
  uses flexe-tp:flexe-client-bandwidth;
}
leaf flexe-group-number {
  type uint32 {
    range 1..1048574 ;
  }
  description
    "The FlexE Group is used to transport the FlexE client.";
}
container alloc-slots{
  description
    "Slots are allocated on the mux(Transmit-direction).";
  container tx-alloc-A-slots{
    uses slot-list;
    description
      "Slots in A calendar are allocated on the mux.
      Refer to TxCCA in G.8023.";
  }
  container tx-alloc-B-slots{
    uses slot-list;
    description
      "Slots in B calendar are allocated on the mux.
      Refer to TxCCB in G.8023.";
  }
}
choice tx-calendar-neg{
  description
    "According to the mode, to determine what should be
    configured.";
  case STATIC-MODE{
    container rx-alloc-slots{
      uses slot-list;
      description
        "Slots for a specific FlexE client allocated on the
        demux(Receive-direction).";
    }
    container rx-expected-A-slots{
      uses slot-list;
      description
        "The expected received slots for a specific FlexE
        client in A calendar are configured on the demux.
        Refer to ExCCA in G.8023.";
      reference
        "ITU-T G.8023";
    }
    container rx-expected-B-slots{
      uses slot-list;
    }
  }
}
```

```
        description
          "The expected received slots for a specific FlexE
           client in B calendar are configured on the demux.
           Refer to ExCCB in G.8023.";
        reference
          "ITU-T G.8023";
      }
    }
    case MASTER-SLAVE{
      }
    }
  }
}

leaf client-interface {
  type if:interface-ref;
  description
    "A FlexE Client is used as an interface.";
}
}
}
}
```

<CODE ENDS>

8. Acknowledgements

9. Authors (Full List)

Xiaobing NIU (editor)

ZTE

Beijing, China

Email: niu.xiaobing@zte.com.cn

Qilei Wang (editor)

ZTE

Nanjing, China

Email: wang.qilei@zte.com.cn

Yunbin Xu

CAICT

Beijing, China

Email: xuyunbin@caict.ac.cn

Sivakumar Munagapati

Cisco

USA

Email: smunagap@cisco.com

10. Contributors

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 namespace URIs in the IETF XML registry[RFC3688]:

URI: urn:ietf:params:xml:ns:yang:ietf-flex-e-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-flex-e-yang

namespace: urn:ietf:params:xml:ns:yang:ietf-flex-e-yang

prefix: flexe

reference: RFC XXXX (TDB)

name: ietf-flex-e-types

namespace: urn:ietf:params:xml:ns:yang:ietf-flex-e-types

prefix: flexe-tp

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] 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].

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.

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Authors' Addresses

Xiaobing Niu (editor)
ZTE
Beijing
CN

Email: niu.xiaobing@zte.com.cn

Qilei Wang (editor)
ZTE
Nanjing
CN

Email: wang.qilei@zte.com.cn

Yunbin Xu
CAICT
Beijing
CN

Email: xuyunbin@caict.ac.cn

Sivakumar Munagapati
Cisco
USA

Email: smunagap@cisco.com

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H. Zheng
A. Guo
I. Busi
Huawei Technologies
Y. Xu
CAICT
Y. Zhao
China Mobile
X. Liu
Volta Networks
July 8, 2019

A YANG Data Model for Ethernet TE Topology
draft-zheng-ccamp-client-topo-yang-06

Abstract

A transport network is a server-layer network to provide connectivity services to its client. In this draft the topology of Ethernet with TE is described with YANG data model.

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1. Introduction

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. The topology model in Traffic-Engineered network has been defined in both generic way and technology-specific way. The generic model, which is the base TE YANG model, can be found at [I-D.ietf-teas-yang-te-topo]. Technology-specific models, such as OTN/WSN topology model, have also been defined in [I-D.ietf-ccamp-otn-topo-yang] and [I-D.ietf-ccamp-wson-yang] respectively. Corresponding topology on client-layer is also required, to have a complete topology view from the perspective of network controllers.

This document defines a data model of all client-layer Topology, using YANG language defined in [RFC7950]. The model is augmenting the generic TE topology model, and can be used by either applications exposing to a network controller or among controllers. Furthermore, it can be used by an application for topology description in client-layer network.

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. YANG Model for Topology of Client Layer

3.1. YANG Tree for Ethernet Topology

```

module: ietf-eth-te-topology
  augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
    +--rw eth-tran-topology!
  augment /nw:networks/nw:network/nw:node/nt:termination-point:
    +--rw ltp-mac-address?                yang:mac-address
    +--rw port-vlan-id?                  etht-types:vlanid
    +--rw maximum-frame-size?            uint16
    +--rw (direction)?
      +--:(symmetrical)
        +--rw ingress-egress-bandwidth-profile
          +--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 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 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 eth-svc!
    +---rw client-facing?                         boolean
    +---rw supported-classification
    |   +---rw transparent?                       boolean
    |   +---rw port-classification?              boolean
    |   +---rw vlan-classification
    |       +---rw vlan-tag-classification?      boolean
    |       +---rw outer-tag
    |           +---rw supported-tag-types*       etht-types:eth-tag-classify
    |           +---rw vlan-bundling?             boolean
    |           +---rw vlan-range?               etht-types:vid-range-type
    |       +---rw second-tag
    |           +---rw second-tag-classification? boolean
    |           +---rw supported-tag-types*       etht-types:eth-tag-classify
    |           +---rw vlan-bundling?             boolean
    |           +---rw vlan-range?               etht-types:vid-range-type
+---rw supported-vlan-operations
    +---rw asymmetrical-operations?              boolean
    +---rw transparent-vlan-operations?          boolean
    +---rw vlan-pop
    |   +---rw vlan-pop-operations?              boolean
    |   +---rw max-pop-tags?                     uint8
    +---rw vlan-push
    |   +---rw vlan-push-operation?              boolean
    |   +---rw outer-tag
    |       +---rw supported-tag-types*          etht-types:eth-tag-type
    |       +---rw vlan-range?                   etht-types:vid-range-type
    |   +---rw second-tag
    |       +---rw push-second-tag?              boolean
    |       +---rw supported-tag-types*          etht-types:eth-tag-type
    |       +---rw vlan-range?                   etht-types:vid-range-type
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:
+---: (eth)

```

