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June 25, 2018

A YANG model to manage the optical interface parameters for an external transponder in a WDM network
draft-dharini-ccamp-dwdm-if-param-yang-05

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.

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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 avaiable 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 |              DWDM Network Elements              | Rs
+--+ | |  | \                                        / |  |  | +--+
Tx L1--|->|   \    +------+            +------+   /   |--|-->Rx L1
+---+  |  |    |   |      |  +------+  |      |  |    |  |    +--+
+---+  |  |    |   |      |  |      |  |      |  |    |  |    +--+
Tx L2--|->| OM |-->|------|->|ROADM |--|------|->| OD |--|-->Rx L2
+---+  |  |    |   |      |  |      |  |      |  |    |  |    +--+
+---+  |  |    |   |      |  +------+  |      |  |    |  |    +--+
Tx L3--|->|   /    | DWDM |    |  ^    | DWDM |   \   |--|-->Rx L3
+---+  |  | /      | Link +----|--|----+ Link |     \ |  |    +--+
       +-----------+           |  |           +-----------+
                            +--+  +--+
                            |        |
                         Rs v        | Ss
                         +-----+  +-----+
                         |RxLx |  |TxLx |
                         +-----+  +-----+
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 netwoks

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 treshold 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 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 osnr-margin?               int32
       |  +--ro q-margin?                  int32
       |  +--ro fec-info?                  string
```

```
     |  +--ro fec-bitrate?                  string
     |  +--ro fec-gain?                     string
     |  +--rw fec-ber-mantissa-threshold?   uint32
     |  +--rw fec-ber-exponent-threshold?   int32
     |  +--ro number-of-lanes?              uint32
     |  +--ro min-laser-temperature?        int32
     |  +--ro max-laser-temperature?        int32
     |  +--ro min-rx-optical-power?         dbm-t
     |  +--ro max-rx-optical-power?         dbm-t
     |  +--ro min-chromatic-dispersion?     int32
     |  +--ro max-chromatic-dispersion?     int32
     |  +--ro min-diff-group-delay?         int32
     |  +--ro max-diff-group-delay?         int32
     |  +--ro modulation-format?            string
     |  +--rw bits-per-symbol?              uint32
     |  +--rw num-symbols-in-alphabet?      uint32
     |  +--rw symbols-index?                uint32
     |  +--ro i-center?                     int32
     |  +--ro q-center?                     int32
     |  +--ro i-noise-variance?             int32
     |  +--ro q-noise-variance?             int32
     |  +--ro a-noise-variance?             int32
     |  +--ro p-noise-variance?             int32
     +--ro if-supported-mode
     |  +--ro number-of-modes-supported?   uint32
     |  +--ro mode-list* [mode-id]
     |     +--ro mode-id                        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 osnr-margin?                   int32
     |     +--ro 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 min-rx-optical-power?          dbm-t
     |     +--ro max-rx-optical-power?          dbm-t
     |     +--ro min-chromatic-dispersion?      int32
     |     +--ro max-chromatic-dispersion?      int32
     |     +--ro min-diff-group-delay?          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 i-center?                     int32
          |     +--ro q-center?                     int32
          |     +--ro i-noise-variance?             int32
          |     +--ro q-noise-variance?             int32
          |     +--ro a-noise-variance?             int32
          |     +--ro p-noise-variance?             int32
          +--rw current-opt-if-och-mode-params
             +--rw mode-id?                          string
             +--ro osnr-margin?                      int32
             +--ro q-margin?                         int32
             +--rw central-frequency?                uint32
             +--rw output-power?                     int32
             +--ro 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 fec-ber-mantissa?                 uint32
             +--ro 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:dharinih@juniper.net>";

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

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        (http://trustee.ietf.org/license-info).";
```

```
       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 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 input-power {
                type int32;
                units ".01dbm";
                config false;
                description "The current 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  fec-ber-mantissa-threshold {
               type uint32;
               description " Mantissa of the FEC BER threshold";

              }
              leaf  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-constellation {
             description "Optical constellation parameters";
             leaf i-center {
                type int32;
                units ".0001";
                config false;
                description "The In-phase coordinate of the selected
                             constellation symbol for this mode";
              }
              leaf q-center {
                type int32;
                units ".0001";
                config false;
                description "The Quadrature coordinate of the selected
                             constellation symbol for this mode";
              }
              leaf i-noise-variance {
                type int32;
```

```
                units ".001";
                config false;
                description "The Variance of the in-phase noise
                             component for this mode";
              }
              leaf q-noise-variance {
                type int32;
                units ".001";
                config false;
                description "The Variance of the quadrature noise
                             component for this mode";
              }
              leaf a-noise-variance {
                type int32;
                units ".001";
                config false;
                description "The Variance of the radial noise
                             component for this mode";
              }
              leaf p-noise-variance {
                type int32;
                units ".001";
                config false;
                description "The Variance of the phase noise
                             component for this mode";
              }
         }

         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  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.";

              }
              uses opt-if-och-constellation;

         }

         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 min-rx-optical-power {
                type dbm-t;
                config false;
                description
                        "Minimum rx optical power of this mode for
                          this interface";
            }
            leaf max-rx-optical-power {
                type dbm-t;
                config false;
                description
                        "Maximum rx optical power of this mode for
                          this interface";
```

```
            }
            leaf min-chromatic-dispersion {
                type int32;
                config false;
                description
                        "Minimum chromatic dispersion 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 min-diff-group-delay {
                type int32;
                config false;
                description
                         "Minimum Differential group delay 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  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  fec-ber-mantissa {
               type uint32;
               config false;
               description " Pre fec FEC errored words mantissa";
              }
              leaf  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 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-input-power {
                  type dbm-t;
                  config false;
                  description "The minimum input power of this
                               interface";
               }
               leaf max-input-power {
                  type dbm-t;
                  config false;
                  description "The maximum input power of this
                               interface";
               }
               leaf min-output-power {
                  type dbm-t;
                  config false;
                  description "The minimum output power of this
                               interface";
               }
               leaf max-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]. he 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

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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.

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June 25, 2018

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

Abstract

This memo defines extensions to LMP(rfc4209) for managing Optical parameters associated with Wavelength Division Multiplexing (WDM) systems in accordance with the Interface Application Identifier approach defined in ITU-T Recommendation G.694.1.[ITU.G694.1] and its extensions.

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Table of Contents

1. Introduction

This extension addresses the use cases described by "draft-ietf-ccamp-dwdm-if-mng-ctrl-fwk". LMP [RFC4902] provides link property correlation capabilities that can be used between a transceiver device and an Optical Line System (OLS) device. Link property correlation is a procedure by which, intrinsic parameters and capabilities are exchanged between two ends of a link. Link property correlation as defined in RFC3591 allows either end of the link to supervise the received signal and operate within a commonly understood parameter window. Here the term 'link' refers in particular to the attachment link between OXC and OLS (see Figure 1). The relevant interface parameters are in line with "draft-dharini-ccamp-dwdm-if-yang".

2. DWDM line system

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

```
              +-------------------------------------------------+
           Ss |               DWDM Network Elements             | Rs
    +--+ |  |  | \                                       / |  |  | +--+
    Tx L1--|->|   \    +------+           +------+   /   |--|-->Rx L1
    +---+  |  |    |   |      |  +------+  |      |  |    |  |    +--+
    +---+  |  |    |   |      |  |      |  |      |  |    |  |    +--+
    Tx L2--|->| OM |-->|------|->|ROADM |--|------|->| OD |--|-->Rx L2
    +---+  |  |    |   |      |  |      |  |      |  |    |  |    +--+
    +---+  |  |    |   |      |  +------+  |      |  |    |  |    +--+
    Tx L3--|->|   /    | DWDM |     |  ^   | DWDM |   \   |--|-->Rx L3
    +---+  |  | /      | Link +----|--|----+ Link |     \ |  |    +--+
           +-----------+           |  |          +----------+
                                +--+  +--+
                                |        |
                             Rs v        | Ss
                             +-----+  +-----+
                             |RxLx |  |TxLx |
                             +-----+  +-----+
```

Ss = Sender reference point at the DWDM network element
     tributary output
Rs = Receiver 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: Linear Single Channel approach

Figure 2 Extended LMP Model (from [RFC4209])

```
         +------+ Ss    +------+       +------+    Rs +------+
         |      | ----- |      |       |      | ----- |      |
         | OXC1 | ----- | OLS1 | ===== | OLS2 | ----- | OXC2 |
         |      | ----- |      |       |      | ----- |      |
         +------+       +------+       +------+       +------+
           ^  ^             ^              ^             ^  ^
           |  |             |              |             |  |
           |  +-----LMP-----+              +-----LMP-----+  |
           |                                                |
           +----------------------LMP-----------------------+
```

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

Figure 2: Extended LMP Model

3. Use Cases

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

4. Extensions to LMP-WDM Protocol

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

The following new messages are defined for the WDM extension for ITU-T G.698.2 [ITU.G698.2]/ITU-T G.698.1 [ITU.G698.1]/ ITU-T G.959.1 [ITU.G959.1]

```
  - OCh_General                  (sub-object Type = TBA)
  - OCh_ApplicationIdentier      (sub-object Type = TBA)
  - OCh_Ss                       (sub-object Type = TBA)
  - OCh_Rs                       (sub-object Type = TBA)
```

5. General Parameters - OCh_General

These are a set of general parameters as described in [G698.2] and [G.694.1]. Please refer to the "draft-galikunze-ccamp-dwdm-if-snmp-mib" and "draft-dharini-ccamp-dwdm-if-yang" for more details about these parameters and the [RFC6205] for the wavelength definition.

The general parameters are

1. Central Frequency - (Tera Hz) 4 bytes (see RFC6205 sec.3.2)
2. Number of Application Identifiers (A.I.) Supported
3. Single-channel Application Identifier in use
4. Application Identifier Type in use
5. Application Identifier in use

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

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type       |    Length     |         (Reserved)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Central Frequency                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Number of Application                 |                     |
|   Identifiers Supported                 |     (Reserved)      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Single-channel|  A.I. Type    |         A.I. length           |
| Application   |   in use      |                               |
| Identifier    |               |                               |
| Number in use |               |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Single-channel Application Identifier in use        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Single-channel Application Identifier in use        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Single-channel Application Identifier in use        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

A.I. Type in use: STANDARD, PROPRIETARY

A.I. Type in use: STANDARD

Refer to G.698.2 recommendation : B-DScW-ytz(v)

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Single-channel Application Code                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Single-channel Application Code                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Single-channel Application Code                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

A.I. Type in use: PROPRIETARY

Note: if the A.I. type = PROPRIETARY, the first 6 Octets of the Application Identifier in use are six characters of the PrintableString must contain the Hexadecimal representation of an OUI (Organizationally Unique Identifier) assigned to the vendor whose implementation generated the Application Identifier; the remaining octets of the PrintableString are unspecified.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        OUI                                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              OUI cont.        |           Vendor value        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Vendor Value                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3: OCh_General

6. ApplicationIdentifier - OCh_ApplicationIdentifier

This message is to exchange the application identifiers supported as described in [G698.2]. There can be more than one Application Identifier supported by the transmitter/receiver in the OXC. The number of application identifiers supported is exchanged in the "OCh_General" message. (from [G698.1]/[G698.2]/[G959.1] and G.874.1)

The parameters are

1. Number of Application Identifiers (A.I.) Supported

2. Single-channel application identifier Number
   uniquely identifiers this entry - 8 bits

3. Application Indentifier Type (A.I.) (STANDARD/PROPRIETARY)

4. Single-channel application identifier -- 96 bits
   (from [G698.1]/[G698.2]/[G959.1]

- this parameter can have
  multiple instances as the transceiver can support multiple
  application identifiers.

Figure 4: The format of the this sub-object (Type = TBA, Length = TBA) is as follows:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type       |    Length     |         (Reserved)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Number of Application                |                      |
|   Identifiers Supported                |     (Reserved)       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Single-channel|  A.I. Type    |         A.I. length           |
| Application   |               |                               |
| Identifier    |               |                               |
| Number        |               |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Single-channel Application Identifier           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Single-channel Application Identifier           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Single-channel Application Identifier           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
//              ....                                            //
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Single-channel|               |         A.I. length           |
| Application   |   A.I. Type   |                               |
| Identifier    |               |                               |
| Number        |               |                               |
|               |               |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
    |               Single-channel Application Identifier           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |               Single-channel Application Identifier           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |               Single-channel Application Identifier           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

A.I. Type in use: STANDARD, PROPRIETARY

A.I. Type in use: STANDARD
Refer to G.698.2 recommendation : B-DScW-ytz(v)

```
     0                   1                   2                   3
     0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                Single-channel Application Code                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                Single-channel Application Code                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                Single-channel Application Code                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

A.I. Type in use: PROPRIETARY

Note: if the A.I. type = PROPRIETARY, the first 6 Octets of the Application Identifier in use are six characters of the PrintableString must contain the Hexadecimal representation of an OUI (Organizationally Unique Identifier) assigned to the vendor whose implementation generated the Application Identifier; the remaining octets of the PrintableString are unspecified.

```
     0                   1                   2                   3
     0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                          OUI                                  |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |              OUI cont.        |            Vendor value       |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                             Vendor Value                      |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4: OCh_ApplicationIdentifier

7. OCh_Ss - OCh transmit parameters

These are the G.698.2 parameters at the Source(Ss reference points). Please refer to "draft-dharini-ccamp-dwdm-if-yang" for more details about these parameters.

1. Output power

Figure 5: The format of the OCh sub-object (Type = TBA, Length = TBA) is as follows:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type       |    Length     |         (Reserved)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Output Power                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5: OCh_Ss transmit parameters

8. OCh_Rs - receive parameters

These are the G.698.2 parameters at the Sink (Rs reference points).

1. Current Input Power   - (0.1dbm) 4bytes

Figure 6: The format of the OCh receive sub-object (Type = TBA, Length = TBA) is as follows:

The format of the OCh receive/OLS Sink sub-object (Type = TBA, Length = TBA) is as follows:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type       |    Length     |                  (Reserved)  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Current Input Power                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 6: OCh_Rs receive parameters

9. Security Considerations

LMP message security uses IPsec, as described in [RFC4204]. This document only defines new LMP objects that are carried in existing LMP messages, similar to the LMP objects in [RFC:4209]. This document does not introduce new security considerations.

10. IANA Considerations

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

- LMP Message Type
- LMP Object Class
- LMP Object Class type (C-Type) unique within the Object Class
- LMP Sub-object Class type (Type) unique within the Object Class

This memo introduces the following new assignments:

LMP Sub-Object Class names:

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

```
  - OCh_General                  (sub-object Type = TBA)
  - OCh_ApplicationIdentifier    (sub-object Type = TBA)
  - OCh_Ss                       (sub-object Type = TBA)
  - OCh_Rs                       (sub-object Type = TBA)
```

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June 25, 2018

A YANG model to manage the optical parameters for in a WDM network
draft-galimbe-ccamp-iv-yang-06

Abstract

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

The Yang model defined in this memo can be used for Optical Parameters monitoring and/or configuration of the multivendor Endpoints and ROADMs

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1. Introduction

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

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

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

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

2. The Internet-Standard Management Framework

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

This memo specifies a Yang model for optical interfaces.

3. Conventions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119] In the description of OIDs the convention: Set (S) Get (G) and Trap (T) conventions will describe the action allowed by the parameter.