```

    +--rw eth-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:
+--:(eth)
    +--rw eth-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:
+--:(eth)
    +--rw eth-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:
+--:(eth)
    +--ro eth-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:
+--:(eth)
    +--ro eth-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:
+--:(eth)
    +--rw eth-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:
+--:(eth)
    +--rw eth-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:
+--:(eth)
    +--rw eth-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:
+--:(eth)
    +--rw eth-bandwidth?    uint64
augment /nw:networks/nw:network/nt:link/tet:te

```

```

        /tet:te-link-attributes/tet:max-link-bandwidth
        /tet:te-bandwidth/tet:technology:
    +--:(eth)
        +--rw eth-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:
    +--:(eth)
        +--rw eth-bandwidth?    uint64
    augment /nw:networks/nw:network/nt:link/tet:te
        /tet:te-link-attributes/tet:unreserved-bandwidth
        /tet:te-bandwidth/tet:technology:
    +--:(eth)
        +--rw eth-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:
    +--:(eth)
        +--ro eth-bandwidth?    uint64
    augment /nw:networks/nw:network/nt:link/tet:te
        /tet:information-source-entry/tet:max-link-bandwidth
        /tet:te-bandwidth/tet:technology:
    +--:(eth)
        +--ro eth-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:
    +--:(eth)
        +--ro eth-bandwidth?    uint64
    augment /nw:networks/nw:network/nt:link/tet:te
        /tet:information-source-entry/tet:unreserved-bandwidth
        /tet:te-bandwidth/tet:technology:
    +--:(eth)
        +--ro eth-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:
    +--:(eth)
        +--rw eth-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:
    +--:(eth)
        +--rw eth-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:
    +--:(eth)
      +--rw eth-bandwidth?   uint64
augment /nw:networks/tet:te/tet:templates/tet:link-template
        /tet:te-link-attributes/tet:unreserved-bandwidth
        /tet:te-bandwidth/tet:technology:
    +--:(eth)
      +--rw eth-bandwidth?   uint64
augment /nw:networks/nw:network/nw:node/tet:te
        /tet:te-node-attributes/tet:connectivity-matrices
        /tet:label-restrictions/tet:label-restriction:
      +--rw tag-type?        eth-types:eth-tag-type
      +--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:
    +--:(eth)
      +--rw vlanid?          eth-types:vlanid
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:
    +--:(eth)
      +--rw vlanid?          eth-types:vlanid
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:
    +--:(eth)
      +--rw eth-step?        uint16
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:
    +--:(eth)
      +--rw vlanid?          eth-types:vlanid
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:
    +--:(eth)
      +--rw vlanid?          eth-types:vlanid
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:
    +--:(eth)
      +--rw vlanid?   etht-types:vlanid
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:
  +--:(eth)
    +--rw vlanid?   etht-types:vlanid
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:
  +--:(eth)
    +--ro vlanid?   etht-types:vlanid
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 tag-type?   etht-types:eth-tag-type
  +--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:
  +--:(eth)
    +--rw vlanid?   etht-types:vlanid
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:
  +--:(eth)
    +--rw vlanid?   etht-types:vlanid
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:

```

```

    +--:(eth)
      +--rw eth-step?   uint16
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
        /tet:connectivity-matrix/tet:to
            /tet:label-restrictions/tet:label-restriction:
    +--rw tag-type?    etht-types:eth-tag-type
    +--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:
    +--:(eth)
      +--rw vlanid?    etht-types:vlanid
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:
    +--:(eth)
      +--rw vlanid?    etht-types:vlanid
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:
    +--:(eth)
      +--rw eth-step?   uint16
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:
    +--:(eth)
      +--rw vlanid?    etht-types:vlanid
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:
    +--:(eth)
      +--rw vlanid?    etht-types:vlanid
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:
    +--:(eth)
      +--rw vlanid?   etht-types:vlanid
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:
  +--:(eth)
    +--rw vlanid?   etht-types:vlanid
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:
  +--:(eth)
    +--ro vlanid?   etht-types:vlanid
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry
    /tet:connectivity-matrices
    /tet:label-restrictions/tet:label-restriction:
  +--ro tag-type?   etht-types:eth-tag-type
  +--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:
  +--:(eth)
    +--ro vlanid?   etht-types:vlanid
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:
  +--:(eth)
    +--ro vlanid?   etht-types:vlanid
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:
+--:(eth)
  +--ro eth-step?   uint16
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:
+--:(eth)
  +--ro vlanid?    etht-types:vlanid
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:
+--:(eth)
  +--ro vlanid?    etht-types:vlanid
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:
+--:(eth)
  +--ro vlanid?    etht-types:vlanid
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:
+--:(eth)
  +--ro vlanid?    etht-types:vlanid
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:
+--:(eth)
  +--ro vlanid?    etht-types:vlanid
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 tag-type?   etht-types:eth-tag-type
+--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:

+--:(eth)
    +--ro vlanid?   etht-types:vlanid
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:

+--:(eth)
    +--ro vlanid?   etht-types:vlanid
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:

+--:(eth)
    +--ro eth-step?   uint16
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:information-source-entry
        /tet:connectivity-matrices
        /tet:connectivity-matrix/tet:to
        /tet:label-restrictions/tet:label-restriction:
+--ro tag-type?   etht-types:eth-tag-type
+--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:

+--:(eth)
    +--ro vlanid?   etht-types:vlanid
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:
+--:(eth)
  +--ro vlanid?   etht-types:vlanid
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:
+--:(eth)
  +--ro eth-step?  uint16
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:
+--:(eth)
  +--ro vlanid?   etht-types:vlanid
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:
+--:(eth)
  +--ro vlanid?   etht-types:vlanid
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:
+--:(eth)
  +--ro vlanid?   etht-types:vlanid
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:

```

```

+--:(eth)
  +--ro vlanid?   etht-types:vlanid
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:

+--:(eth)
  +--ro vlanid?   etht-types:vlanid
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point
    /tet:local-link-connectivities
    /tet:label-restrictions/tet:label-restriction:

+--rw tag-type?   etht-types:eth-tag-type
+--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:

+--:(eth)
  +--rw vlanid?   etht-types:vlanid
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:

+--:(eth)
  +--rw vlanid?   etht-types:vlanid
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:

+--:(eth)
  +--rw eth-step?   uint16
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:

+--:(eth)
  +--rw vlanid?   etht-types:vlanid
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:
+--:(eth)
  +--rw vlanid?   etht-types:vlanid
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:
+--:(eth)
  +--rw vlanid?   etht-types:vlanid
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:
+--:(eth)
  +--rw vlanid?   etht-types:vlanid
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:
+--:(eth)
  +--ro vlanid?   etht-types:vlanid
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 tag-type? etht-types:eth-tag-type
  +--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:

```

```

+--:(eth)
  +--rw vlanid?   etht-types:vlanid
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:

+--:(eth)
  +--rw vlanid?   etht-types:vlanid
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:

+--:(eth)
  +--rw eth-step?  uint16
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:

+--:(eth)
  +--rw vlanid?   etht-types:vlanid
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:

+--:(eth)
  +--rw vlanid?   etht-types:vlanid
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point
    /tet:local-link-connectivities
    /tet:local-link-connectivity/tet:optimizations
    /tet:algorithm/tet:metric/tet:optimization-metric
    /tet:explicit-route-exclude-objects
    /tet:route-object-exclude-object/tet:type/tet:label
    /tet:label-hop/tet:te-label/tet:technology:

+--:(eth)
  +--rw vlanid?   etht-types:vlanid
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:
+--:(eth)
  +--rw vlanid?   etht-types:vlanid
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:
+--:(eth)
  +--ro vlanid?   etht-types:vlanid
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:
+--:(eth)
  +--rw vlanid?   etht-types:vlanid
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:
+--:(eth)
  +--rw vlanid?   etht-types:vlanid
augment /nw:networks/nw:network/nt:link/tet:te
  /tet:te-link-attributes/tet:label-restrictions
    /tet:label-restriction:
+--rw tag-type?   etht-types:eth-tag-type
+--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:
+--:(eth)
  +--rw vlanid?   etht-types:vlanid
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:
+--:(eth)
  +--rw vlanid?   etht-types:vlanid

```

```

augment /nw:networks/nw:network/nt:link/tet:te
  /tet:te-link-attributes/tet:label-restrictions
    /tet:label-restriction/tet:label-step
      /tet:technology:
  +--:(eth)
    +--rw eth-step?    uint16
augment /nw:networks/nw:network/nt:link/tet:te
  /tet:information-source-entry
    /tet:label-restrictions/tet:label-restriction:
  +--ro tag-type?    etht-types:eth-tag-type
  +--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:
  +--:(eth)
    +--ro vlanid?    etht-types:vlanid
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:
  +--:(eth)
    +--ro vlanid?    etht-types:vlanid
augment /nw:networks/nw:network/nt:link/tet:te
  /tet:information-source-entry
    /tet:label-restrictions/tet:label-restriction
      /tet:label-step/tet:technology:
  +--:(eth)
    +--ro eth-step?    uint16
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:
  +--:(eth)
    +--rw vlanid?    etht-types:vlanid
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:
  +--:(eth)
    +--rw vlanid?    etht-types:vlanid
augment /nw:networks/tet:te/tet:templates
  /tet:link-template/tet:te-link-attributes
    /tet:label-restrictions
      /tet:label-restriction:
  +--rw tag-type?    etht-types:eth-tag-type

```

```

    +--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:
    +--:(eth)
        +--rw vlanid?    eth-types:vlanid
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:
    +--:(eth)
        +--rw vlanid?    eth-types:vlanid
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:
    +--:(eth)
        +--rw eth-step?    uint16

```

4. YANG Code for Topology Client Layer

4.1. The ETH Topology YANG Code

```

<CODE BEGINS> file "ietf-eth-te-topology@2019-07-08.yang"
module ietf-eth-te-topology {

    namespace "urn:ietf:params:xml:ns:yang:ietf-eth-te-topology";

    prefix "ethtetopo";