4. Definition

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

5. Applicability

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

6. Properties

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

7. Overview

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

```
          +--------------------------------------------------+
       Ss |                   DWDM Network                   | Rs
   +--+ | |  | \                                       / |  |  | +--+
   Tx L1--|->|   \                                   /   |--|-->Rx L1
   +---+  |  |    |            +------+            |    |  |    +--+
   +---+  |  |    |            |      |            |    |  |    +--+
   Tx L2--|->| OM |------------>|ROADM |-- -------->| OD |--|-->Rx L2
   +---+  |  |    |     DWDM   |      |    DWDM    |    |  |    +--+
   +---+  |  |    |     Link   +------+    Link    |    |  |    +--+
   Tx L3--|->|   /                |  ^               \   |--|-->Rx L3
   +---+  |  | /                  |  |                 \ |  |    +--+
          +-----------------------|--|-----------------------+
                               +--+  +--+
                               |        |
                            Rs v        | Ss
                            +-----+  +-----+
                            |RxLx |  |TxLx |
                            +-----+  +-----+
   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 netwoks

7.1. Optical Parameters Description

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

The definitions of the optical parameters are provided below to increase the readability of the document, where the definition is ended by (R) the parameter can be retrieve with a read, when (W) it can be provisioned by a write, (R,W) can be either read or written.

7.1.1. Optical path from point Ss to Rs

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

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

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

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

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

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

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

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

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

Maximum ripple:
Although is defined in G.698.2 (R).

7.1.2. Rs and Ss Configuration

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

7.1.3. Table of Application Codes

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

7.2. Use Cases

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

7.3. Optical Parameters for impairment validation in a WDM network

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

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

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

8. Structure of the Yang Module

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

9. Yang Module

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

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

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


     import ietf-interfaces {
       prefix if;
     }

     import iana-if-type {
       prefix ianaift;
     }



     organization
       "IETF CCAMP
       Working Group";

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


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

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

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```

```
           (http://trustee.ietf.org/license-info).";

       revision "2018-03-06" {
              description
                  "Revision 1.0";
              reference
                  "";
       }
       revision "2016-10-30" {
              description
                  "Initial revision.";
              reference
                "RFC XXXX: A YANG Data Model for Optical Paramenters
                of DWDM Networks
                   ";
       }



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


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

     typedef active-channel-t {
       type union {
         type uint8 {
           range "0..200";
         }
       }
       description "
         Number of channels active on a span - and on an amplifier";
     }

     typedef dbm-t {
```

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

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

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

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

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

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

       leaf opwr-min-clear {
```

```
         type dbm-t;
         units "dBm";
         default -1;
         description "threshold to clear Minimum Power value Alarm";
       }

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

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

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

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

     grouping power-degrade-high-alarm-grp {
       description "
         High Optical Power gain alarm ";

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

```
     }

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

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


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


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

     grouping chromatic-dispersion-grp {
         description "Chromatic Dispersion";
       leaf chromatic-dispersion {
         type decimal64 {
```

```
          fraction-digits 2;
        }
        units "ps/nm";
        description "Chromatic Dispersion (CD) related to the OMS";
      }
    }

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

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

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

    grouping drop-power-grp {
        description "Drop power at DWDM if RX feasibility";
      leaf drop-power {
        type decimal64 {
          fraction-digits 2;
```

```
         }
         units "dBm";
         description "Drop Power value at the DWDM Transceiver RX
              side";
       }
     }

     grouping drop-power-sigma-grp {
         description "Drop power sigma at DWDM if RX feasibility ";
       leaf drop-power-sigma {
         type decimal64 {
           fraction-digits 2;
         }
         units "db";
         description "Drop Power Sigma value at the DWDM Transceiver
         RX side";
       }
     }

       grouping ripple-grp {
           description "Channel Ripple";
       leaf ripple {
         type decimal64 {
           fraction-digits 2;
         }
         units "db";
         description "Channel Ripple";
       }
     }

       grouping ch-noise-figure-grp {
       list ch-noise-figure {
           key "ch-noise-fig";
           description "Channel signal-spontaneous noise figure";

       leaf ch-noise-fig {
           type ch-noise-figure-point;
           description  "Channel signal-spontaneous noise
           figure point";
           }

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

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

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

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

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

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

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

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

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

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


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

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

         leaf offset {
```

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

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

         leaf tilt-calibration {
           type tilt-t;
           description "Amplifier Tilt tuning";
         }
        }
        container opwr-threshold-warning {
           description "Optical power threshold warning";
         uses opwr-threshold-warning-grp;
             }
        container gain-degrade-alarm {
           description "Gain degrade alarm";
         uses gain-degrade-alarm-grp;
             }
        container power-degrade-high-alarm {
           description "Power degrade high aparm";
         uses power-degrade-high-alarm-grp;
             }
        container power-degrade-low-alarm {
           description "Power degrade low alarm";
         uses power-degrade-low-alarm-grp;
             }
        container noise {
           description "Channel Noise feasibility";
         uses noise-grp;
             }
        container noise-sigma {
           description "Channel Noise sigma feasibility";
         uses noise-grp;
             }
        container chromatic-dispersion {
           description "Chromatic Dispersion";
         uses noise-sigma-grp;
             }
```

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

      }
    }
   }

   <CODE ENDS>
```

10. Security Considerations

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

11. IANA Considerations

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

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

Registrant Contact: The IESG.

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

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

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

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

12. Acknowledgements

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Appendix A. Change Log

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

Appendix B. Open Issues

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Intended status: Experimental Juniper
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June 25, 2018

Extension to the Link Management Protocol (LMP/DWDM -rfc4209) for Dense Wavelength Division Multiplexing (DWDM) Optical Line Systems to manage the application code of optical interface parameters in DWDM application
draft-ggalimbe-ccamp-flex-if-lmp-05

Abstract

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

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Table of Contents

1. Introduction

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

2. DWDM line system

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

```
       +-------------------------------------------------+
    Ss |             DWDM Network Elements               | Rs
+--+ | |  | \                                       / |  |  | +--+
Tx L1--|->|   \    +------+           +------+   /   |--|-->Rx L1
+---+  |  |     |  |      |  +------+  |      |  |     |  |    +--+
+---+  |  | FX |  |      |  | FLEX |  |      |  | FX |  |    +--+
Tx L2--|->| OM |-->|------|->|ROADM |--|------|->| OD |--|-->Rx L2
+---+  |  |     |  |      |  |      |  |      |  |     |  |    +--+
+---+  |  |     |  |      |  +------+  |      |  |     |  |    +--+
Tx L3--|->|   /    | DWDM |     |  ^    | DWDM |   \    |--|-->Rx L3
+---+  |  | /      | Link +----|--|----+ Link |     \ |  |    +--+
       +-----------+          |  |          +-----------+
                            +--+  +--+
                            |        |
                         Rs v        | Ss
                         +-----+  +-----+
                         |RxLx |  |TxLx |
                         +-----+  +-----+
```

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

FX OM = Flex-Spectrum Optical Mux
FX OD = Flex-Spectrum Optical Demux
Flex ROADM = Flex-Spectrum Optical Add Drop Mux (reconfigurable)

extending Fig. 5.1/G.698.2

Figure 1: Linear Single Channel approach

Figure 2 Extended LMP Model (from [RFC4209])

```
+------+ Ss    +------+       +------+    Rs +------+
|      | ----- |      |       |      | ----- |      |
| OXC1 | ----- | OLS1 | ===== | OLS2 | ----- | OXC2 |
|      | ----- |      |       |      | ----- |      |
+------+       +------+       +------+       +------+
  ^  ^            ^              ^              ^  ^
  |  |            |              |              |  |
  |  +-----LMP-----+             +-----LMP-----+  |
  |                                                |
  +----------------------LMP-----------------------+
```

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

Figure 2: Extended LMP Model

3. Use Cases

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

4. Extensions to LMP-WDM Protocol

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

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

5. Multi carrier Transceiver

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

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

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

10 Max-pol-power-difference: max power difference between the polarised components

11 Max-pol-skew-difference: maw Skew between polarised signal and subcarriers supported by the transceiver

12. Sub-carrier OSNR robustness

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

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type       |    Length     |         (Reserved)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|S|I|         Modulation ID     |               FEC             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         baud rate  (Symbol Rate)              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Number of subcarriers    |            Bit/Symbol         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          subcarrier band      |           guard band          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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

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

Figure 3: Multi carrier Transceiver

6. Security Considerations

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

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

7. IANA Considerations

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

- LMP Message Type
- LMP Object Class
- LMP Object Class type (C-Type) unique within the Object Class
- LMP Sub-object Class type (Type) unique within the Object Class

This memo introduces the following new assignments:

LMP Sub-Object Class names:

under DATA_LINK Class name (as defined in <xref target="RFC4204"/>)
  - Multi carrier Transceiver   (sub-object Type = TBA)

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9. References

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October 22, 2018

YANG data model for Flexi-Grid media-channels
draft-ietf-ccamp-flexigrid-media-channel-yang-01.txt

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Abstract

This document defines a YANG model for managing flexi-grid optical media channels, complementing the information provided by the flexi-grid TED model.
It is also grounded on other defined YANG abstract models.

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1. Introduction

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

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

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

2. Conventions used in this document

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].

In this document, these words will appear with that interpretation only when in ALL CAPS. Lower case uses of these words are not to be interpreted as carrying RFC-2119 significance.

In this document, the characters ">>" preceding an indented line(s) indicates a compliance requirement statement using the key words listed above. This convention aids reviewers in quickly identifying or finding the explicit compliance requirements of this RFC.

3. Flexi-grid media-channel overview

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

- source address
- source flexi-grid port
- source flexi-grid transponder
- destination address
- destination flexi-grid port
- destination flexi-grid transponder
- A list of links that defines the path
- Other optical attributes

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

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

4. Example of use

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

```
                               Media channel
            <===================================================>
                                  Path x
            <--------------------------------------------------->

                     +----------+          +----------+
              Link 1 |Flexi-grid|  Link 2  |Flexi-grid| Link 3
                .--->|   node   |<-------->|   node   |<---.
                |    |    B     |          |    C     |    |
                |    +----------+          +----------+    |
                v                                          v
             /-----------\                         /-----------\
            / Flexi-grid  \                       / Flexi-grid  \
            | transponder |                       | transponder |
            \      A      /                       \      E      /
             \-----------/                         \-----------/
                  ^                                      ^
                  |             +----------+             |
                  |    Link 4   |Flexi-grid|   Link 5    |
                  '------------>|   node   |<------------'
                                |    D     |
                                +----------+
            <--------------------------------------------------->
                                  Path y
```

Figure 1. Topology example.

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

1. Depending on the case, it is possible to define either the source and destination node ports, or the source and destination node and transponder. In our case, we would define a network media channel, with source transponder A and source node B, and destination transponder E and destination node C. Thus, we are going to follow path x.

2. Then, for each link in the path x, we indicate which channel we are going to use, providing information about the slots, and what nodes are connected.

3. Finally, the flexi-grid TED has to be updated with each element usage status each time a media channel is created or torn down.

5. Media Channel YANG Model

5.1. YANG Model - Tree

```
module: ietf-flex-grid-media-channel
  augment /te:te/te:tunnels/te:tunnel:
    +--rw src-client-signal?   identityref
    +--rw dst-client-signal?   identityref
    +--rw fec-type?            identityref
    +--rw termination-type?    identityref
    +--rw bit-stuffing?        boolean
  augment /te:te/te:globals/te:named-path-constraints/
    te:named-path-constraint/te:te-bandwidth/te:technology:
    +--:(flex-grid)
       +--rw bandwidth-type?   identityref
  augment /te:te/te:tunnels/te:tunnel/te:te-bandwidth/te:technology:
    +--:(flex-grid)
       +--rw bandwidth-type?   identityref
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:te-bandwidth/te:technology:
    +--:(flex-grid)
       +--rw bandwidth-type?   identityref
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-primary-path/te:te-bandwidth/
    te:technology:
    +--:(flex-grid)
       +--rw bandwidth-type?   identityref
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/
    te:p2p-secondary-path/te:te-bandwidth/te:technology:
    +--:(flex-grid)
       +--rw bandwidth-type?   identityref
```

```
  augment /te:te/te:globals/te:named-path-constraints/
    te:named-path-constraint/te:explicit-route-objects/
    te:route-object-exclude-always/te:type/te:label/te:label-hop/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  augment /te:te/te:globals/te:named-path-constraints/
    te:named-path-constraint/te:explicit-route-objects/
    te:route-object-include-exclude/te:type/te:label/te:label-hop/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  augment /te:te/te:globals/te:named-path-constraints/
    te:named-path-constraint/te:path-in-segment/te:forward/
    te:label-restrictions/te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
  augment /te:te/te:globals/te:named-path-constraints/
    te:named-path-constraint/te:path-in-segment/te:forward/
    te:label-restrictions/te:label-restriction/te:label-start/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:globals/te:named-path-constraints/
    te:named-path-constraint/te:path-in-segment/te:forward/
    te:label-restrictions/te:label-restriction/te:label-end/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
```

```
  augment /te:te/te:globals/te:named-path-constraints/
    te:named-path-constraint/te:path-in-segment/te:reverse/
    te:label-restrictions/te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
  augment /te:te/te:globals/te:named-path-constraints/
    te:named-path-constraint/te:path-in-segment/te:reverse/
    te:label-restrictions/te:label-restriction/te:label-start/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:globals/te:named-path-constraints/
    te:named-path-constraint/te:path-in-segment/te:reverse/
    te:label-restrictions/te:label-restriction/te:label-end/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:globals/te:named-path-constraints/
    te:named-path-constraint/te:path-out-segment/te:forward/
    te:label-restrictions/te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
  augment /te:te/te:globals/te:named-path-constraints/
    te:named-path-constraint/te:path-out-segment/te:forward/
    te:label-restrictions/te:label-restriction/te:label-start/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:globals/te:named-path-constraints/
    te:named-path-constraint/te:path-out-segment/te:forward/
    te:label-restrictions/te:label-restriction/te:label-end/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:globals/te:named-path-constraints/
    te:named-path-constraint/te:path-out-segment/te:reverse/
    te:label-restrictions/te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
```

```
  augment /te:te/te:globals/te:named-path-constraints/
    te:named-path-constraint/te:path-out-segment/te:reverse/
    te:label-restrictions/te:label-restriction/te:label-start/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:globals/te:named-path-constraints/
    te:named-path-constraint/te:path-out-segment/te:reverse/
    te:label-restrictions/te:label-restriction/te:label-end/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
```

```
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:explicit-route-objects/
    te:route-object-exclude-always/te:type/te:label/te:label-hop/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:explicit-route-objects/
    te:route-object-include-exclude/te:type/te:label/te:label-hop/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:path-in-segment/te:forward/
    te:label-restrictions/te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:path-in-segment/te:forward/
    te:label-restrictions/te:label-restriction/te:label-start/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:path-in-segment/te:forward/
    te:label-restrictions/te:label-restriction/te:label-end/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
```

```
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:path-in-segment/te:reverse/
    te:label-restrictions/te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:path-in-segment/te:reverse/
    te:label-restrictions/te:label-restriction/te:label-start/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:path-in-segment/te:reverse/
    te:label-restrictions/te:label-restriction/te:label-end/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:path-out-segment/te:forward/
    te:label-restrictions/te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:path-out-segment/te:forward/
    te:label-restrictions/te:label-restriction/te:label-start/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:path-out-segment/te:forward/
    te:label-restrictions/te:label-restriction/te:label-end/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:path-out-segment/te:reverse/
    te:label-restrictions/te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
```

```
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:path-out-segment/te:reverse/
    te:label-restrictions/te:label-restriction/te:label-start/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:path-out-segment/te:reverse/
    te:label-restrictions/te:label-restriction/te:label-end/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:state/te:path-properties/
    te:path-route-objects/te:path-computed-route-object/te:state/
    te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:state/te:lsps/te:lsp/
    te:lsp-record-route-subobjects/te:record-route-subobject/te:type/
    te:label/te:label-hop/te:te-label/te:technology:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:state/te:lsps/te:lsp/te:path-properties/
    te:path-route-objects/te:path-computed-route-object/te:state/
    te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
```

```
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-primary-path/
    te:explicit-route-objects/te:route-object-exclude-always/
    te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
```

```
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-primary-path/
    te:explicit-route-objects/te:route-object-include-exclude/
    te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-primary-path/
    te:path-in-segment/te:forward/te:label-restrictions/
    te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-primary-path/te:path-in-segment/
    te:forward/te:label-restrictions/te:label-restriction/
    te:label-start/te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-primary-path/te:path-in-segment/
    te:forward/te:label-restrictions/te:label-restriction/te:label-end/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-primary-path/
    te:path-in-segment/te:reverse/te:label-restrictions/
    te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-primary-path/
    te:path-in-segment/te:reverse/te:label-restrictions/
    te:label-restriction/te:label-start/te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
```

```
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-primary-path/
    te:path-in-segment/te:reverse/te:label-restrictions/
    te:label-restriction/te:label-end/te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-primary-path/
    te:path-out-segment/te:forward/te:label-restrictions/
    te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-primary-path/
    te:path-out-segment/te:forward/te:label-restrictions/
    te:label-restriction/te:label-start/te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-primary-path/
    te:path-out-segment/te:forward/te:label-restrictions/
    te:label-restriction/te:label-end/te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-primary-path/
    te:path-out-segment/te:reverse/te:label-restrictions/
    te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-primary-path/
    te:path-out-segment/te:reverse/te:label-restrictions/
    te:label-restriction/te:label-start/te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-primary-path/
    te:path-out-segment/te:reverse/te:label-restrictions/
    te:label-restriction/te:label-end/te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
```

```
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-primary-path/
    te:state/te:path-properties/te:path-route-objects/
    te:path-computed-route-object/te:state/te:type/te:label/
    te:label-hop/te:te-label/te:technology:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-primary-path/te:state/te:lsps/
    te:lsp/te:lsp-record-route-subobjects/te:record-route-subobject/
    te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/
    te:p2p-primary-path/te:p2p-reverse-primary-path/
    te:state/te:lsps/te:lsp/te:path-properties/te:path-route-objects/
    te:path-computed-route-object/te:state/te:type/te:label/
    te:label-hop/te:te-label/te:technology:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
```

```
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/
    te:p2p-secondary-path/te:explicit-route-objects/
    te:route-object-exclude-always/te:type/te:label/
    te:label-hop/te:te-label/te:technology:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
```

```
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/
    te:p2p-secondary-path/te:explicit-route-objects/
    te:route-object-include-exclude/te:type/te:label/
    te:label-hop/te:te-label/te:technology:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/
    te:p2p-secondary-path/te:path-in-segment/te:forward/
    te:label-restrictions/te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/
    te:p2p-secondary-path/te:path-in-segment/te:forward/
    te:label-restrictions/te:label-restriction/te:label-start/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/
    te:p2p-secondary-path/te:path-in-segment/te:forward/
    te:label-restrictions/te:label-restriction/te:label-end/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/
    te:p2p-secondary-path/te:path-in-segment/te:reverse/
    te:label-restrictions/te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/
    te:p2p-secondary-path/te:path-in-segment/te:reverse/
    te:label-restrictions/te:label-restriction/te:label-start/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
```

```
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/
    te:p2p-secondary-path/te:path-in-segment/te:reverse/
    te:label-restrictions/te:label-restriction/te:label-end/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/
    te:p2p-secondary-path/te:path-out-segment/te:forward/
    te:label-restrictions/te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/
    te:p2p-secondary-path/te:path-out-segment/te:forward/
    te:label-restrictions/te:label-restriction/te:label-start/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/
    te:p2p-secondary-path/te:path-out-segment/te:forward/
    te:label-restrictions/te:label-restriction/te:label-end/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/
    te:p2p-secondary-path/te:path-out-segment/te:reverse/
    te:label-restrictions/te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/
    te:p2p-secondary-path/te:path-out-segment/te:reverse/
    te:label-restrictions/te:label-restriction/te:label-start/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/
    te:p2p-secondary-path/te:path-out-segment/te:reverse/
    te:label-restrictions/te:label-restriction/te:label-end/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
```

```
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/
    te:p2p-secondary-path/te:state/te:path-properties/
    te:path-route-objects/te:path-computed-route-object/
    te:state/te:type/te:label/te:label-hop/te:te-label/
    te:technology:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/
    te:p2p-secondary-path/te:state/te:lsps/te:lsp/
    te:lsp-record-route-subobjects/te:record-route-subobject/
    te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/
    te:p2p-secondary-path/te:state/te:lsps/te:lsp/
    te:path-properties/te:path-route-objects/
    te:path-computed-route-object/te:state/te:type/te:label/
    te:label-hop/te:te-label/te:technology:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
```

```
  augment /te:te/te:lsps-state/te:lsp/te:lsp-record-route-subobjects/
    te:record-route-subobject/te:type/te:label/te:label-hop/
    te:te-label/te:technology:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
  augment /te:tunnels-rpc/te:input/te:tunnel-info/tepc:path-request:
    +---- src-client-signal?       identityref
    +---- dst-client-signal?       identityref
    +---- fec-type?                identityref
    +---- termination-type?        identityref
    +---- bit-stuffing?            boolean
    +---- wavelength-assignment?   identityref
```

5.2. YANG Model - Code

```
<CODE BEGINS> file "ietf-flexi-grid-media-channel@2018-10-22.yang"

module ietf-flex-grid-media-channel {
  yang-version 1.1;

  namespace "urn:ietf:params:xml:ns:yang:ietf-flex-grid-media-channel";
  prefix "flex-grid-tunnel";

  import ietf-te { prefix "te"; }
  import ietf-layer0-types{ prefix "layer0-types"; }
  import ietf-te-path-computation { prefix "tepc"; }
  import ietf-otn-types { prefix "otn-types"; }

  organization
    "IETF CCAMP Working Group";

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

     WG Chair: Daniele Ceccarelli
               <mailto:daniele.ceccarelli@ericsson.com>

     WG Chair: Fatai Zhang
               <mailto:zhangfatai@huawei.com>

     Editor: Jorge E. Lopez de Vergara <jorge.lopez_vergara@uam.es>
     Editor: Daniel Perdices Burrero <daniel.perdices@naudit.es>
     Editor: Victor Lopez Alvarez <victor.lopezalvarez@telefonica.com>
     Editor: Young Lee <leeyoung@huawei.com>";
```

```
     description
       "This module defines a model for Flex-grid Tunnel Services.";


  revision "2018-10-22" {
    description
      "version 1";
    reference "version 1";
  }

  /* Groupings. */

  grouping flex-grid-tunnel-attributes {
    description "Parameters for flexgrid tunnel.";

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

    leaf dst-client-signal {
      type identityref {
        base otn-types:client-signal;
      }
      description
        "Client signal at the destination endpoint of
         the tunnel.";
    }

    leaf fec-type {
      type identityref {
        base layer0-types:fec-type;
      }
      description
        "FEC type.";
    }

    leaf termination-type {
      type identityref {
        base layer0-types:term-type;
      }
      description
        "Termination type.";
    }
```

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


  grouping flex-grid-path-constraints {
    description
      "Global named path constraints configuration
       grouping for flexi-grid tunnel";

    leaf wavelength-assignment {
      type identityref {
        base layer0-types:wavelength-assignment;
      }
      description "Wavelength Allocation Method";
    }
  }

 /*
  * Data nodes
  */

  augment "/te:te/te:tunnels/te:tunnel" {
    description
      "Augment with additional parameters required for flex-grid
       tunnel.";
    uses flex-grid-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 "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-path-bandwidth;
    }
  }
```

```
  /* Augment bandwdith of tunnel */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:te-bandwidth/te:technology" {
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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 "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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-reverse-primary-path/"
        + "te:te-bandwidth/te:technology" {
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-path-bandwidth;
    }
  }

  /* Augment bandwidht of secondary path */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-secondary-paths/te:p2p-secondary-path/"
        + "te:te-bandwidth/te:technology" {
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
        + "te:route-object-exclude-always/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
        + "te:route-object-include-exclude/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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:forward/te:label-restrictions/"
        + "te:label-restriction" {
    description "flex-grid label.";
    uses layer0-types:flex-grid-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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }

  /* Augment label restrictions for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction" {
    description "flex-grid label.";
    uses layer0-types:flex-grid-label-restriction;
  }

  /* Augment label restrictions start for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }

  /* Augment label restrictions end for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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:forward/te:label-restrictions/"
        + "te:label-restriction" {
    description "flex-grid label.";
    uses layer0-types:flex-grid-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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }
  /* Augment label restrictions for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction" {
    description "flex-grid label.";
    uses layer0-types:flex-grid-label-restriction;
  }
  /* Augment label restrictions start for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }
```

```
  /* Augment label restrictions end for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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 "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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 "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
        + "te:route-object-exclude-always/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
        + "te:route-object-include-exclude/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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:forward/te:label-restrictions/"
        + "te:label-restriction" {
    description "flex-grid label.";
    uses layer0-types:flex-grid-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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }
  /* Augment label restrictions for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction" {
    description "flex-grid label.";
    uses layer0-types:flex-grid-label-restriction;
  }
```

```
  /* Augment label restrictions start for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }
  /* Augment label restrictions end for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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:forward/te:label-restrictions/"
        + "te:label-restriction" {
    description "flex-grid label.";
    uses layer0-types:flex-grid-label-restriction;
  }
  /* Augment label restrictions start for the forwarding direction of
     path-out-segment of primary path */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-primary-paths/te:p2p-primary-path/"
        + "te:path-out-segment/te:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }
```

```
  /* Augment label restrictions end for the forwarding direction of
     path-out-segment of primary path */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-primary-paths/te:p2p-primary-path/"
        + "te:path-out-segment/te:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }
  /* Augment label restrictions for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction" {
    description "flex-grid label.";
    uses layer0-types:flex-grid-label-restriction;
  }
  /* Augment label restrictions start for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }
  /* Augment label restrictions end for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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:state/te:path-properties/"
        + "te:path-route-objects/te:path-computed-route-object/"
        + "te:state/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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:state/te:lsps/te:lsp/te:lsp-record-route-subobjects/"
        + "te:record-route-subobject/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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:state/te:lsps/te:lsp/te:path-properties/"
        + "te:path-route-objects/te:path-computed-route-object/"
        + "te:state/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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-reverse-primary-path/"
        + "te:optimizations/te:algorithm/te:metric/"
        + "te:optimization-metric/te:explicit-route-exclude-objects/"
        + "te:route-object-exclude-object/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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-reverse-primary-path/"
        + "te:optimizations/te:algorithm/te:metric/"
        + "te:optimization-metric/te:explicit-route-include-objects/"
        + "te:route-object-include-object/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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-reverse-primary-path/"
        + "te:explicit-route-objects/"
        + "te:route-object-exclude-always/"
        + "te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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-reverse-primary-path/"
        + "te:explicit-route-objects/"
        + "te:route-object-include-exclude/"
        + "te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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-reverse-primary-path/"
        + "te:path-in-segment/te:forward/te:label-restrictions/"
        + "te:label-restriction" {
    description "flex-grid label.";
    uses layer0-types:flex-grid-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-reverse-primary-path/"
        + "te:path-in-segment/te:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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-reverse-primary-path/"
        + "te:path-in-segment/te:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }
  /* Augment label restrictions for the reverse 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-reverse-primary-path/"
        + "te:path-in-segment/te:reverse/te:label-restrictions/"
        + "te:label-restriction" {
    description "flex-grid label.";
    uses layer0-types:flex-grid-label-restriction;
  }
  /* Augment label restrictions start for the reverse 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-reverse-primary-path/"
        + "te:path-in-segment/te:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }
```

```
 /* Augment label restrictions end for the reverse 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-reverse-primary-path/"
        + "te:path-in-segment/te:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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-reverse-primary-path/"
        + "te:path-out-segment/te:forward/te:label-restrictions/"
        + "te:label-restriction" {
    description "flex-grid label.";
    uses layer0-types:flex-grid-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-reverse-primary-path/"
        + "te:path-out-segment/te:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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-reverse-primary-path/"
        + "te:path-out-segment/te:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }
```

```
  /* Augment label restrictions for the reverse 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-reverse-primary-path/"
        + "te:path-out-segment/te:reverse/te:label-restrictions/"
        + "te:label-restriction" {
    description "flex-grid label.";
    uses layer0-types:flex-grid-label-restriction;
  }
  /* Augment label restrictions start for the reverse 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-reverse-primary-path/"
        + "te:path-out-segment/te:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }
  /* Augment label restrictions end for the reverse 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-reverse-primary-path/"
        + "te:path-out-segment/te:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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-reverse-primary-path/"
        + "te:state/te:path-properties/"
        + "te:path-route-objects/te:path-computed-route-object/"
        + "te:state/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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-reverse-primary-path/"
        + "te:state/te:lsps/te:lsp/te:lsp-record-route-subobjects/"
        + "te:record-route-subobject/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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-reverse-primary-path/"
        + "te:state/te:lsps/te:lsp/te:path-properties/"
        + "te:path-route-objects/te:path-computed-route-object/"
        + "te:state/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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 "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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 "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
        + "te:route-object-exclude-always/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
        + "te:route-object-include-exclude/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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:forward/te:label-restrictions/"
        + "te:label-restriction" {
    description "flex-grid label.";
    uses layer0-types:flex-grid-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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }
  /* Augment label restrictions for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction" {
    description "flex-grid label.";
    uses layer0-types:flex-grid-label-restriction;
  }
  /* Augment label restrictions start for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }
  /* Augment label restrictions end for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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:forward/te:label-restrictions/"
        + "te:label-restriction" {
    description "flex-grid label.";
    uses layer0-types:flex-grid-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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }
  /* Augment label restrictions for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction" {
    description "flex-grid label.";
    uses layer0-types:flex-grid-label-restriction;
  }
```

```
  /* Augment label restrictions start for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }
  /* Augment label restrictions end for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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:state/te:path-properties/te:path-route-objects/"
        + "te:path-computed-route-object/te:state/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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:state/te:lsps/te:lsp/te:lsp-record-route-subobjects/"
        + "te:record-route-subobject/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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:state/te:lsps/te:lsp/te:path-properties/"
        + "te:path-route-objects/"
        + "te:path-computed-route-object/te:state/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-path-label;
    }
  }
  /* Augment label hop of record-route of LSP */
  augment "/te:te/te:lsps-state/"
        + "te:lsp/te:lsp-record-route-subobjects/"
        + "te:record-route-subobject/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-path-label;
    }
  }
  augment "/te:tunnels-rpc/te:input/te:tunnel-info/"
        + "tepc:path-request" {
    description
       "Augment with additional constraints flex-grid
        tunnel.";
    uses flex-grid-tunnel-attributes;
    uses flex-grid-path-constraints;
  }
}

<CODE ENDS>
```

5.3. License

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6. Security Considerations

The transport protocol used for sending the managed information MUST support authentication and SHOULD support encryption.

The defined data-model by itself does not create any security implications.

7. IANA Considerations

The namespace used in the defined models is currently based on the METRO-HAUL project URI. Future versions of this document could register a URI in the IETF XML registry [RFC3688], as well as in the YANG Module Names registry [RFC6020].

8. References

8.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC6020] Bjorklund, M., Ed., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", RFC 6020, October 2010.

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8.2. Informative References

[RFC7698] Gonzalez de Dios, O., Casellas, R., Eds. "Framework and Requirements for GMPLS-Based Control of Flexi-Grid Dense Wavelength Division Multiplexing (DWDM) Networks", RFC7698, November 2015.

[I-D.draft-ietf-ccamp-flexigrid-yang] Lopez de Vergara, J., Perdices, D., Lopez, V., Gonzalez de Dios, O., King, D., Lee, Y., Galimberti, G., "YANG data model for Flexi-Grid Optical Networks", Internet Draft, draft-ietf-ccamp-flexigrid-yang-02, 2018.

[I-D.draft-ietf-teas-yang-te] Saad, T., Gandhi, R., Liu, X., Beeram, V., Shah, H., Bryskin, I., Chen, X., Jones, R., and B. Wen, "A YANG Data Model for Traffic Engineering Tunnels and Interfaces", draft-ietf-teas-yang-te-17, 2018.

9. Contributors

The model presented in this paper was contributed to by more people than can be listed on the author list. Additional contributors include:

- o Zafar Ali, Cisco Systems
- o Daniel Michaud Vallinoto, Universidad Autonoma de Madrid

10. Acknowledgments

The work presented in this Internet-Draft has been partially funded by the European Commission under the project H2020 METRO-HAUL (Metro High bandwidth, 5G Application-aware optical network, with edge storage, compUte and low Latency), Grant Agreement number: 761727, and by the Spanish Ministry of Economy and Competitiveness under the project TRAFICA, MINECO/FEDER TEC2015-69417-C2-1-R.

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YANG data model for Flexi-Grid Optical Networks
draft-ietf-ccamp-flexigrid-yang-02.txt

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Abstract

This document defines a YANG model for managing flexi-grid optical Networks. The model described in this document defines a flexi-grid traffic engineering database. A complementary module is referenced to detail the flexi-grid media channels.

This module is grounded on other defined YANG abstract models.

Table of Contents

1. Introduction

Internet-based traffic is dramatically increasing every year. Moreover, such traffic is also becoming more dynamic. Thus, transport networks need to evolve from current DWDM systems towards elastic optical networks, based on flexi-grid transmission and switching technologies [RFC7698]. This technology aims at increasing both transport network scalability and flexibility, allowing the optimization of bandwidth usage.

This document presents a YANG model for flexi-grid objects in the dynamic optical network, including the nodes, transponders and links between them, as well as how such links interconnect nodes and transponders.

The YANG model for flexi-grid networks allows the representation of the flexi-grid optical layer of a network, combined with the underlying physical layer.

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

2. Conventions used in this document

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].

In this document, these words will appear with that interpretation only when in ALL CAPS. Lower case uses of these words are not to be interpreted as carrying RFC-2119 significance.

In this document, the characters ">>" preceding an indented line(s) indicates a compliance requirement statement using the key words listed above. This convention aids reviewers in quickly identifying or finding the explicit compliance requirements of this RFC.