    import ietf-network {
        prefix "nw";
    }

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

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

```

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

import 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:
      Haomian Zheng (zhenghaomian@huawei.com);
      Italo Busi (italo.busi@huawei.com);
      Aihua Guo (aihuaguo@huawei.com);
      Yunbin Xu (xuyunbin@rutt.cn);
      Yang Zhao (zhaoyangyjy@chinamobile.com);
      Xufeng Liu (Xufeng_Liu@jabil.com);
  ";

description
  "This module defines a YANG data model for describing
  layer-2 Ethernet transport topologies.";

revision 2019-07-08 {
  description
    "Initial Revision";
  reference
    "RFC XXXX: A YANG Data Model for Client-layer Topology";
  // RFC Ed.: replace XXXX with actual RFC number, update date
  // information and remove this note
}

/*
 * Groupings
 */

grouping eth-tran-topology-type {
  description
    "Identifies the Ethernet Transport topology type";

  container eth-tran-topology {
    presence "indicates a topology type of
    Ethernet Transport Network.";
    description "Eth transport topology type";
  }
}
```

```
    }
  }

  grouping ltp-bandwidth-profiles {
    description
      "A grouping which represents the bandwidth profile(s) for the ETH LTP.";

    choice direction {
      description
        "Whether the bandwidth profiles are symmetrical or asymmetrical";
      case symmetrical {
        description
          "The same bandwidth profile is used to describe the ingress and the egress bandwidth profile.";

        container ingress-egress-bandwidth-profile {
          description
            "The bandwidth profile used in the ingress and egress direction.";
            uses eth-types:eth-bandwidth-profiles;
        }
      }
      case asymmetrical {
        description
          "Different ingress and egress bandwidth profiles can be specified.";
        container ingress-bandwidth-profile {
          description
            "The bandwidth profile used in the ingress direction.";
            uses eth-types:eth-bandwidth-profiles;
        }
        container egress-bandwidth-profile {
          description
            "The bandwidth profile used in the egress direction.";
            uses eth-types:eth-bandwidth-profiles;
        }
      }
    }
  }

  grouping eth-ltp-attributes {
    description
      "Ethernet transport link termination point attributes";

    /*
     * Open Issue: should we remove this attribute (duplicates with I2RS L2 attributes)?
     */
    leaf ltp-mac-address {
```

```
        type yang:mac-address;
        description "the MAC address of the LTP.";
    }
    /*
     * Open Issue: should we remove this attribute (duplicates with I2RS L2 attr
ibutes)?
     */
    leaf port-vlan-id {
        type eth-types:vlanid;
        description "the port VLAN ID of the LTP.";
    }
    /*
     * Open Issue: should we remove this attribute (duplicates with I2RS L2 attr
ibutes)?
     */
    leaf maximum-frame-size {
        type uint16 {
            range "64 .. 65535";
        }
        description
            "Maximum frame size";
    }
    uses ltp-bandwidth-profiles;
}

grouping svc-vlan-classification {
    description
        "Grouping defining the capabilities for VLAN classification.";

    leaf-list supported-tag-types {
        type eth-types:eth-tag-classify;
        description
            "List of VLAN tag types that can be used for the VLAN classification.
            In case VLAN classification is not supported, the list is empty.";
    }
    leaf vlan-bundling {
        type boolean;
        description
            "In case VLAN classification is supported, indicates whether VLAN bundli
ng classification is also supported.";
    }
    leaf vlan-range {
        type eth-types:vid-range-type;
        description
            "In case VLAN classification is supported, indicates the of available VL
AN ID values.";
    }
}

grouping svc-vlan-push {
    description
        "Grouping defining the capabilities for VLAN push or swap operations.";
```



```
leaf-list supported-tag-types {
  type eth-types:eth-tag-type;
  description
    "List of VLAN tag types that can be used to push or swap a VLAN tag.
    In case VLAN push/swap is not supported, the list is empty.";
}
leaf vlan-range {
  type eth-types:vid-range-type;
  description
    "In case VLAN push/swap operation is supported, the range of available V
LAN ID values.";
}
}

grouping eth-ltp-svc-attributes {
  description
    "Ethernet link termination point (LTP) service attributes.";

  container supported-classification {
    description
      "Service classification capabilities supported by the ETH LTP.";

    leaf transparent{
      type boolean;
      description
        "Indicates that the ETH LTP support transparent ETH client service.";
    }
    leaf port-classification {
      type boolean;
      description
        "Indicates that the ETH LTP support port-based service classification.
";
    }
  }
  container vlan-classification {
    description
      "Service classification capabilities based on the VLAN tag(s)
      supported by the ETH LTP.";

    leaf vlan-tag-classification {
      type boolean;
      description
        "Indicates that the ETH LTP supports VLAN service classification.";
    }
  }
  container outer-tag {
    description
      "Service classification capabilities based on the outer VLAN tag,
      supported by the ETH LTP.";
    uses svc-vlan-classification;
  }
  container second-tag {
```

```

        description
            "Service classification capabilities based on the second VLAN tag,
            supported by the ETH LTP.";
        /*
        * Open issue: indicates that second-tag-classification can be True on
ly if
        * outer-tag-classification is also True.
        */
        leaf second-tag-classification {
            type boolean;
            description
                "Indicates that the ETH LTP support VLAN service classification
                based on the second VLAN tag.";
        }
        uses svc-vlan-classification;
    }
}

container supported-vlan-operations {
    description
        "Reports the VLAN operations supported by the ETH LTP.";

    leaf asymmetrical-operations {
        type boolean;
        description
            "Indicates whether the ETH LTP supports also asymmetrical VLAN operati
ons.
            It is assumed that symmetrical VLAN operations are always supported."
;
    }

    leaf transparent-vlan-operations {
        type boolean;
        description
            "Indicates that the ETH LTP supports transparent operations.";
    }

    container vlan-pop {
        description
            "Indicates VLAN pop or swap operations capabilities.";

        leaf vlan-pop-operations {
            type boolean;
            description
                "Indicates that the ETH LTP supports VLAN pop or swap operations.";
        }

        leaf max-pop-tags {
            type uint8 {
                range "1..2";
            }
            description
                "Indicates the maximum number of tags that can be popped/swapped.";
        }
    }
}

```

```

    }
  }
  container vlan-push {
    description
      "Indicates VLAN push or swap operations capabilities.";

    leaf vlan-push-operation {
      type boolean;
      description
        "Indicates that the ETH LTP supports VLAN push or swap operations.";
    }
    container outer-tag {
      description
        "Indicates the supported VLAN operation capabilities on the outer VL
AN tag.";
      uses svc-vlan-push;
    }
    container second-tag {
      description
        "Indicates the supported VLAN operation capabilities on the second V
LAN tag.";

      leaf push-second-tag {
        type boolean;
        description
          "Indicates that the ETH LTP supports VLAN push or swap operations
          for the second VLAN tag.";
      }
      uses svc-vlan-push;
    }
  }
}

/*
 * Data nodes
 */

augment "/nw:networks/nw:network/nw:network-types/tet:te-topology" {
  description
    "Augment network types to include ETH transport newtork";

  uses eth-tran-topology-type;
}

augment "/nw:networks/nw:network/nw:node/nt:termination-point" {
  when "../nw:network-types/tet:te-topology/eth-tran-topology" {
    description
      "Augment only for ETH transport network";
  }
}