3. Flexi-grid network topology model overview

YANG is a data modeling language used to model configuration data manipulated by the NETCONF protocol. Several YANG models have already been specified for network configurations. For instance, the work in [RFC8345] has proposed a generic YANG model for network/service topologies and inventories. The work in [I-D.draft-ietf-teas-yang-te-topo] presents a data model to represent, retrieve and manipulate Traffic Engineering (TE) Topologies. These models serve as base models that other technology specific models can augment. A YANG model has also been proposed in [I-D.draft-dharini-ccamp-dwdm-if-yang] to manage single channel optical interface parameters of DWDM applications, and in

[I-D.draft-ietf-ccamp-wson-yang] another model has been specified for the routing and wavelength assignment TE topology in wavelength switched optical networks (WSONs). None of them are specific for flexi-grid technology.

Then, as stated before, we propose a model to describe a flexi-grid topology that is split in two YANG sub-modules:

o Flexi-grid-TED: In order to be compatible with existing proposals, we augment the definitions contained in [RFC8345] and [I-D.draft-ietf-teas-yang-te-topo], by defining the different elements we can find in a flexi-grid network: a node, a transponder and a link. For that, each of those elements is defined as a container that includes a group of attributes. References to the elements are provided to be later used in the definition of a media channel. It also includes the data types for the type of modulation, the flexi-grid technology, the FEC, etc.

o Media-channel: This module defines the whole path from a source transponder to the destination through a number of intermediate nodes and links. For this, it takes the information defined before in the flexi-grid TED. This module is described in [I-D.draft-ietf-ccamp-flexigrid-media-channel-yang]

The following section provides a detailed view of the first module.

4. Main building blocks of the Flexi-grid TED

This section details the defined YANG module. It is listed below in section 6.

The description of the three main components, flexi-grid-node, flexi-grid-transponder and flexi-grid-link is provided below. flexi-grid-sliceable-transponders are also defined.

<flexi-grid-node> ::= <config> <state>

<flexi-grid-node>: This element designates a node in the network.

<config> ::= <flexi-grid-node-attributes-config>

<config>: Contains the configuration of a node.
<flexi-grid-node-attributes-config> ::= <list-interface>
<connectivity_matrix>

<flexi-grid-node-attributes-config>: Contains all the attributes related to the node configuration, such as its interfaces or its management addresses.

```
<list-interface> ::= <name> <port-number>
<input-port> <output-port> <description>
<interface-type>
[<numbered-interface> / <unnumbered-interface>]

    <list-interface>: The list containing all the
    information of the interfaces.

    <name>: Determines the interface name.

    <port-number>: Port number of the interface.

    <input-port>: Boolean value that defines
    whether the interface is input or not.

    <output-port>: Boolean value that defines
    whether the interface is output or not.

    <description>: Description of the usage of
    the interface.

    <interface-type>: Determines if the interface
    is numbered or unnumbered.

    <numbered-interface> ::= <n-i-ip-address>
        <numbered-interface>: An interface with
        its own IP address.

        <n-i-ip-address>: Only available if
        <interface-type> is "numbered-interface".
        Determines the IP address of the interface.

    <unnumbered-interface> ::= <u-i-ip-address>
    <label>
        <unnumbered-interface>: A interface that
        needs a label to be unique.

        <u-i-ip-address>: Only available if
        <interface-type> is "numbered-interface".
        Determines the node IP address, which with
        the label defines the interface.

        <label>: Label that determines the
        interface, joint with the node IP address.

<connectivity-matrix> ::= <connections>

    <connectivity-matrix>: Determines whether a
    connection port in/port out exists.

    <connections> ::= <input-port-id>
    <output-port-id>
```

<flexi-grid-transponder> ::= <transponder-type> <config> <state>

<flexi-grid-transponder>: This item designates a transponder of a node.

<config> ::= <flexi-grid-transponder-attributes-config>

<config>: Contains the configuration of a transponder.

<flexi-grid-transponder-attributes-config> ::= <available-operational-mode> <operational-mode>

<flexi-grid-transponder-attributes>: Contains all the attributes related to the transponder.

<available-operational-mode>: It provides a list of the operational modes available at this transponder.

<operational-mode>: Determines the type of operational mode in use.

<state> ::= <flexi-grid-transponder-attributes-config> <flexi-grid-transponder-attributes-state>

<state>: Contains the state of a transponder.

<flexi-grid-transponder-attributes-config>: See above.

<flexi-grid-transponder-attributes-state>: Contains the state of a transponder.

<link> ::= <config> <state>

<link>: This element describes all the information of a link.

<config> ::= <flexi-grid-link-attributes-config>

<config>: Contains the configuration of a link.

```
         <flexi-grid-link-attributes-config> ::= <technology-type>
         <available-label-flexi-grid> <N-max> <base-frequency>
         <nominal-central-frequency-granularity>
         <slot-width-granularity>

            <flexi-grid-link-attributes>: Contains all the
            attributes related to the link, such as its unique id,
            its N value, its latency, etc.

            <link-id>: Unique id of the link.

            <available-label-flexi-grid>: Array of bits that
            determines, with each bit, the availability of each
            interface for flexi-grid technology.

            <N-max>: The max value of N in this link, being N
            the number of slots.

            <base-frequency>: The default central frequency
            used in the link.

            <nominal-central-frequency-granularity>: It is the
            spacing between allowed nominal central frequencies
            and it is set to 6.25 GHz (note: sometimes referred
            to as 0.00625 THz).

            <slot-width-granularity>: 12.5 GHz, as defined
            in G.694.1.
    <state> ::= <flexi-grid-link-attributes-config>
    <flexi-grid-link-attributes-state>

        <state>: Contains the state of a link.

        <flexi-grid-link-attributes-config>: See above.

        <flexi-grid-link-attributes-state>: Contains all the
        the information related to the state of a link.
```

4.1. Formal Syntax

The previous syntax specification uses the augmented Backus-Naur Form (BNF) as described in [RFC5234].

5. Example of use

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

```
                               Media channel
            <==================================================>
                                  Path x
            <-------------------------------------------------->

                     +----------+          +----------+
              Link 1 |Flexi-grid|  Link 2  |Flexi-grid| Link 3
                .--->|   node   |<-------->|   node   |<---.
                |    |    B     |          |    C     |    |
                |    +----------+          +----------+    |
                v                                          v
             /-----------\                           /-----------\
            / Flexi-grid  \                         / Flexi-grid  \
            | transponder |                         | transponder |
            \      A      /                         \      E      /
             \-----------/                           \-----------/
                  ^                                     ^
                  |             +----------+            |
                  |    Link 4   |Flexi-grid|   Link 5   |
                  '------------>|   node   |<-----------'
                                |    D     |
                                +----------+
            <-------------------------------------------------->
                                  Path y
```

Figure 1. Topology example.

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

1. We define the transponders A and E, including their FEC type, if enabled, and modulation type. We also provide node identifiers and addresses for the transponders, as well as interfaces included in the transponders. Sliceable transponders can also be defined if needed.

2. We do the same for the nodes B, C and D, providing their identifiers, addresses and interfaces, as well as the internal connectivity matrix between interfaces.

3. Then, we also define the links 1 to 5 that interconnect nodes and transponders, indicating which flexi-grid labels are available. Other information, such as the slot frequency and granularity are also provided.

Next, we can configure the media channel from the information we have stored in the flexi-grid TED, by querying which elements are available, and planning the resources that have to be provided on each situation. Note that every element in the flexi-grid TED has a reference, and this is the way in which they are called in the media channel. We refer to [I-D.draft-ietf-ccamp-flexigrid-media-channel-yang] to complete this example.

6. Flexi-grid TED YANG Model

6.1. Yang Model - Tree Structure

```
module: ietf-flex-grid-topology
  augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
    +--rw flex-grid-topology!
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes:
  augment /nw:networks/nw:network/nw:node/nt:termination-point/tet:te:
    +--rw supported-payload-types* [index]
    |  +--rw index           uint16
    |  +--rw payload-type?   string
    +--rw client-facing?            boolean
  augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes:
    +--rw flex-grid-node
       +--rw node-type?   identityref
  augment /nw:networks/nw:network/nw:node/tet:te/
     tet:tunnel-termination-point:
    +--rw supported-operational-modes*    layer0-types:operational-mode
    +--rw configured-operational-modes?   layer0-types:operational-mode
    +--rw supported-fec-types*            identityref
    +--rw supported-termination-types*    identityref
    +--rw supports-bit-stuffing?          boolean
    +--rw is-tunable?                     boolean
    +--rw max-subcarrier-channel-num?     uint8
    +--rw supports-flex-grid?             boolean
  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:
    +--:(flex-grid)
       +--rw bandwidth-type?   identityref
  augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes/
    tet:connectivity-matrices/tet:path-constraints/tet:te-bandwidth/
    tet:technology:
    +--:(flex-grid)
       +--rw supported-bandwidth-list*   identityref
```

```
  augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes/
    tet:connectivity-matrices/tet:connectivity-matrix/
    tet:path-constraints/tet:te-bandwidth/tet:technology:
    +--:(flex-grid)
       +--rw supported-bandwidth-list*   identityref
  augment /nw:networks/nw:network/nw:node/tet:te/
    tet:information-source-entry/tet:connectivity-matrices/
    tet:path-constraints/tet:te-bandwidth/tet:technology:
    +--:(flex-grid)
       +--ro supported-bandwidth-list*   identityref
  augment /nw:networks/nw:network/nw:node/tet:te/
    tet:information-source-entry/tet:connectivity-matrices/
    tet:connectivity-matrix/tet:path-constraints/
    tet:te-bandwidth/tet:technology:
    +--:(flex-grid)
       +--ro supported-bandwidth-list*   identityref
  augment /nw:networks/nw:network/nw:node/tet:te/
    tet:tunnel-termination-point/tet:client-layer-adaptation/
    tet:switching-capability/tet:te-bandwidth/tet:technology:
    +--:(flex-grid)
       +--rw supported-bandwidth-list*   identityref
  augment /nw:networks/nw:network/nw:node/tet:te/
    tet:tunnel-termination-point/tet:local-link-connectivities/
    tet:path-constraints/tet:te-bandwidth/tet:technology:
    +--:(flex-grid)
       +--rw supported-bandwidth-list*   identityref
  augment /nw:networks/nw:network/nw:node/tet:te/
    tet:tunnel-termination-point/tet:local-link-connectivities/
    tet:local-link-connectivity/tet:path-constraints/tet:te-bandwidth/
    tet:technology:
    +--:(flex-grid)
       +--rw supported-bandwidth-list*   identityref
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/
    tet:interface-switching-capability/tet:max-lsp-bandwidth/
    tet:te-bandwidth/tet:technology:
    +--:(flex-grid)
       +--rw bandwidth-type?   identityref
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/
    tet:max-link-bandwidth/tet:te-bandwidth/tet:technology:
    +--:(flex-grid)
       +--rw supported-bandwidth-list*   identityref
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/
    tet:max-resv-link-bandwidth/tet:te-bandwidth/tet:technology:
    +--:(flex-grid)
       +--rw supported-bandwidth-list*   identityref
```

```
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/
    tet:unreserved-bandwidth/tet:te-bandwidth/tet:technology:
    +--:(flex-grid)
       +--rw supported-bandwidth-list*   identityref
  augment /nw:networks/nw:network/nt:link/tet:te/
    tet:information-source-entry/tet:interface-switching-capability/
    tet:max-lsp-bandwidth/tet:te-bandwidth/tet:technology:
    +--:(flex-grid)
       +--ro bandwidth-type?   identityref
  augment /nw:networks/nw:network/nt:link/tet:te/
    ttet:information-source-entry/et:max-link-bandwidth/
    tet:te-bandwidth/tet:technology:
    +--:(flex-grid)
       +--ro supported-bandwidth-list*   identityref
  augment /nw:networks/nw:network/nt:link/tet:te/
    tet:information-source-entry/tet:max-resv-link-bandwidth/
    tet:te-bandwidth/tet:technology:
    +--:(flex-grid)
       +--ro supported-bandwidth-list*   identityref
  augment /nw:networks/nw:network/nt:link/tet:te/
    tet:information-source-entry/tet:unreserved-bandwidth/
    tet:te-bandwidth/tet:technology:
    +--:(flex-grid)
       +--ro supported-bandwidth-list*   identityref
  augment /nw:networks/tet:te/tet:templates/tet:link-template/
    tet:te-link-attributes/tet:interface-switching-capability/
    tet:max-lsp-bandwidth/tet:te-bandwidth/tet:technology:
    +--:(flex-grid)
       +--rw bandwidth-type?   identityref
  augment /nw:networks/tet:te/tet:templates/tet:link-template/
    tet:te-link-attributes/tet:max-link-bandwidth/tet:te-bandwidth/
    tet:technology:
    +--:(flex-grid)
       +--rw supported-bandwidth-list*   identityref
  augment /nw:networks/tet:te/tet:templates/tet:link-template/
    tet:te-link-attributes/tet:max-resv-link-bandwidth/tet:te-bandwidth/
    tet:technology:
    +--:(flex-grid)
       +--rw supported-bandwidth-list*   identityref
  augment /nw:networks/tet:te/tet:templates/tet:link-template/
    tet:te-link-attributes/tet:unreserved-bandwidth/tet:te-bandwidth/
    tet:technology:
    +--:(flex-grid)
       +--rw supported-bandwidth-list*   identityref
```

```
  augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes/
    tet:connectivity-matrices/tet:label-restrictions/
    tet:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
  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:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  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:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
```

```
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  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:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
  augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes/
    tet:connectivity-matrices/tet:connectivity-matrix/tet:from/
    tet:label-restrictions/tet:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
```

```
  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:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  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:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes/
    tet:connectivity-matrices/tet:connectivity-matrix/tet:to/
    tet:label-restrictions/tet:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
  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:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  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:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
```

```
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
```

```
  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:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
  augment /nw:networks/nw:network/nw:node/tet:te/
    tet:information-source-entry/tet:connectivity-matrices/
    tet:label-restrictions/tet:label-restriction:
    +--ro grid-type?   identityref
    +--ro priority?    uint8
    +--ro flex-grid
       +--ro nominal-central-frequency-granularity?   frequency-ghz
       +--ro slot-width-granularity?                  frequency-ghz
  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:
    +--:(flex-grid)
       +--ro central-frequency?   frequency-thz
  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:
    +--:(flex-grid)
       +--ro central-frequency?   frequency-thz
  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:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
```

```
  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:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
  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:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
  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:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
```

```
  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:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
  augment /nw:networks/nw:network/nw:node/tet:te/tet:
    information-source-entry/tet:connectivity-matrices/
    tet:connectivity-matrix/tet:from/tet:label-restrictions/
    tet:label-restriction:
    +--ro grid-type?   identityref
    +--ro priority?    uint8
    +--ro flex-grid
       +--ro nominal-central-frequency-granularity?   frequency-ghz
       +--ro slot-width-granularity?                  frequency-ghz
  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:
    +--:(flex-grid)
       +--ro central-frequency?   frequency-thz
  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:
    +--:(flex-grid)
       +--ro central-frequency?   frequency-thz
  augment /nw:networks/nw:network/nw:node/tet:te/
    tet:information-source-entry/tet:connectivity-matrices/
    tet:connectivity-matrix/tet:to/tet:label-restrictions/
    tet:label-restriction:
    +--ro grid-type?   identityref
    +--ro priority?    uint8
    +--ro flex-grid
       +--ro nominal-central-frequency-granularity?   frequency-ghz
       +--ro slot-width-granularity?                  frequency-ghz
```

```
  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:
    +--:(flex-grid)
       +--ro central-frequency?   frequency-thz
  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:
    +--:(flex-grid)
       +--ro central-frequency?   frequency-thz
  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:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
  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:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
```

```
  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:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
  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:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
  augment /nw:networks/nw:network/nw:node/tet:te/
    tet:information-source-entry/tet:connectivity-matrices/es/
    tet:connectivity-matrix/tet:path-propertitet:path-route-objects/
    tet:path-route-object/tet:type/tet:label/tet:label-hop/tet:te-label/
    tet:technology:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
```

```
  augment /nw:networks/nw:network/nw:node/tet:te/
    tet:tunnel-termination-point/tet:local-link-connectivities/
    tet:label-restrictions/tet:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
  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:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  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:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
```

```
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  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:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
  augment /nw:networks/nw:network/nw:node/tet:te/
    tet:tunnel-termination-point/tet:local-link-connectivities/
    tet:local-link-connectivity/tet:label-restrictions/
    tet:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
```

```
  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:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  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:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
```

```
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz

  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  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:
    +--:(flex-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro central-frequency?     frequency-thz
          |  +--ro slot-width?            frequency-ghz
          +--:(super)
             +--ro subcarrier-channels* [central-frequency]
                +--ro central-frequency     frequency-thz
                +--ro slot-width?           frequency-ghz
```

```
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz

  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/
    tet:label-restrictions/tet:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
  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:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  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:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  augment /nw:networks/nw:network/nt:link/tet:te/
    tet:information-source-entry/tet:label-restrictions/
    tet:label-restriction:
    +--ro grid-type?   identityref
    +--ro priority?    uint8
    +--ro flex-grid
       +--ro nominal-central-frequency-granularity?   frequency-ghz
       +--ro slot-width-granularity?                  frequency-ghz
```

```
  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:
    +--:(flex-grid)
       +--ro central-frequency?   frequency-thz
  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:
    +--:(flex-grid)
       +--ro central-frequency?   frequency-thz
  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:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  augment /nw:networks/tet:te/tet:templates/tet:link-template/
    tet:te-link-attributes/tet:underlay/tet:backup-path/
    ttet:path-element/et:type/tet:label/tet:label-hop/tet:te-label/
    tet:technology:
    +--:(flex-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw central-frequency?     frequency-thz
          |  +--rw slot-width?            frequency-ghz
          +--:(super)
             +--rw subcarrier-channels* [central-frequency]
                +--rw central-frequency     frequency-thz
                +--rw slot-width?           frequency-ghz
  augment /nw:networks/tet:te/tet:templates/tet:link-template/
    tet:te-link-attributes/tet:label-restrictions/tet:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
    +--rw flex-grid
       +--rw nominal-central-frequency-granularity?   frequency-ghz
       +--rw slot-width-granularity?                  frequency-ghz
  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:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
  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:
    +--:(flex-grid)
       +--rw central-frequency?   frequency-thz
```

A.2. YANG Model - Code

```
   <CODE BEGINS> file "ietf-flexi-grid-ted@2018-10-22.yang"
module ietf-flex-grid-topology {

  yang-version 1.1;

  namespace "urn:ietf:params:xml:ns:yang:ietf-flex-grid-topology";

  prefix "flex-grid";

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

     WG Chair: Daniele Ceccarelli
               <mailto:daniele.ceccarelli@ericsson.com>

     WG Chair: Fatai Zhang
               <mailto:zhangfatai@huawei.com>

     Editor: Jorge E. Lopez de Vergara  <jorge.lopez_vergara@uam.es>
     Editor: Daniel Perdices Burrero <daniel.perdices@naudit.es>
     Editor: Victor Lopez Alvarez <victor.lopezalvarez@telefonica.com>
     Editor: Young Lee <leeyoung@huawei.com>
     Editor: Aihua Guo <aihuaguo@huawei.com>";
```

```
     description
       "This module defines a model for Flex-grid topology

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     as authors of the code.  All rights reserved.

     Redistribution and use in source and binary forms, with
     or without modification, is permitted pursuant to, and
     subject to the license terms contained in, the Simplified BSD
     License set forth in Section 4.c of the IETF Trust's Legal
     Provisions Relating to IETF Documents
     (http://trustee.ietf.org/license-info).";

  revision 2018-10-22 {
    description
      "version 1.";

    reference
      "RFC XXX: A Yang Data Model for Flex-grid Optical Networks ";
  }

  /*
   * Groupings
   */
  grouping flex-grid-node-attributes {
    description "Flex-grid node attributes.";

    container flex-grid-node {
      description "Flex-grid node attrtibutes.";
      leaf node-type {
        type identityref {
          base layer0-types:layer0-node-type;
        }
        description "Flex-grid node type.";
      }
    }
  }

  grouping flex-grid-link-attributes {
    description
     "Future flex-grid link attributes extensions";
  }
```

```
  grouping flex-grid-tp-attributes {
    description "flex-grid-tp-attributes";

    list supported-payload-types {
      key "index";
      description
        "Supported payload types of a TP. The payload type is defined
         as the generalized PIDs in GMPLS.";
      leaf index {
        type uint16;
        description "payload type index";
      }
      leaf payload-type {
        type string;
        description "the payload type supported by this client tp";
        reference
          "http://www.iana.org/assignments/gmpls-sig-parameters
           /gmpls-sig-parameters.xhtml";
      }
    }
    leaf client-facing {
      type boolean;
      default 'false';
      description
        "Indicating if it is a client-facing TP.";
    }
  }

  grouping flex-grid-ttp-attributes {
    description
     "Flex-grid tunnel termination point (e.g.tranponder)
       attributes";
    leaf-list supported-operational-modes {
      type layer0-types:operational-mode;
      description
        "List of all supported vendor-specific
         mode identifiers";
    }
```

```
    leaf configured-operational-modes {
      type layer0-types:operational-mode;
      description
       "Vendor-specific mode identifier configured
         on the TTP.";
    }

    leaf-list supported-fec-types {
      type identityref {
        base layer0-types:fec-type;
      }
       description
        "List of all supported FEC types by this TTP.";
    }

    leaf-list supported-termination-types {
      type identityref {
        base layer0-types:term-type;
      }
        description
         "List of all supported termination types by this TTP.";
    }

    leaf supports-bit-stuffing {
       type boolean;
       description
         "Indicate whether bit stuffing is supported by this TTP.";
    }

    leaf is-tunable {
      type boolean;
      description
        "Indicates if the TTP, or transponder, is tunable. Tunable
         transponders are assumed to be fully tunable to any of the
         96 channels within DWDM C-band.";
    }

    leaf max-subcarrier-channel-num {
      type uint8 {
     range "1..max";
      }
      default 1;
      description
     "Indicate the maximum number of subcarrier channels for
          super-channel transponders. When the value equals 1 it
          represents regular single-channel transponder.";
    }
```

```
    leaf supports-flex-grid {
      type boolean;
      description
        "Indicates if the TTP, or transponder, supports flex grid.";
    }
  }

  /*
   * Data nodes
   */

  augment "/nw:networks/nw:network/nw:network-types"
   + "/tet:te-topology" {
      description "flex-grid-topology augmented";
      container flex-grid-topology {
        presence "indicates a topology of Flex Grid";
        description
          "Container to identify Flex-grid 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/flex-grid:flex-grid-topology" {
       description "This augment is only valid for flex-grid.";
    }
    description "Flex-grid Link augmentation.";
    uses flex-grid-link-attributes;
  }

  augment "/nw:networks/nw:network/nw:node/nt:termination-point/"
        + "tet:te" {
    when "/nw:networks/nw:network/nw:network-types"
        +"/tet:te-topology/flex-grid:flex-grid-topology" {
       description "This augment is only valid for flex-grid.";
    }
    description "Flex-grid TP attributes.";
    uses flex-grid-tp-attributes;
  }

  augment "/nw:networks/nw:network/nw:node/tet:te"
        + "/tet:te-node-attributes" {
    when "/nw:networks/nw:network/nw:network-types"
       +"/tet:te-topology/flex-grid:flex-grid-topology" {
       description "This augment is only valid for flex-grid.";
    }
    description "Flex-grid Node augmentation.";
    uses flex-grid-node-attributes;
  }
```

```
  augment "/nw:networks/nw:network/nw:node/tet:te"
        + "/tet:tunnel-termination-point" {
    when "/nw:networks/nw:network/nw:network-types"
       +"/tet:te-topology/flex-grid:flex-grid-topology" {
      description "This augment is only valid for flex-grid.";
    }
    description "Flex-grid tunnel termination point augmentation.";
    uses flex-grid-ttp-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE bandwidth";
    }
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE bandwidth";
    }
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE bandwidth";
    }
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE bandwidth";
    }
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-link-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE bandwidth";
    }
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE bandwidth";
    }
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE bandwidth";
    }
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE bandwidth";
    }
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "flex-grid TE bandwidth.";
    }
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "flex-grid TE bandwidth.";
    }
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "flex-grid TE bandwidth.";
    }
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "flex-grid TE bandwidth.";
    }
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "flex-grid TE bandwidth.";
    }
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "flex-grid TE bandwidth.";
    }
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "flex-grid TE bandwidth.";
    }
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "flex-grid TE bandwidth.";
    }
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "flex-grid TE bandwidth.";
    }
*/
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
        + "flex-grid:flex-grid-topology" {
      description "flex-grid TE bandwidth.";
    }
*/
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
        + "flex-grid:flex-grid-topology" {
      description "flex-grid TE bandwidth.";
    }
*/
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
        + "flex-grid:flex-grid-topology" {
      description "flex-grid TE bandwidth.";
    }
*/
```

```
    description "flex-grid bandwidth.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }

  /* 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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }

  /* 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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }

  /* 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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
        + "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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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" {
    when "../../../../../../nw:network-types/tet:te-topology/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    uses layer0-types:flex-grid-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/"
        + "tet:label-start/tet:te-label/tet:technology" {
    when "../../../../../../../../../"
       + "nw:network-types/tet:te-topology/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
        + "tet:label-end/tet:te-label/tet:technology" {
    when "../../../../../../../../"
       + "nw:network-types/tet:te-topology/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }

  /* 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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }

  /* 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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }

  /* 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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-path-label;
    }
  }

  /* Augment label hop of underlay backup 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:backup-path/tet:path-element/tet:type/"
        + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
    when "../../../../../../../../../../../"
       + "nw:network-types/tet:te-topology/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-path-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-path-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }

  /* 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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }

  /* 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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }

  /* 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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }

  /* 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/"
       + "flex-grid:flex-grid-topology" {
          description "Augment flex-grid TE label";
    }
*/
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
       + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
*/

    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
        + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
*/
    description "flex-grid label.";
    uses layer0-types:flex-grid-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/"
        + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
*/
    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-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/"
        + "flex-grid:flex-grid-topology" {
      description "Augment flex-grid TE label";
    }
*/

    description "flex-grid label.";
    case flex-grid {
      uses layer0-types:flex-grid-link-label;
    }
  }
}
   <CODE ENDS>
```

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7. Security Considerations

The transport protocol used for sending the managed information MUST support authentication and SHOULD support encryption.

The defined data-model by itself does not create any security implications.

8. IANA Considerations

The namespace used in the defined models is currently based on the METRO-HAUL project URI. Future versions of this document could register a URI in the IETF XML registry [RFC3688], as well as in the YANG Module Names registry [RFC6020].

9. References

9.1. Normative References

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10. Contributors

The model presented in this paper was contributed to by more people than can be listed on the author list. Additional contributors include:

o Zafar Ali, Cisco Systems
o Daniel Michaud Vallinoto, Universidad Autonoma de Madrid

11. Acknowledgments

The work presented in this Internet-Draft has been partially funded by the European Commission under the project H2020 METRO-HAUL (Metro High bandwidth, 5G Application-aware optical network, with edge storage, compUte and low Latency), Grant Agreement number: 761727, and by the Spanish Ministry of Economy and Competitiveness under the project TRAFICA, MINECO/FEDER TEC2015-69417-C2-1-R.

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September 12, 2018

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

draft-ietf-ccamp-l1csm-yang-08

Abstract

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

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Table of Contents

1. Introduction

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

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

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

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

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

The data model presented in Section 3 is in consistent with [MEF-L1CS]. The data model includes configuration and state data according to the new Network Management Datastore Architecture [RFC8342].

1.1. Deployment Scenarios

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

```
                    +------------+
                    |  Customer  |
                    |   Service  |
                    |Orchestrator|
                    +------------+
                          |
          .. .. .. .. .. .|.. .. .. .. .. ..
          :               |                :
          :     +--------------------+     :
          :     |                    |     :
          :     |    +----------+    |     :
          :     |    | Network  |    |     :
          :     |    |   SDN    |    |     :
          :     |    |Controller|    |     :
          :     |    |/NMS/EMS  |    |     :
          :     |    +----------+    |     :
          :     |                    |     :
          :     |                    |     :
+----+    :   +----+    +----+    +----+   :   +----+
| CE |----:---| PE |----| P  |----| PE |---:---| CE |
+----+    :   +----+    +----+    +----+   :   +----+
          :     |                    |     :
          :     |                    |     :
          :     +--------------------+     :
          :     |                    |     :
          :     |<-Provider network->|     :

      Customer                          Customer
      Interface                         Interface
```

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

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

Figure 2 depicts another deployment scenario for internal customer (e.g., higher-layer service management department(s)) interfacing the layer 1 transport network department. With this scenario, a multi-service backbone is characterized such that each service department of a provider (e.g., L2/3 services) that receives the same provider's L1VPN service provides a different kind of higher-layer service. The customer receiving the L1VPN service (i.e., each service department) can offer its own services, whose payloads can be any layer (e.g., ATM, IP, TDM). The layer 1 transport network and each service network belong to the same organization, but may be managed separately. The Service SDN Controller is the control/management entity owned by higher-layer service department (e.g., L2/3 VPN) whereas the Network SDN Controller is the control/management entity responsible for Layer 1 connectivity service. The CE's in Figure 2 are L2/3 devices that interface with L1 PE devices.

```
                            +----------+
                            | Service  |
                            |   SDN    |
                            |Controller|
                            |/EMS/NMS  |
                            | for L2/3 |
                            +----------+
                                 |
                                 |
                                 |
```

```
                           +--------------------+
                           |                    |
                           |    +----------+    |
                           |    | Network  |    |
                           |    |   SDN    |    |
                           |    |Controller|    |
                           |    |/EMS/NMS  |    |
                           |    | for L1VPN|    |
                           |    +----------+    |
                           |                    |
                           |                    |
           +----+        +----+    +----+    +----+      +----+
           | CE |--------| PE |----| P  |----| PE |------| CE |
           +----+        +----+    +----+    +----+      +----+
              |            |                    |           |
              |            |                    |           |
              |            +--------------------+           |
              |            |                    |           |
              |            |<------------------>|           |
              |               Provider Network              |
              |                  For Layer 1                |
              |<------------------------------------------->|
                          Provider Network for L2/3
```

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

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

1.2. Terminology

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

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

- client
- server

o augment

o data model

o data node

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

o configuration data

o state data

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

1.3. Tree diagram

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

1.4. Prefixes in Data Node Names

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

Prefix	YANG module	Reference
l1csm	ietf-l1cms	[RFC XXXX]
l1-st	ietf-l1-service-types	[RFC XXXX]
yang	ietf-yang-types	[RFC6991]

Table 1: Prefixes and corresponding YANG modules

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

2. Definitions

L1VC Layer 1 Virtual Connection

SLS Service Level Specification

UNI User Network Interface

PE Provider Edge

CE Customer Edge

EP End Point

P Protocol

C Coding

O Optical Interface

3. L1SM YANG Model (Tree Structure)

```
module: ietf-l1csm
    +--rw l1-connectivity
       +--rw access
       |  +--rw unis
       |     +--rw uni* [id]
       |        +--rw id                     string
       |        +--rw protocol?              identityref
       |        +--rw coding?                identityref
       |        +--rw optical-interface?     identityref
       +--rw services
          +--rw service* [service-id]
             +--rw service-id            string
             +--rw endpoint-1
             |  +--rw id     string
             |  +--rw uni    -> /l1-connectivity/access/unis/uni/id
             +--rw endpoint-2
             |  +--rw id     string
             |  +--rw uni    -> /l1-connectivity/access/unis/uni/id
             +--rw start-time?           yang:date-and-time
             +--rw time-interval?        int32
             +--rw performance-metric*   identityref
```

4. L1SM YANG Code

The YANG code is as follows:

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

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

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

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

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

  contact

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


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

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

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

  revision "2018-09-12" {
      description "Initial revision.";
```

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


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

      }
      leaf coding {
         type identityref {
           base "l1-st:coding-func";
         }
         description "coding function";
      }

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

     }

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

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

      leaf time-interval {
```

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

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

  }

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

      container endpoint-1 {
        description "One end of UNI id’s - string and id";
        leaf id {
          type string;
          mandatory true;
          description "subscriber end point ID of one end";
        }

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

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

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

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

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

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

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

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

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

```
              uses subscriber-l1vc-endpoint-attributes;
              uses subscriber-l1vc-sls-service-attribute;

          }//end of service list
      } //end of services container
  }//end of l1 connectivity top container
}

   <CODE ENDS>

   <CODE BEGINS> file "ietf-l1-service-types@2018-09-12.yang"

   module ietf-l1-service-types {
     namespace "urn:ietf:params:xml:ns:yang:ietf-l1-service-types";
     prefix "l1-st";

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

       Editor: G. Fioccolla(giuseppe.fioccola@telecomitalia.it)
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       Editor: O. G. de-Dios(oscar.gonzalezdedios@telefonica.com)
       Editor: D. Ceccarelli(daniele.ceccarelli@ericsson.com)";

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

        Copyright (c) 2018 IETF Trust and the persons identified as
        authors of the code.  All rights reserved.
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        Provisions Relating to IETF Documents
        (http://trustee.ietf.org/license-info).

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

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


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

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

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

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

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

  identity ETH-100GbE {
     base "protocol-type";
     description
        "100 Gigabit Ethernet protocol type";
```

```
         reference "MEF63 & G.709";
      }

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

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

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

      identity FC-800 {
         base "protocol-type";
         description
            "Fiber Channel - 800 protocol type";
         reference "MEF63 & G.709";
      }

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

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

      identity FC-3200 {
         base "protocol-type";
```

```
         description
            "Fiber Channel - 3200 protocol type";
         reference "MEF63 & G.709";
      }

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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


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

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

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

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

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

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

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

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

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

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

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

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

      identity LR4-PMD-clause-88 {
         base "optical-interface-func";
         description
            "LR4-PMD-clause-88 Optical Interface function for
            100GBASE-R PCS-82";
         reference "MEF63 & IEEE802.3";
      }

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

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


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

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

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

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

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

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


   }

   <CODE ENDS>
```

5. JSON Example

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


```
{
 "l1-connectivity": {
   "access": {
     "unis": {
       "uni": [
```

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


6. Security Considerations

The configuration, state, and action data defined in this document are designed to be accessed via a management protocol with a secure transport layer, such as NETCONF [RFC6241] or RESTCONF [RFC8040]. The lowest NETCONF layer is the secure transport layer, and the mandatory-to-implement secure transport is Secure Shell (SSH) [RFC6242]. The lowest RESTCONF layer is HTTPS, and the mandatory-to-implement secure transport is TLS [RFC8446].