```

```
description
  "Augment ETH LTP attributes";

uses eth-ltp-attributes;

container eth-svc {
  presence "client-facing LTP.";
  description
    "ETH LTP Service attributes.";

  leaf client-facing {
    type boolean;
    default "false";
    description
      "Indicates whether this LTP is a client-facing LTP.";
  }
  uses eth-ltp-svc-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/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE bandwidth";
  }
  description "Ethernet bandwidth.";
  case eth {
    uses etht-types:eth-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/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE bandwidth";
  }
  description "Ethernet bandwidth.";
  case eth {
```

```

        uses etht-types:eth-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/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE bandwidth";
    }
    description "Ethernet bandwidth.";
    case eth {
        uses etht-types:eth-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/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE bandwidth";
    }
    description "Ethernet bandwidth.";
    case eth {
        uses etht-types:eth-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/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE bandwidth";
    }
    description "Ethernet bandwidth.";
    case eth {
        uses etht-types:eth-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/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE bandwidth";
  }
  description "Ethernet bandwidth.";
  case eth {
    uses etht-types:eth-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/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE bandwidth";
  }
  description "Ethernet bandwidth.";
  case eth {
    uses etht-types:eth-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/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE bandwidth";
  }
  description "Ethernet bandwidth.";
  case eth {
    uses etht-types:eth-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/"
+ "ethrtopo:eth-tran-topology" {
description "Ethernet TE bandwidth";
}
description "Ethernet bandwidth.";
case eth {
uses ethr-types:eth-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/"
+ "ethrtopo:eth-tran-topology" {
description "Ethernet TE bandwidth";
}
description "Ethernet bandwidth.";
case eth {
uses ethr-types:eth-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/"
+ "ethrtopo:eth-tran-topology" {
description "Ethernet TE bandwidth";
}
description "Ethernet bandwidth.";
case eth {
uses ethr-types:eth-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/"
      + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE bandwidth";
      }
    description "Ethernet bandwidth.";
    case eth {
      uses etht-types:eth-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/"
    + "ethtetopo:eth-tran-topology" {
      description "Ethernet TE bandwidth";
    }
  description "Ethernet bandwidth.";
  case eth {
    uses etht-types:eth-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/"
    + "ethtetopo:eth-tran-topology" {
      description "Ethernet TE bandwidth";
    }
  description "Ethernet bandwidth.";
  case eth {
    uses etht-types:eth-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/"
    + "ethtetopo:eth-tran-topology" {
      description "Ethernet TE bandwidth";
    }
}

```



```

    }
    description "Ethernet bandwidth.";
    case eth {
        uses etht-types:eth-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/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE bandwidth";
    }
    description "Ethernet bandwidth.";
    case eth {
        uses etht-types:eth-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" {
/*
    when "../.../.../.../.../nw:network-types/tet:te-topology/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE bandwidth";
    }
*/
    description "Ethernet bandwidth.";
    case eth {
        uses etht-types:eth-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" {
/*
    when "../.../.../.../.../nw:network-types/tet:te-topology/"
        + "ethtetopo:eth-tran-topology" {

```

```
        description "Ethernet TE bandwidth";
    }
*/
    description "Ethernet bandwidth.";
    case eth {
        uses etht-types:eth-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" {
/*
    when "../..../nw:network-types/tet:te-topology/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE bandwidth";
    }
*/
    description "Ethernet bandwidth.";
    case eth {
        uses etht-types:eth-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" {
/*
    when "../..../nw:network-types/tet:te-topology/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE bandwidth";
    }
*/
    description "Ethernet bandwidth.";
    case eth {
        uses etht-types:eth-bandwidth;
    }
}

/*
* Augment TE label.
*/

/* Augment label restrictions of connectivity-matrices */
```

```

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/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
  }
  description "Ethernet label restriction.";
  uses etht-types:eth-label-restriction;
}

/* Augment label restrictions start of connectivity-matrices */
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/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
  }
  description "Ethernet label.";
  case eth {
    uses etht-types:eth-label;
  }
}

/* Augment label restrictions end of connectivity-matrices */
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/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
  }
  description "Ethernet label.";
  case eth {
    uses etht-types:eth-label;
  }
}

/* Augment label restrictions step of connectivity-matrices */
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/"
    + "ethtetopo:eth-tran-topology" {

```

```

    description "Ethernet TE label";
  }
  description "Ethernet label.";
  case eth {
    uses etht-types:eth-label-step;
  }
}

/* Augment label hop of underlay primary path of connectivity-matrices */
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/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
  }
  description "Ethernet label.";
  case eth {
    uses etht-types:eth-label;
  }
}

/* Augment label hop of underlay backup path of connectivity-matrices */
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/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
  }
  description "Ethernet label.";
  case eth {
    uses etht-types:eth-label;
  }
}

/* Augment label hop of route-exclude of connectivity-matrices */
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/"
    + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE label";
    }
description "Ethernet label.";
case eth {
    uses etht-types:eth-label;
}
}

/* Augment label hop of route-include of connectivity-matrices (added) */
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/"
    + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE label";
    }
description "Ethernet label.";
case eth {
    uses etht-types:eth-label;
}
}

/* Augment label hop of path-route of connectivity-matrices */
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/"
    + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE label";
    }
description "Ethernet label.";
case eth {
    uses etht-types:eth-label;
}
}

```

```

}

/* Augment ingress label restrictions of connectivity-matrix */
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/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
  }
  description "Ethernet label.";
  uses etht-types:eth-label-restriction;
}

/* Augment ingress label restrictions start of connectivity-matrix */
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/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
  }
  description "Ethernet label.";
  case eth {
    uses etht-types:eth-label;
  }
}

/* Augment ingress label restrictions end of connectivity-matrix */
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/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
  }
  description "Ethernet label.";
  case eth {
    uses etht-types:eth-label;
  }
}