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

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

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

unis:
- id

Service:
- service-id
- endpoint-1
- endpoint-2
- start-time
- time-interval
- performance-metric

7. IANA Considerations

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

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

--------------------------------------------------------------------
```

```
URI: urn:ietf:params:xml:ns:yang:ietf-l1-service-types
Registrant Contact: The IESG.
XML: N/A, the requested URI is an XML namespace.
--------------------------------------------------------------------
```

This document registers the following YANG modules in the YANG Module

Names registry [RFC6020]:

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

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

8. Acknowledgments

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

9. References

9.1. Normative References

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[RFC8446] Dierks, T. and E. Rescorla, "The Transport Layer Security (TLS) Protocol Version 1.3", RFC 8446, August 2018.

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[RFC8341] Bierman, A. and M. Bjorklund, "Network Configuration Access Control Model", RFC 8341, March 2018.

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[IEEE802.3] IEEE Std 802.3, IEEE Standard for Ethernet, 2015.

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Expires: April 2019 October 22, 2018

Transport Northbound Interface Applicability Statement
draft-ietf-ccamp-transport-nbi-app-statement-03

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Abstract

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

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

This document analyses the applicability of the YANG models being defined by IETF (TEAS and CCAMP WGs in particular) to support OTN single and multi-domain scenarios.

Table of Contents

1. Introduction

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

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

This document analyses the applicability of the YANG models being defined by IETF (TEAS and CCAMP WGs in particular) to support OTN single and multi-domain scenarios.

1.1. The scope of this document

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

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

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

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

The relationship between the current IETF YANG models and the type of ACTN interfaces can be found in [ACTN-YANG]. Therefore, it considers the TE Topology YANG model defined in [TE-TOPO], with the OTN Topology augmentation defined in [OTN-TOPO] and the TE Tunnel YANG model defined in [TE-TUNNEL], with the OTN Tunnel augmentation defined in [OTN-TUNNEL].

[Editors' note:] Add information about the additional models which are needed for service configuration.

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

1.2. Assumptions

This document is making the following assumptions, still to be validated with TEAS WG:

1. The MDSC can request, at the MPI, a PNC to setup a Transit Tunnel Segment using the TE Tunnel YANG model: in this case, since the endpoints of the E2E Tunnel are outside the domain controlled by that PNC, the MDSC would not specify any source or destination TTP (i.e., it would leave the source, destination, src-tp-id and dst-tp-id attributes empty) for the tunnel and it would use the explicit-route-object/route-object-include-exclude list to specify the ingress and egress links for each path of the Transit Tunnel Segment.

2. Each PNC provides to the MDSC, at the MPI, the list of available timeslots on the inter-domain links using the TE Topology YANG model and OTN Topology augmentation. The TE Topology YANG model in [TE-TOPO] is being updated to report the label set information.

[Editors' note:] These assumptions should be described in the TE Tutorial and removed from this section (need to check the TE Tutorial document).

This document is also making the following assumptions, still to be validated with CCAMP WG:

1. The topology information for the Ethernet access links is modelled using the YANG model defined in [Client-Topo].

2. The service information for Ethernet and other OTN client layer services are modelled using the YANG model defined in [Client-Signal].

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

2. Terminology

Domain: defined as a collection of network elements within a common realm of address space or path computation responsibility [RFC5151]

E-LINE: Ethernet Line

EPL: Ethernet Private Line

EVPL: Ethernet Virtual Private Line

OTN: Optical Transport Network

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

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

UNI: User Network Interface

MDSC: Multi-Domain Service Coordinator

CNC: Customer Network Controller

PNC: Provisioning Network Controller

MAC Bridging: Virtual LANs (VLANs) on IEEE 802.3 Ethernet network

[Editors' note:] Add terminology for end-to-end data plane connection, data plane segment connection.

3. Conventions used in this document

3.1. Topology and traffic flow processing

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

```
<node> (<processing>){, <node> (<processing>)}
```

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

The processing can be either an adaptation of a client layer into a server layer "(client -> server)" or switching at a given layer "([switching])". Multi-layer switching is indicated by two layer switching with client/server adaptation: "([client] -> [server])".

For example, the following traffic flow:

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

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

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

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

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

3.2. JSON code

This document provides some detailed JSON code examples to describe how the YANG models being developed by IETF (TEAS and CCAMP WG in particular) can be used.

The examples are provided using JSON because JSON code is easier for humans to read and write.

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

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

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

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

In order to have successful validation of the examples, some numbering scheme has been defined to assign identifiers to the different entities which would pass the syntax checks. In that case, to simplify the reading, another JSON name/value pair formatted as a comment and using the mnemonic identifiers is also provided. For example, the identifier of node S3 (S3-NODE-ID) has been assumed to be "10.0.0.3" and would be shown in the JSON code example using the two JSON name/value pair:

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

"te-node-id": "10.0.0.3",
```

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

4. Scenarios Description

4.1. Reference Network

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

```
                ........................
   ..........   :                      :
            :   :   Network domain 1   :   .............
    Customer:   :                      :   :           :
     domain :   :     S1 -------+      :   :  Network  :
            :   :    /           \     :   :  domain 3 :   ..........
        R1 ------- S3 ----- S4    \    :   :           :   :
            :   :    \        \    S2 --------+        :   :Customer
            :   :     \        \    |  :   :  \        :   : domain
            :   :      S5       \   |  :   :   \       :   :
        R2 ------+    /  \       \  |  :   :    S31 --------- R7
            :   : \ /     \       \ |  :   :   /   \   :   :
            :   :  S6 ---- S7 ---- S8 ------ S32   S33 ------ R8
            :   : /        |       |   :   : / \   /   :   :.......
        R3 ------+         |       |   :   :/   S34    :          :
            :   :..........|.......|...:   /    /      :          :
    ........:              |       |      /:.../.......:          :
                           |       |     /    /                   :
                ...........|.......|..../..../...                 :
                :          |       |   /    /   :    ..............
                : Network  |       |  /    /    :    :
                : domain 2 |       | /    /     :    :Customer
                :         S11 ---- S12   /      :    : domain
                :        /          | \ /       :    :
                :     S13     S14   | S15 ------------- R4
                :     | \   /   \   |    \      :    :
                :     |   S16     \ |     \     :    :
                :     |  /         S17 -- S18 --------- R5
                :     | /             \   /     :    :
                :    S19 ---- S20 ---- S21 ------------ R6
                :                               :    :
                :...............................:    :.............
```

Figure 1 - Reference network

This document assumes that all the transport network switching nodes Si are OTN switching nodes capable of switching in the electrical domain (ODU switching) and that all the Si-Sj OTN links within the transport network (intra-domain or inter-domain) are 100G links while the access Ri-Sj links are 10G links. Different technologies can be used at the access links (e.g., Ethernet, STM-n, OTN).

It is also assumed that, within the transport network, the physical/optical interconnections supporting the Si-Sj OTN links (up to the OTU4 trail), are pre-configured using mechanisms which are outside the scope of this document and are not exposed at the MPIs to the MDSC.

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

```
                           --------------
                          |              |
                          |     CNC      |
                          |              |
                           --------------
                                 |
             ....................|....................... CMI
                                 |
                          ----------------
                         |                |
                         |      MDSC      |
                         |                |
                          ----------------
                            /    |    \
                           /     |     \
            ............../......|......\................ MPIs
                         /       |       \
                        /    ----------   \
                       /    |   PNC2   |   \
                      /      ----------     \
            ----------           |           \
           |   PNC1   |        -----          \
            ----------       (       )     ----------
                |           (         )   |   PNC3   |
              -----        (  Network  )   ----------
            (       )      (  Domain 2 )       |
           (         )      (         )      -----
          (  Network  )      (       )     (       )
          (  Domain 1 )        -----      (         )
           (         )                   (  Network  )
            (       )                    (  Domain 3 )
              -----                       (         )
                                           (       )
                                             -----
```

Figure 2 - Controlling Hierarchy

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

This document assumes that the CNC controls the customer IP network and requests, at the CMI, transport connectivity between IP routers. The MDSC coordinates, via three MPIs, the control of a multi-domain transport network through three PNCs.

The control interfaces within the scope of this document are the three MPIs, while the control interface(s) between the CNC and the IP routers is outside the scope of this document. It is also assumed that the CMI allows the CNC to provide all the information that is required by the MDSC to properly configure the transport connectivity requested by the customer.

[Editors' note:] Check the assumption above with the latest version of the ACTN framework: it is the CNC or "something" above the CNC which controls the customer IP network

In case the CNC requests transport connectivity between IP routers attached to different transport domains (e.g., between R1 and R5), the MDSC coordinates the setup of a multi-domain end-to-end OTN connection across multiple PNCs (e.g., PNC1, PNC2 and PNC3 in in Figure 2) as well as the configuration of the client signal mapping at the PNCs controlling the edge domains (e.g., PNC1 and PNC2 in Figure 2).

4.1.1. Single-Domain Scenario

In case the CNC requests transport connectivity between IP routers attached to the same transport domain (e.g., between R1 and R3 in Figure 1), the MDSC can request the PNC controlling that domain (e.g., PNC1 in Figure 2) to setup an intra-domain end-to-end OTN connection and configure the client signal mapping.

Alternatively, the MDSC can just configure the client signal mapping and let the PNC take decisions about how to implement the service (e.g., setting up the intra-domain end-to-end OTN connection).

4.2. Topology Abstractions

Abstraction provides a selective method for representing connectivity information within a domain. There are multiple methods to abstract a network topology. This document assumes the abstraction method defined in [RFC7926]:

> "Abstraction is the process of applying the policy to the available TE information within a domain, to produce selective

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

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

- o White topology: This is a case where the PNC provides the actual network topology to the MDSC without any hiding or filtering. In this case, the MDSC has the full knowledge of the underlying network topology;

- o Black topology: The entire domain network is abstracted as a single virtual node with the access/egress links without disclosing any node internal connectivity information;

- o Grey topology: This abstraction level is between black topology and white topology from a granularity point of view. This is an abstraction of TE tunnels for all pairs of border nodes. We may further differentiate from a perspective of how to abstract internal TE resources between the pairs of border nodes:

    - Grey topology type A: border nodes with TE links between them in a full mesh fashion;

    - Grey topology type B: border nodes with some internal abstracted nodes and abstracted links.

Each PNC should provide the MDSC with a topology abstraction of the domain's network topology.

Each PNC provides topology abstraction of its own domain topology independently from each other, and therefore it is possible that different PNCs provide different types of topology abstractions.

The MPI operates on the abstract topology regardless of, and independently from, the type of abstraction provided by the PNC.

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

o PNC1 provides a black topology abstraction which exposes at MPI1 a single virtual node (representing the whole network domain 1).

o PNC2 provides a black topology abstraction which exposes at MPI2 a single virtual node (representing the whole network domain 2).

o PNC3 provides a white topology abstraction which exposes at MPI3 all the physical nodes and links within network domain 3.

[Editors' note:] Evaluate whether to change the description of the PNC2 abstraction to provide an example of a grey topology abstraction (pending discussion about grey topology abstraction)

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

The MDSC can also provide topology abstraction of its own view of the multi-domain network topology at its CMIs depending on the customers' needs: it can provide different types of topology abstractions at different CMIs.

4.3. Service Configuration

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

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

The control of different adaptations inside IP routers, Ri (PKT -> foo) and Rj (foo -> PKT), are assumed to be performed by means that are not under the control of, and not visible to, the MDSC nor to the PNCs. Therefore, these mechanisms are outside the scope of this document.

It is just assumed that the CNC is capable of requesting the proper configuration of the different adaptation functions inside the customer's IP routers, by means which are outside the scope of this document.

4.3.1. ODU Transit

The physical links interconnecting the IP routers and the transport network can be 10G OTN links. In this case, it is assumed that the physical/optical interconnections below the ODU layer (up to the OTU2 trail) are pre-configured using mechanisms which are outside the scope of this document and not exposed at the MPIs between the PNCs and the MDSC. For simplicity of the description, it is also assumed that these interfaces are not channelized (i.e., they can only support one ODU2).

To setup a 10Gb IP link between R1 and R5, an ODU2 end-to-end connection needs be created in the data plane between R1 and R5, through transport nodes S3, S1, S2, S31, S33, S34, S15 and S18 which belong to different PNC domains (multi-domain service request):

```
R1 ([PKT] -> ODU2), S3 ([ODU2]), S1 ([ODU2]), S2 ([ODU2]),
S31 ([ODU2]), S33 ([ODU2]), S34 ([ODU2]),
S15 ([ODU2]), S18 ([ODU2]), R5 (ODU2 -> [PKT])
```

It is assumed that, at the CMI, the CNC requests, using mechanisms which are outside the scope of this document, the MDSC to setup of an ODU2 transit service between the access links on S3 and S8 and that the MDSC understands that it shall setup an ODU2 segment connection between the access links on S3 and S18, which belongs to different PNC domains (multi-domain service request).

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

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

Since the CNC is not aware of the transport network controlling hierarchy, the mechanisms used by the CNC to request at the CMI the MDSC to setup an ODU2 transit service are independent on whether the service request is single-domain or multi-domain.

Based on the assumption above, the MDSC understands that it shall setup an ODU2 segment connection between the access links on S3 and S6, which belong to the same PNC domain (single-domain service request) and it can just pass the request at the MPI to PNC1 to setup a single-domain ODU2 segment connection between its access links on S3 and S6.

4.3.2. EPL over ODU

The physical links interconnecting the IP routers and the transport network can be Ethernet physical links.

To setup a 10Gb IP link between R1 and R5, an EPL service needs to be created between R1 and R5, supported by an ODU2 end-to-end connection in the data plane between transport nodes S3 and S18, through transport nodes S1, S2, S31, S33, S34 and S15, which belong to different PNC domains (multi-domain service request:

```
R1 ([PKT] -> ETH), S3 (ETH -> [ODU2]), S1 ([ODU2]),
S2 ([ODU2]), S31 ([ODU2]), S33 ([ODU2]), S34 ([ODU2]),
S15 ([ODU2]), S18 ([ODU2] -> ETH), R5 (ETH -> [PKT])
```

Based on the assumptions described in section 4.3.1, the CNC requests at the CMI the MDSC to setup an EPL service between the access links on S3 and S8 and the MDSC understands that it shall setup an ODU2 end-to-end connection between nodes S3 and S18, which belongs to different PNC domains (multi-domain service request). The MDSC also understands how the adaptation functions inside nodes S3 and S18 (i.e., S3 (ETH -> [ODU2]), S18 ([ODU2] -> ETH), S18 (ETH -> [ODU2]) and S3 ([ODU2] -> ETH)) should be configured.

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

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

As described in section 4.3.1, the mechanisms used by the CNC at the CMI are independent on whether the service request is single-domain service or multi-domain.

Based on the assumption above, the MDSC understands that it shall setup an EPL service between the access links on S3 and S6, which belong to the same PNC domain (single-domain service request) and it can just pass the request at the MPI to PNC1 to setup a single-domain EPL service its access links on S3 and S6. In this case, PNC1 can take care of setting up the single-domain ODU2 end-to-end connection between nodes S3 and S6 as well as of configuring the adaptation functions on these edge nodes.

4.3.3. Other OTN Clients Services

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

The physical links interconnecting the IP routers and the transport network can be any of these types.

In order to setup a 10Gb IP link between R1 and R5 using, for example SDH physical links between the IP routers and the transport network, an STM-64 Private Line service needs to be created between R1 and R5, supported by an ODU2 end-to-end connection in the data plane between transport nodes S3 and S18, through transport nodes S1, S2, S31, S33, S34 and S15, which belong to different PNC domains (multi-domain service request):

```
R1 ([PKT] -> STM-64), S3 (STM-64 -> [ODU2]), S1 ([ODU2]),
S2 ([ODU2]), S31 ([ODU2]), S33 ([ODU2]), S34 ([ODU2]),
S15 ([ODU2]), S18 ([ODU2] -> STM-64), R5 (STM-64 -> [PKT])
```

Based on the assumptions described in section 4.3.1, the CNC requests the CMI the MDSC to setup an STM-64 Private Line service between the access links on S3 and S8 and the MDSC understands what to do as described in section 4.3.2 (multi-domain service request).

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

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

As described in section 4.3.1, the mechanisms used by the CNC at the CMI are independent on whether the service request is single-domain or multi-domain.

As described in section 4.3.2, the MDSC can just pass the request at the MPI to PNC1 to setup a single-domain STM-64 Private Line service between it access links on S3 and S6.

4.3.4. EVPL over ODU

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

To setup two 1Gb IP links between R1 to R3 and between R1 and R5, two EVPL services need to be created, supported by two ODU0 end-to-end connections in the data plane respectively between transport nodes S3 and S6, through transport node S5, which belong ot the same PNC domain (single-domain service request) and between transport nodes S3 and S18, through transport nodes S1, S2, S31, S33, S34 and S15, which belong to different PNC domains (multi-domain service request):

```
R1 ([PKT] -> VLAN), S3 (VLAN -> [ODU0]), S1 ([ODU0]),
S2 ([ODU0]), S31 ([ODU0]), S33 ([ODU0]), S34 ([ODU0]),
S15 ([ODU0]), S18 ([ODU0] -> VLAN), R5 (VLAN -> [PKT])

R1 ([PKT] -> VLAN), S3 (VLAN -> [ODU0]), S5 ([ODU0]),
S6 ([ODU0] -> VLAN), R3 (VLAN -> [PKT])
```

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

Based on the assumptions described in section 4.3.1, the CNC requests at the CMI the MDSC to setup these EVPL services and the MDSC understands what to do as described in section 4.3.2.

4.3.5. EVPLAN and EVPTree Services

When the physical links interconnecting the IP routers and the transport network are Ethernet links, multipoint Ethernet services (e.g., EPLAN and EPTree) can also be supported. It is also possible that multiple Ethernet services (e.g., EVPL, EVPLAN and EVPTree) share the same physical link using different VLANs.

Note - it is assumed that EPLAN and EPTree services can be supported by configuring EVPLAN and EVPTree with port mapping.

Since this EVPLAN/EVPTree service can share the same Ethernet physical links between IP routers and transport nodes (e.g., with the EVPL services described in section 4.3.4), a different VLAN ID (e.g., 30) can be associated with this EVPLAN/EVPTree service.

In order to setup an IP subnet between R1, R2, R3 and R5, an EVPLAN/EVPTree service needs to be created, supported by two ODUflex end-to-end connections respectively between S3 and S6, crossing transport node S5, and between S3 and S18, crossing transport nodes S1, S2, S31, S33, S34 and S15 which belong to different PNC domains.

Some MAC Bridging capabilities are also required on some nodes at the edge of the transport network: for example, Ethernet Bridging capabilities can be configured in nodes S3 and S6:

- o MAC Bridging in node S3 is needed to select, based on the MAC Destination Address, whether received Ethernet frames should be forwarded to R1 or to the ODUflex terminating on node S6 or to the other ODUflex terminating on node S18;

- o MAC bridging function in node S6 is needed to select, based on the MAC Destination Address, whether received Ethernet frames should be sent to R2 or to R3 or to the ODUflex terminating on node S3.

In order to support an EVPTree service instead of an EVPLAN, additional configuration of the Ethernet Bridging capabilities on the nodes at the edge of the transport network is required.

The traffic flows between R1 and R3, between R3 and R5 and between R1 and R5 can be summarized as:

```
R1 ([PKT] -> VLAN), S3 (VLAN -> [MAC] -> [ODUflex]),
S5 ([ODUflex]), S6 ([ODUflex] -> [MAC] -> VLAN),
R3 (VLAN -> [PKT])

R3 ([PKT] -> VLAN), S6 (VLAN -> [MAC] -> [ODUflex]),
S5 ([ODUflex]), S3 ([ODUflex] -> [MAC] -> [ODUflex]),
S1 ([ODUflex]), S2 ([ODUflex]), S31 ([ODUflex]),
```

```
S33 ([ODUflex]), S34 ([ODUflex]),
S15 ([ODUflex]), S18 ([ODUflex] -> VLAN), R5 (VLAN -> [PKT])

R1 ([PKT] -> VLAN), S3 (VLAN -> [MAC] -> [ODUflex]),
S1 ([ODUflex]), S2 ([ODUflex]), S31 ([ODUflex]),
S33 ([ODUflex]), S34 ([ODUflex]),
S15 ([ODUflex]), S18 ([ODUflex] -> VLAN), R5 (VLAN -> [PKT])
```

As described in section 4.3.2, it is assumed that the CNC is capable, via the CMI, to request the setup of this EVPLAN/EVPTree service, providing all the information that the MDSC needs to understand that it need to request PNC1 to setup an ODUflex connection between nodes S3 and S6 (single-domain service request) and it also needs to coordinate the setup of a multi-domain ODUflex connection between nodes S3 and S16 as well as the MAC bridging and the adaptation functions on these edge nodes.

In case the CNC needs the setup of an EVPLAN/EVPTree service only between R1, R2 and R3 (single-domain service request), it would request the setup of this service in the same way as before and the information provided at the CMI is sufficient for the MDSC to understand that this is a single-domain service request.

The MDSC can then just request PNC1 to setup a single-domain EVPLAN/EVPTree service between nodes S3 and S6. PNC1 can take care of setting up the single-domain ODUflex end-to-end connection between nodes S3 and S6 as well as of configuring the MAC bridging and the adaptation functions on these edge nodes.

4.3.6. Dynamic Service Configuration

Given the service established in the previous sections, there is a demand for an update of some service characteristics. A straightforward approach would be terminate the current service and replace with a new one. Another more advanced approach would be a dynamic configuration, in which case there will be no interruption for the connection.

An example application would be updating the SLA information for a certain connection. For example, an ODU transit connection is set up according to section 4.3.1, with the corresponding SLA level of "no protection". After the establishment of this connection, the user would like to enhance this service by providing a restoration after potential failure, and a request is generated on the CMI. In this case, after receiving the request, the MDSC would need to send an update message to the PNC, changing the SLA parameters in TE Tunnel model. Then the connection characteristic would be changed by PNC, and a notification would be sent to MDSC for acknowledgement.

4.4. Multi-function Access Links

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

This configuration can be done a-priori by means outside the scope of this document. In this case, these links will appear at the MPI either as an ODU Link or as an STM-64 Link or as a 10GE Link (depending on the a-priori configuration) and will be controlled at the MPI as discussed in section 4.3.

It is also possible not to configure these links a-priori and give the control to the MPI to decide, based on the service configuration, how to configure it.

For example, if the physical link between R1 and S3 is a multi-functional access link while the physical links between R7 and S31 and between R5 and S18 are STM-64 and 10GE physical links respectively, it is possible to configure either an STM-64 Private Line service between R1 and R7 or an EPL service between R1 and R5.

The traffic flow between R1 and R7 can be summarized as:

```
R1 ([PKT] -> STM-64), S3 (STM-64 -> [ODU2]), S1 ([ODU2]),
S2 ([ODU2]), S31 ([ODU2] -> STM-64), R3 (STM-64 -> [PKT])
```

The traffic flow between R1 and R5 can be summarized as:

```
R1 ([PKT] -> ETH), S3 (ETH -> [ODU2]), S1 ([ODU2]),
S2 ([ODU2]), S31 ([ODU2]), S33 ([ODU2]), S34 ([ODU2]),
S15 ([ODU2]), S18 ([ODU2] -> ETH), R5 (ETH -> [PKT])
```

As described in section 4.3.2, it is assumed that the CNC is capable, via the CMI, to request the setup either an STM-64 Private Line service between R1 and R7 or an EPL service between R1 and R5, providing all the information that the MDSC needs to understand that it needs to coordinate the setup of a multi-domain ODU2 connection, either between nodes S3 and S31, or between nodes S3 and S18, as well as the adaptation functions on these edge nodes, and in particular whether the multi-function access link on between R1 and S3 should operate as an STM-64 or as a 10GE link.

4.5. Protection and Restoration Configuration

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

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

This section describes only services which are protected with linear protection and with dynamic restoration.

The MDSC needs to be capable of coordinating different PNCs to configure protection switching when requesting the setup of the protected connectivity services described in section 4.3.

Since in these service examples, switching within the transport network domain is performed only in the OTN ODU layer. Also protection switching within the transport network domain can only be provided at the OTN ODU layer.

4.5.1. Linear Protection (end-to-end)

In order to protect any service defined in section 4.3 from failures within the OTN multi-domain transport network, the MDSC should be capable of coordinating different PNCs to configure and control OTN linear protection in the data plane between nodes S3 and node S18.

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

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

Two cases can be considered:

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

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

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

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

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

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

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

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

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

4.5.2. Segmented Protection

To protect any service defined in section 4.3 from failures within the OTN multi-domain transport network, the MDSC should be capable of requesting each PNC to configure OTN intra-domain protection when requesting the setup of the ODU2 data plane connection segment.

If PNC1 provides linear protection, the working and protection transport entities could be:

```
Working transport entity:   S3, S1, S2

Protection transport entity: S3, S4, S8, S2
```

If PNC2 provides linear protection, the working and protection transport entities could be:

Working transport entity: S15, S18

Protection transport entity: S15, S12, S17, S18

If PNC3 provides linear protection, the working and protection transport entities could be:

Working transport entity: S31, S33, S34

Protection transport entity: S31, S32, S34

4.5.3. End-to-End Dynamic restoration

To restore any service defined in section 4.3 from failures within the OTN multi-domain transport network, the MDSC should be capable of coordinating different PNCs to configure and control OTN end-to-end dynamic Restoration in the data plane between nodes S3 and node S18. For example, the MDSC can request the PNC1, PNC2 and PNC3 to create a service with no-protection, MDSC set the end-to-end service with the dynamic restoration.

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

When a link failure between S1 and s2 occurred in network domain 1, PNC1 does not restore the tunnel and send the alarm notification to the MDSC, MDSC will perform the end-to-end restoration.

```
Restored transport entity:   S3, S4, S8,
                    S12, S15, S18
```

4.5.4. Segmented Dynamic Restoration

To restore any service defined in section 4.3 from failures within the OTN multi-domain transport network, the MDSC should be capable of coordinating different PNCs to configure and control OTN segmented dynamic Restoration in the data plane between nodes S3 and node S18.

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

When a link failure between S1 and s2 occurred in network domain 1, PNC1 will restore the tunnel and send the alarm or tunnel update notification to the MDSC, MDSC will update the restored tunnel.

```
      Restored transport entity:   S3, S4, S8, S2
                                   S31, S33, S34,
                                   S15, S18
```

When a link failure between network domain 1 and network domain 2 occurred, PNC1 and PNC2 will send the alarm notification to the MDSC, MDSC will update the restored tunnel.

```
      Restored transport entity:   S3, S4, S8,
                                   S12, S15, S18
```

In order to improve the efficiency of recovery, the controller can establish a recovery path in a concurrent way. When the recovery fails in one domain or one network element, the rollback operation should be supported.

The creation of the recovery path by the controller can use the method of "make-before-break", in order to reduce the impact of the recovery operation on the services.

4.6. Service Modification and Deletion

[Editors' Note:] The service configuration include service creation, modification and deletion.

For example, the service modification includes the service bandwidth modification and service SLA level upgrade and degrade, such as service protection type changed from no protection to 1+1 protection.

To be discussed in future versions of this document.

4.7. Notification

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

1. Object create

2. Object delete

3. Object state change

4. Alarm

Because there are three types of topology abstraction type defined in section 4.2, the notification should also be abstracted. The PNC and MDSC should coordinate together to determine the notification policy, such as when an intra-domain alarm occurred, the PNC may not report the alarm but the service state change notification to the MDSC.

4.8. Path Computation with Constraint

It is possible to have constraint during path computation procedure; typical cases include IRO/XRO and so on. This information is carried in the TE Tunnel model and used when there is a request with constraint. Consider the example in section 4.3.1. , the request can be a Tunnel from R1 to R5 with an IRO from S2 to S31, then qualified feedback would become:

R1 ([PKT] -> ODU2), S3 ([ODU2]), S1 ([ODU2]), S2 ([ODU2]),
S31 ([ODU2]), S33 ([ODU2]), S34 ([ODU2]),
S15 ([ODU2]), S18 ([ODU2]), R5 (ODU2 -> [PKT])

If the request covers the IRO from S8 to S12, then the above path would not be qualified, while a possible computation result may be:

R1 ([PKT] -> ODU2), S3 ([ODU2]), S1 ([ODU2]), S2 ([ODU2]),
S8 ([ODU2]), S12 ([ODU2]), S15 ([ODU2]), S18 ([ODU2]), R5 (ODU2 ->
[PKT])

Similarly, the XRO can be represented by the TE tunnel model as well.

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

5. YANG Model Analysis

This section provides a high-level overview of how IETF YANG models can be used at the MPIs, between the MDSC and the PNCs, to support the scenarios described in section 4.

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

Section 5.2 describes how the MDSC can coordinate different requests to different PNCs, via their own MPIs, to setup the different services described in section 4.3.

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

5.1. YANG Models for Topology Abstraction

Each PNC reports its respective abstract topology to the MDSC, as described in section 4.2.

5.1.1. Domain 1 Black Topology Abstraction

PNC1 provides the required black topology abstraction, as described in section 4.2, to expose to the MDSC, at MPI1, one TE Topology instance for the ODU layer (MPI1 OTN Topology) containing only one abstract TE node (i.e., AN1) and only inter-domain and access abstract TE links (which represent the inter-domain and access physical links), as shown in Figure 3 below.

```
                ..................................
                :                                :
                :       +-----------------+      :
                :       |                 |      :
        (R1)- - --------|                 |-------- - -(S31)
                : AN1-1 |                 | AN1-2 :
                :       |                 |       :
        (R2)- - --------|                 |       :
                : AN1-3 |       AN1       |       :
                :       |                 |       :
        (R3)- - --------|                 |-------- - -(S32)
                : AN1-7 |                 | AN1-4 :
                :       |                 |       :
                :       +-----------------+       :
                :          |          |           :
                :    AN1-6 |          | AN1-5     :
                :..........|..........|...........:

                           |          |
                         (S11)      (S12)
```

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

[Editors' note:] Update figure 3 to match with the new topology abstraction

As described in section 4.1, it is assumed that the physical links between the physical nodes are pre-configured and therefore PNC1 exports at MPI1 one abstract TE Link, within the MPI1 OTN topology, for each OTU2 or OTU4 trail which support an abstract TE link in the MPI1 ODU Topology.