```

```

/* Augment ingress label restrictions step of connectivity-matrix */
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/"
    + "ethrtopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
case eth {
uses ethrtypes:eth-label-step;
}
}

/* Augment egress label restrictions of connectivity-matrix */
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/"
    + "ethrtopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
uses ethrtypes:eth-label-restriction;
}

/* Augment egress label restrictions start of connectivity-matrix */
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/"
    + "ethrtopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
case eth {
uses ethrtypes:eth-label;
}
}

/* Augment egress label restrictions end of connectivity-matrix */

```

```

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/"
+ "ethtetopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
case eth {
uses etht-types:eth-label;
}
}

/* Augment egress label restrictions step of connectivity-matrix */
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/"
+ "ethtetopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
case eth {
uses etht-types:eth-label-step;
}
}

/* Augment label hop of underlay primary path of connectivity-matrix */
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/"
+ "ethtetopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
case eth {
uses etht-types:eth-label;
}
}

```



```

}
}

/* Augment label hop of underlay backup path of connectivity-matrix */
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/"
  + "ethrtopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
case eth {
  uses ethrtypes:eth-label;
}
}

/* Augment label hop of route-exclude of connectivity-matrix */
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/"
  + "ethrtopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
case eth {
  uses ethrtypes:eth-label;
}
}

/* Augment label hop of route-include of connectivity-matrix */
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/"
      + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE label";
      }
    description "Ethernet label.";
    case eth {
      uses etht-types:eth-label;
    }
  }

/* Augment label hop of path-route of connectivity-matrix */
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/"
      + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE label";
      }
    description "Ethernet label.";
    case eth {
      uses etht-types:eth-label;
    }
  }

/* Augment label restrictions of connectivity-matrices information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/"
  + "tet:connectivity-matrices/tet:label-restrictions/tet:label-restriction"
n" {
  when "../../../../../../../../../../../nw:network-types/tet:te-topology/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
  }
  description "Ethernet label.";
  uses etht-types:eth-label-restriction;
}

/* Augment label restrictions start of connectivity-matrices information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/"
  + "tet:connectivity-matrices/tet:label-restrictions/tet:label-restriction"
n/"
  + "tet:label-start/tet:te-label/tet:technology" {
    when "../../../../../../../../../../../"
      + "nw:network-types/tet:te-topology/"

```

```

        + "ethtetopo:eth-tran-topology" {
            description "Ethernet TE label";
        }
        description "Ethernet label.";
        case eth {
            uses etht-types:eth-label;
        }
    }

/* Augment label restrictions end of connectivity-matrices information-source
*/
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:information-source-entry/"
    + "tet:connectivity-matrices/tet:label-restrictions/tet:label-restrictio
n/"
    + "tet:label-end/tet:te-label/tet:technology" {
        when "../.../.../.../.../.../.../..."
        + "nw:network-types/tet:te-topology/"
        + "ethtetopo:eth-tran-topology" {
            description "Ethernet TE label";
        }
        description "Ethernet label.";
        case eth {
            uses etht-types:eth-label;
        }
    }

/* Augment label restrictions step of connectivity-matrices information-source
*/
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:information-source-entry/"
    + "tet:connectivity-matrices/tet:label-restrictions/tet:label-restrictio
n/"
    + "tet:label-step/tet:technology" {
        when "../.../.../.../.../.../.../..."
        + "nw:network-types/tet:te-topology/"
        + "ethtetopo:eth-tran-topology" {
            description "Ethernet TE label";
        }
        description "Ethernet label.";
        case eth {
            uses etht-types:eth-label-step;
        }
    }

/* Augment label hop of underlay primary path of connectivity-matrices informa
tion-source */
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/"

```

```

        + "ethtetopo:eth-tran-topology" {
            description "Ethernet TE label";
        }
        description "Ethernet label.";
        case eth {
            uses etht-types:eth-label;
        }
    }

    /* Augment label hop of underlay backup path of connectivity-matrices informat
ion-source */
    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/"
            + "ethtetopo:eth-tran-topology" {
                description "Ethernet TE label";
            }
        description "Ethernet label.";
        case eth {
            uses etht-types:eth-label;
        }
    }

    /* Augment label hop of route-exclude of connectivity-matrices information-sou
rce */
    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/"
            + "ethtetopo:eth-tran-topology" {
                description "Ethernet TE label";
            }
        description "Ethernet label.";
        case eth {
            uses etht-types:eth-label;
        }
    }

    /* Augment label hop of route-include of connectivity-matrices information-sou
rce */
    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/"
    + "ethrtopo:eth-tran-topology" {
        description "Ethernet TE label";
    }
description "Ethernet label.";
case eth {
    uses ethr-types:eth-label;
}
}

/* Augment label hop of path-route of connectivity-matrices information-source */
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/"
    + "ethrtopo:eth-tran-topology" {
        description "Ethernet TE label";
    }
description "Ethernet label.";
case eth {
    uses ethr-types:eth-label;
}
}

/* Augment ingress label restrictions of connectivity-matrix information-sourc
e */
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/"
    + "ethrtopo:eth-tran-topology" {
        description "Ethernet TE label";
    }
description "Ethernet label.";
uses ethr-types:eth-label-restriction;
}

/* Augment ingress label restrictions start 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:from/tet:label-restrictions/tet:label-restriction/"
    + "tet:label-start/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "ethtetopo:eth-tran-topology" {
description "Ethernet TE label";
    }
description "Ethernet label.";
case eth {
    uses etht-types:eth-label;
}
}

/* Augment ingress label restrictions end of connectivity-matrix information-s
source */
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/"
    + "ethtetopo:eth-tran-topology" {
description "Ethernet TE label";
    }
description "Ethernet label.";
case eth {
    uses etht-types:eth-label;
}
}

/* Augment ingress label restrictions step 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:from/tet:label-restrictions/tet:label-restriction/"
    + "tet:label-step/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "ethtetopo:eth-tran-topology" {
description "Ethernet TE label";
    }
description "Ethernet label.";
case eth {
    uses etht-types:eth-label-step;
}
}

```

```

/* Augment egress label restrictions 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:to/tet:label-restrictions/tet:label-restriction" {
when "../.../.../.../.../.../.../.../.../.../.../.../.../.../..."
+ "ethrtetopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
uses ethrtypes:eth-label-restriction;
}

/* Augment egress label restrictions start 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:to/tet:label-restrictions/tet:label-restriction/"
+ "tet:label-start/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../.../.../.../..."
+ "nw:network-types/tet:te-topology/"
+ "ethrtetopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
case eth {
uses ethrtypes:eth-label;
}
}

/* Augment egress label restrictions end of connectivity-matrix information-so
urce */
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/"
+ "ethrtetopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
case eth {
uses ethrtypes:eth-label;
}
}

/* Augment egress label restrictions step of connectivity-matrix information-s
ource */

```

```

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/"
  + "tet:to/tet:label-restrictions/tet:label-restriction/"
  + "tet:label-step/tet:technology" {
when "../.../.../.../.../.../.../.../.../..."
  + "nw:network-types/tet:te-topology/"
  + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
  }
  description "Ethernet label.";
  case eth {
    uses etht-types:eth-label-step;
  }
}

/* Augment label hop of underlay primary path of connectivity-matrix informati
on-source */
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/"
  + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
  }
  description "Ethernet label.";
  case eth {
    uses etht-types:eth-label;
  }
}

/* Augment label hop of underlay backup path of connectivity-matrix informatio
n-source */
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/"
  + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
  }
  description "Ethernet label.";
  case eth {
    uses etht-types:eth-label;
  }
}

```



```

    }

    /* Augment label hop of route-exclude 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: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/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE label";
    }
    description "Ethernet label.";
    case eth {
        uses etht-types:eth-label;
    }
}

    /* Augment label hop of route-include 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: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/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE label";
    }
    description "Ethernet label.";
    case eth {
        uses etht-types:eth-label;
    }
}

    /* Augment label hop of path-route 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-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/"
    + "ethtetopo:eth-tran-topology" {
description "Ethernet TE label";
    }
description "Ethernet label.";
case eth {
    uses etht-types:eth-label;
}
}
/* Augment label restrictions of local-link-connectivities */
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/"
    + "ethtetopo:eth-tran-topology" {
description "Ethernet TE label";
    }
description "Ethernet label.";
uses etht-types:eth-label-restriction;
}

/* Augment label restrictions start of local-link-connectivities */
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/"
    + "ethtetopo:eth-tran-topology" {
description "Ethernet TE label";
    }
description "Ethernet label.";
case eth {
    uses etht-types:eth-label;
}
}

/* Augment label restrictions end of local-link-connectivities */
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/"
    + "ethtetopo:eth-tran-topology" {

```

```

        description "Ethernet TE label";
    }
    description "Ethernet label.";
    case eth {
        uses etht-types:eth-label;
    }
}

/* Augment label restrictions step of local-link-connectivities */
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/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE label";
    }
    description "Ethernet label.";
    case eth {
        uses etht-types:eth-label-step;
    }
}

/* Augment label hop of underlay primary path of local-link-connectivities */
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/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE label";
    }
    description "Ethernet label.";
    case eth {
        uses etht-types:eth-label;
    }
}

/* Augment label hop of underlay backup path of local-link-connectivities */
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/"

```

```

    + "nw:network-types/tet:te-topology/"
    + "ethtetopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
case eth {
    uses etht-types:eth-label;
}
}

/* Augment label hop of route-exclude of local-link-connectivities */
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/"
    + "ethtetopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
case eth {
    uses etht-types:eth-label;
}
}

/* Augment label hop of route-include of local-link-connectivities */
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/"
    + "ethtetopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
case eth {
    uses etht-types:eth-label;
}
}

```

```

}

/* Augment label hop of path-route of local-link-connectivities */
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/"
+ "ethhtetopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
case eth {
uses etht-types:eth-label;
}
}

/* Augment label restrictions 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:label-restrictions/tet:label-restriction" {
when "../../../../../../../../../../../nw:network-types/tet:te-topology/"
+ "ethhtetopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
uses etht-types:eth-label-restriction;
}

/* Augment label restrictions start 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:label-restrictions/tet:label-restriction/"
+ "tet:label-start/tet:te-label/tet:technology" {
when "../../../../../../../../../../../"
+ "nw:network-types/tet:te-topology/"
+ "ethhtetopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
case eth {

```

```

    uses etht-types:eth-label;
  }
}

/* Augment label restrictions end 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:label-restrictions/tet:label-restriction/"
  + "tet:label-end/tet:te-label/tet:technology" {
  when "../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
  }
  description "Ethernet label.";
  case eth {
    uses etht-types:eth-label;
  }
}

/* Augment label restrictions step 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:label-restrictions/tet:label-restriction/"
  + "tet:label-step/tet:technology" {
  when "../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
  }
  description "Ethernet label.";
  case eth {
    uses etht-types:eth-label-step;
  }
}

/* Augment label hop of underlay primary path 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: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/"
        + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
    }
    description "Ethernet label.";
    case eth {
        uses etht-types:eth-label;
    }
}

/* Augment label hop of underlay backup path 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: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/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE label";
    }
    description "Ethernet label.";
    case eth {
        uses etht-types:eth-label;
    }
}

/* Augment label hop of route-exclude 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: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/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE label";
    }
    description "Ethernet label.";
    case eth {
        uses etht-types:eth-label;
    }
}

```

```

/* Augment label hop of route-include 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: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/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
  }
  description "Ethernet label.";
  case eth {
    uses etht-types:eth-label;
  }
}

/* Augment label hop of path-route 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-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/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
  }
  description "Ethernet label.";
  case eth {
    uses etht-types:eth-label;
  }
}

/* Augment label hop of underlay primary path of TE link */
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/"
    + "ethtetopo:eth-tran-topology" {

```



```

        description "Ethernet TE label";
    }
    description "Ethernet label.";
    case eth {
        uses etht-types:eth-label;
    }
}

/* Augment label hop of underlay backup path of TE link */
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/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE label";
    }
    description "Ethernet label.";
    case eth {
        uses etht-types:eth-label;
    }
}

/* Augment label restrictions of TE link */
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/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE label";
    }
    description "Ethernet label.";
    uses etht-types:eth-label-restriction;
}

/* Augment label restrictions start of TE link */
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/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE label";
    }
    description "Ethernet label.";
    case eth {
        uses etht-types:eth-label;
    }
}

```

```

    }
}

/* Augment label restrictions end of TE link */
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/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
  }
  description "Ethernet label.";
  case eth {
    uses etht-types:eth-label;
  }
}

/* Augment label restrictions step of TE link */
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/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
  }
  description "Ethernet label.";
  case eth {
    uses etht-types:eth-label-step;
  }
}

/* Augment label restrictions of TE link information-source */
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/"
    + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
  }
  description "Ethernet label.";
  uses etht-types:eth-label-restriction;
}

/* Augment label restrictions start of TE link information-source */
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/"
+ "ethrtopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
case eth {
uses ethr-types:eth-label;
}
}

/* Augment label restrictions end of TE link information-source */
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/"
+ "ethrtopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
case eth {
uses ethr-types:eth-label;
}
}

/* Augment label restrictions step of TE link information-source */
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/"
+ "ethrtopo:eth-tran-topology" {
description "Ethernet TE label";
}
description "Ethernet label.";
case eth {
uses ethr-types:eth-label-step;
}
}

/* Augment label hop of underlay primary path of TE link template */
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" {
when "../.../nw:network-types/tet:te-topology/"

```

```

        + "nw:network-types/tet:te-topology/"
        + "ethtetopo:eth-tran-topology" {
    description "Ethernet TE label";
    }
*/
    description "Ethernet label.";
    case eth {
        uses etht-types:eth-label;
    }
}

/* Augment label hop of underlay backup path of TE link template */
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" {
/*
    when "../../../nw:network-types/tet:te-topology/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE label";
    }
*/
    description "Ethernet label.";
    case eth {
        uses etht-types:eth-label;
    }
}

/* Augment label restrictions of TE link template */
augment "/nw:networks/tet:te/tet:templates/"
    + "tet:link-template/tet:te-link-attributes/"
    + "tet:label-restrictions/tet:label-restriction" {
/*
    when "../../../nw:network-types/tet:te-topology/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE label";
    }
*/
    description "Ethernet label.";
    uses etht-types:eth-label-restriction;
}

/* Augment label restrictions start of TE link template */
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" {
/*

```

```
        when "../../../../../../../nw:network-types/tet:te-topology/"
            + "ethtetopo:eth-tran-topology" {
            description "Ethernet TE label";
        }
    */
    description "Ethernet label.";
    case eth {
        uses etht-types:eth-label;
    }
}

/* Augment label restrictions end of TE link template */
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" {
/*
    when "../../../../../../../nw:network-types/tet:te-topology/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE label";
    }
    */
    description "Ethernet label.";
    case eth {
        uses etht-types:eth-label;
    }
}

/* Augment label restrictions step of TE link template */
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" {
/*
    when "../../../../../../../nw:network-types/tet:te-topology/"
        + "ethtetopo:eth-tran-topology" {
        description "Ethernet TE label";
    }
    */
    description "Ethernet label.";
    case eth {
        uses etht-types:eth-label-step;
    }
}
}

<CODE ENDS>
```

5. 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. 201902: we have noticed that Ethernet is the only client signal (on the perspective of OTN) which need a topology. So it is possible that the title of this document will be changed to "A YANG Data Model for Ethernet Topology". The proposal of this work is that the document will follow up the progress of draft-zheng-ccamp-client-signal-yang, with draft-zheng-ccamp-client-tunnel-yang together. (solved in -06) 201902: will have to align with TE topology model, currently is a totally different format with necessary parameters, a big change is expected. (solved in -06.)

6. IANA Considerations

TBD.

7. Manageability Considerations

TBD.

8. Security Considerations

The data following the model defined in this document is exchanged via, for example, the interface between an orchestrator and a transport network controller. The security concerns mentioned in [I-D.ietf-teas-yang-te-topo] for using ietf-te-topology.yang model also applies to this document.

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.

Editors note: to list specific subtrees and data nodes and their sensitivity/vulnerability.

9. Acknowledgements

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10. Contributors

Yanlei Zheng
China Unicom
Email: zhengyl@dimpt.com

Zhe Liu
Huawei Technologies,
Email: liuzhe123@huawei.com

Zheyu Fan
Huawei Technologies,
Email: fanzheyu2@huawei.com

Sergio Belotti
Nokia,
Email: sergio.belotti@nokia.com

Yingxi Yao
Shanghai Bell,
yingxi.yao@nokia-sbell.com

Giuseppe Fioccola
Huawei Technologies
giuseppe.fioccola@huawei.com

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Authors' Addresses

Haomian Zheng
Huawei Technologies
H1-1-A043S Huawei Industrial Base, Songshanhu
Dongguan, Guangdong 523808
China

Email: zhenghaomian@huawei.com

Aihua Guo
Huawei Technologies

Email: aihuaguo@huawei.com

Italo Busi
Huawei Technologies

Email: Italo.Busi@huawei.com

Yunbin Xu
CAICT

Email: xuyunbin@rictt.cn

Yang Zhao
China Mobile

Email: zhaoyangyjy@chinamobile.com

Xufeng Liu
Volta Networks

Email: xufeng.liu.ietf@gmail.com