[Editors' note:] Add some description about the relationship between the abstract and the physical topology within the PNC1 "brain."

```
                 .................................
                 :                               :
                 :   ODU Abstract Topology @ MPI :
                 :        Gotham City Area       :
                 :      Metro Transport Network  :
                 :                               :
                 :        +----+        +----+   :
                 :        |    |S1-1    |    |S2-1:
                 :        | S1 |--------| S2 |----- - -(S31)
                 :        +----+    S2-2+----+   :
                 :     S1-2/              |S2-3  :
                 :    S3-2/ Robinson Park |      :
                 :    +----+   +----+     |      :
                 :    |    |3 1|    |     |      :
         (R1)- - -----| S3 |---| S4 |     |      :
                 :S3-1+----+   +----+     |      :
                 :   S3-4 \        \S4-2  |      :
                 :         \S5-1    \     |      :
                 :        +----+     \    |      :
                 :        |    |      \S8-3      :
                 :        | S5 |       \  |      :
                 :        +----+ Metro  \ |S8-2  :
         (R2)- - ------  2/ E  \3 Main   \|      :
                 :S6-1 \ /3 a E \1 Ring   \|     :
                 :    +----+s-n+----+   +----+   :
                 :    |    |t d|    |   |    |S8-1:
                 :    | S6 |---| S7 |---| S8 |----- - -(S32)
                 :    +----+4 2+----+3 4+----+   :
                 :      /           |        |       :
         (R3)- - ------     S7-4    |        |  S8-5  :
                 :S6-2              |        |       :
                 :..................|........|.......:

                                    |        |
                                  (S11)    (S12)
```

Figure 4 - Physical Topology discovered by PNC1

LTP mapping table:

AN1-1 -> S3-1

AN1-2 -> S2-1

AN1-3 -> S6-1

AN1-4 -> S8-1

AN1-5 -> S8-5

AN1-6 -> S7-4

AN1-7 -> S6-2

Appendix B.1.1 provides the detailed JSON code example ("mpi1-otn-topology.json") describing how this ODU Topology is reported by the PNC, using the [TE-TOPO] and [OTN-TOPO] YANG models at MPI1.

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

- o YANG attributes which are outside the scope of this document are not shown

- o The attributes describing the label restrictions are also not shown to simplify the JSON code example

- o The comments describing the rationale for not including some attributes in this JSON code example even if in the scope of this document are identified with the prefix "// __COMMENT__" and included only in the first object instance (e.g., in the Access Link from the AN1-1 description or in the AN1-1 LTP description)

5.1.2. Domain 2 Black Topology Abstraction

PNC2 provides the required black topology abstraction, as described in section 4.2, to expose to the MDSC, at MPI2, one TE Topology instance for the ODU layer (MPI2 OTN Topology) containing only one abstract node (i.e., AN2) and only inter-domain and access abstract TE links (which represent the inter-domain and access physical links).

5.1.3. Domain 3 White Topology Abstraction

PNC3 provides the required white topology abstraction, as described in section 4.2, to expose to the MDSC, at MPI3, one TE Topology instance for the ODU layer (MPI3 OTN Topology) containing one abstract TE node for each physical node and one abstract TE link for each physical link (internal links, inter-domain links or access links).

5.1.4. Multi-domain Topology Stitching

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

Given the topologies reported from multiple PNCs, the MDSC need to stitch the multi-domain topology and obtain the full map of topology. The topology of each domain may be in an abstracted shape (refer to section 5.2 of [ACTN-Fwk] for a different level of abstraction), while the inter-domain link information MUST be complete and fully configured by the MDSC.

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

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

One possibility is to use the plug-id information, defined in [TE-TOPO]: two inter-domain links reporting the same plug-id value can be merged as a single intra-domain link within any MDSC native topology. The value of the reported plug-id information can be either assigned by a central network authority, and configured within the two PNC domains, or it can be discovered using automatic discovery mechanisms (e.g., LMP-based, as defined in [RFC6898]).

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

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

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

Another possibility is to pre-configure, either in the adjacent PNCs or in the MDSC, the association between the inter-domain link identifiers (topology-id, node-id and tp-id) assigned by the two adjacent PNCs to the same inter-domain link.

This last scenario requires further investigation and will be discussed in a future version of this document.

[Editors' note:] Add some description of the abstract multi-domain topology within the MDSC "brain."

```
                ........................
                :                      :
                :   Network domain 1   :   .............
                :   Grey Topology      :   :           :
                :     Abstraction      :   :  Network  :
                :                      :   :  domain 3 :
        (R1)- - -------+               :   :  (White)  :
                :       \      +--------------+        :
                :        \    /        :   :   \       :
                :         \  /         :   :    \      :
        (R2)- - --------- AN1 --+      :   :    S31 ---- - (R7)
                :         /|\    \     :   :   /   \   :   :
                :        / | \    +--------- S32   S33 - - (R8)
                :       /  |  \        :   :/  \   /   :
        (R3)- - -------+   |   +---+   :   /    S34    :
                :..........|.......|...:  /:   /       :
                           |       |     / :../........:
                           |       |    /    /
                ...........|.......|.../..../....
                :          |       |  /    /    :
                : Network  |       + /    /     :
                : domain 2 |      / /    /      :
                :          |     / /    /       :
                :          |    + / +--+        :
                :          |    |/ /         +--- - -(R4)
                : Black    +--- AN2 ---------+  :
                : Topology      | |             :
                : Abstraction   | +-------------- - -(R5)
                :               |               :
                :               +---------------- - -(R6)
                :                               :
                :...............................:
```

Figure 5 - Multi-domain Abstract Topology discovered by MDSC

5.1.5. Access Links

Access links in Figure 3 are shown as ODU Links: the modeling of the access links for other access technologies is currently an open issue.

The modeling of the access link in case of non-ODU access technology has also an impact on the need to model ODU TTPs and layer transition capabilities on the edge nodes (e.g., nodes S2, S3, S6 and S8 in Figure 3).

If, for example, the physical NE S6 is implemented in a "pizza box", the data plane would have only set of ODU termination resources (where up to 2xODU4, 4xODU3, 20xODU2, 80xODU1, 160xODU0 and 160xODUflex can be terminated). The traffic coming from each of the 10GE access links can be mapped into any of these ODU terminations.

Instead if, for example, the physical NE S6 can be implemented as a multi-board system where access links reside on different/dedicated access cards with a separated set of ODU termination resources (where up to 1xODU4, 2xODU3, 10xODU2, 40xODU1, 80xODU0 and 80xODUflex for each resource can be terminated). The traffic coming from one 10GE access links can be mapped only into the ODU terminations which reside on the same access card.

The more generic implementation option for a physical NE (e.g., S6) would be the case is of a multi-board system with multiple access cards with separated sets of access links and ODU termination resources (where up to 1xODU4, 2xODU3, 10xODU2, 40xODU1, 80xODU0 and 80xODUflex for each resource can be terminated). The traffic coming from each of the 10GE access links on one access card can be mapped only into any of the ODU terminations which reside on the same access card.

In the last two cases, only the ODUs terminated on the same access card where the access links reside can carry the traffic coming from that 10GE access link. Terminated ODUs can instead be sent to any of the OTU4 interfaces

In all these cases, terminated ODUs can be sent to any of the OTU4 interfaces assuming the implementation is based on a non-blocking ODU cross-connect.

If the access links are reported via MPI in some, still to be defined, client topology, it is possible to report each set of ODU termination resources as an ODU TTP within the ODU Topology of Figure 3 and to use either the inter-layer lock-id or the transitional link, as described in sections 3.4 and 3.10 of [TE-TOPO], to correlate the access links, in the client topology, with the ODU TTPs, in the OTN topology, to which access link are connected to.

5.2. YANG Models for Service Configuration

The service configuration procedure is assumed to be initiated (step 1 in Figure 6) at the CMI from CNC to MDSC. Analysis of the CMI models is (e.g., L1SM, L2SM, Transport-Service, VN, et al.) is outside the scope of this document.

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

```
                                 |
                                 | {1}
                                 V
                          ----------------
                         |           {2}  |
                         | {3}  MDSC      |
                         |                |
                          ----------------
                           ^     ^      ^
                    {3.1}  |     |      |
                 +---------+     |{3.2} |
                 |               |      +----------+
                 |               V                 |
                 |           ----------            |{3.3}
                 |          |   PNC2   |           |
                 |           ----------            |
                 |               ^                 |
                 V               | {4.2}           |
             ----------          V                 |
            |   PNC1   |       -----               V
             ----------      (Network)        ----------
                 ^          ( Domain 2)      |   PNC3   |
                 | {4.1}   (          _)      ----------
                 V          (        )            ^
               -----       C==========D           | {4.3}
             (Network)    /  (       ) \          V
            ( Domain 1)  /     -----    \       -----
           (           )/                \    (Network)
           A===========B                  \  ( Domain 3)
          / (         )                    \(           )
      AP-1   (       )                      X===========Z
               -----                         (         ) \
                                              (       )   AP-2
                                                -----
```

Figure 6 - Multi-domain Service Setup

As an example, the objective in this section is to configure a transport service between R1 and R5. The cross-domain routing is assumed to be R1 <-> S3 <-> S2 <-> S31 <-> S33 <-> S34 <->S15 <-> S18 <-> R5.

According to the different client signal type, there is different adaptation required.

After receiving such request, MDSC determines the domain sequence, i.e., domain 1 <-> domain 2 <-> domain 3, with corresponding PNCs and inter-domain links (step 2 in Figure 6).

As described in [PATH-COMPUTE], the domain sequence can be determined by running the MDSC own path computation on the MDSC internal topology, defined in section 5.1.4, if and only if the MDSC has enough topology information. Otherwise, the MDSC can send path computation requests to the different PNCs (steps 2.1, 2.2 and 2.3 in Figure 6) and use this information to determine the optimal path on its internal topology and therefore the domain sequence.

The MDSC will then decompose the tunnel request into a few tunnel segments via tunnel model (including both TE tunnel model and OTN tunnel model), and request different PNCs to setup each intra-domain tunnel segment (steps 3, 3.1, 3.2 and 3.3 in Figure 6).

Assume that each intra-domain tunnel segment can be set up successfully, and each PNC response to the MDSC respectively. Based on each segment, MDSC will take care of the configuration of both the intra-domain tunnel segment and inter-domain tunnel via corresponding MPI (via TE tunnel model and OTN tunnel model). More specifically, for the inter-domain configuration, the ts-bitmap and tpn attributes need to be configured using the OTN Tunnel model. Then the end-to-end OTN tunnel will be ready.

In any case, the access link configuration is done only on the PNCs that control the access links (e.g., PNC-1 and PNC-3 in our example) and not on the PNCs of transit domain (e.g., PNC-2 in our example). An access link will be configured by MDSC after the OTN tunnel is set up. Access configuration is different and dependent on the different type of service. More details can be found in the following sections.

[Editor's Note:] Add some notes for the single-domain case

5.2.1. ODU Transit Service

In this scenario, described in section 4.3.1, the access links are configured as ODU Links.

Since it is assumed that the physical access links are pre-configured, each PNC exposes, at its MPI, one TE Link (called "ODU Link") for each of these physical access link. These links are reported, together with any other ODU internal or inter-domain link, within the OTN abstract topology exposed by each PNC, at its own MPI.

To setup this IP link, between R1 and R5, the CNC requests, at the CMI, the MDSC to setup an ODU transit service.

From the topology information described in section 5.1 above, the MDSC understands that R1 is attached to the access link terminating on S3-1 LTP in the ODU Topology exposed by PNC1 and that R5 is attached to the access link terminating on AN2-1 LTP in the ODU Topology exposed by PNC2.

[Editors' note:] Add some information about the path computation step.

MDSC would then request, at MPI1, the PNC1 to setup an ODU2 (Transit Segment) Tunnel with one primary path between S3-1 and S2-1 LTPs:

o Source and Destination TTPs are not specified (since it is a Transit Tunnel)

o Ingress and egress points are indicated in the route-object-include-exclude list of the explicit-route-objects of the primary path:

   o The first element references the access link terminating on S3-1 LTP

[Editor's note:] The need for the second element is for further study.

   o The last two element references respectively the inter-domain link terminating on S2-1 LTP and the data plane resources (i.e., the timeslots and the TPN, called "OTN Label") used by the ODU2 connection over that link.

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

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

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

[Editor's note:] These working assumptions seem generic and not specific for the YANG models defined by IETF: should we move it to section 4?

Appendix B.2.1 provides the detailed JSON code ("mpi1-odu2-service-config.json") describing how the setup of this ODU2 (Transit Segment) Tunnel can be requested by the MDSC, using the [TE-TUNNEL] and [OTN-TUNNEL] YANG models at MPI1.

The Transport PNC performs path computation and sets up the ODU2 cross-connections within the physical nodes S3, S5 and S6, as shown in section 4.3.1.

[Editor's note:] Complete the description to cover the other domains as well as the status reporting.

5.2.1.1. Single Domain Example

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

[Editor's note:] Complete the description of the single-domain scenario.

The Transport PNC reports the status of the created ODU2 (Transit Segment) Tunnel and its path within the ODU Topology as shown in Figure 7 below:

```
                    ..................................
                    :                                :
                    :   ODU Abstract Topology @ MPI  :
                    :                                :
                    :        +----+        +----+    :
                    :        |    |        |    |    :
                    :        | S1 |--------| S2 |- - - - -(R4)
                    :        +----+        +----+    :
                    :         /               |      :
                    :        /                |      :
                    :    +----+   +----+      |      :
                    :    |    |   |    |      |      :
            (R1)- - - - -  S3 |---| S4 |      |      :
                    :S3-1 <<= +   +----+      |      :
                    :       =        \        |      :
                    :       = \       \       |      :
                    :       == ---+    \      |      :
                    :        =    |     \     |      :
                    :        = S5 |      \    |      :
                    :        == --+       \   |      :
            (R2)- - - - -     =  \         \  |      :
                    :S6-1 \ / =   \         \ |      :
                    :    +--- =   +----+   +----+    :
                    :    |    =   |    |   |    |    :
                    :    | S6 = --| S7 |---| S8 |- - - - -(R5)
                    :    +--- =   +----+   +----+    :
                    :     /   =                      :
            (R3)- - - - -  <<==                      :
                    :S6-2                            :
                    :................................:
```

Figure 7 - ODU2 Transit Tunnel

5.2.2. EPL over ODU Service

In this scenario, described in section 4.3.2, the access links are configured as Ethernet Links.

[Editors' note:] Need to add information about the use of the Ethernet client topology.

[Editor's Note:] Add considerations for the case the access links are multi-function access links

To setup this IP link, between R1 and R5, the CNC requests, at the CMI, the MDSC to setup an EPL service.

As described in section 5.1.5 above, it is not clear in this case how the Ethernet access links between the transport network and the IP router, are reported by the PNC to the MDSC.

If the 10GE physical links are not reported as ODU links within the OTN topology information, described in section 5.1.1 above than the MDSC will not have sufficient information to know that R1 and R5 are attached to the access links terminating on S3 and S6.

Assuming that the MDSC knows how R1 and R3 are attached to the transport network, the MDSC would request the Transport PNC to setup an ODU2 end-to-end Tunnel between S3 and S6.

This ODU Tunnel is setup between two TTPs of nodes S3 and S6. In case of nodes S3 and S6 support more than one TTP, the MDSC should decide which TTP to use.

As discussed in 5.1.5, depending on the different hardware implementations of the physical nodes S3 and S6, not all the access links can be connected to all the TTPs. The MDSC should therefore select not only the optimal TTP but also a TTP that would allow the Tunnel to be used by the service.

It is assumed that in case of node S3 or node S6 supports only one TTP, this TTP can be accessed by all the access links.

Appendix B.2.2 provides the detailed JSON code ("mpi1-odu2-tunnel-config.json") describing how the setup of this ODU2 (Head Segment) Tunnel can be requested by the MDSC, using the [TE-TUNNEL] and [OTN-TUNNEL] YANG models at MPI1.

Once the ODU2 Tunnel setup has been requested, unless there is a one-to-one relationship between the S3 and S6 TTPs and the Ethernet access links toward R1 and R3 (as in the case, described in section 5.1.5, where the Ethernet access links reside on different/dedicated access card such that the ODU2 tunnel can only carry the Ethernet traffic from the only Ethernet access link on the same access card where the ODU2 tunnel is terminated), the MDSC also needs to request the setup of an EPL service from the access links on S3 and S6, attached to R1 and R3, and this ODU2 Tunnel.

Appendix B.2.3 provides the detailed JSON code ("mpi1-epl-service-config.json") describing how the setup of this EPL service using the ODU2 Tunnel can be requested by the MDSC, using the [CLIENT-SVC] YANG model at MPI1.

5.2.3. Other OTN Client Services

[Editor's Note:] Update this section to describe the multi-domain scenario

In this scenario, the access links are configured as one of the OTN clients (e.g., STM-64) links.

[Editor's Note:] Add considerations for the case the access links are multi-function access links

As described in section 4.3.3, the CNC needs to setup an STM-64 Private Link service, supporting an IP link, between R1 and R3 and requests this service at the CMI to the MDSC.

MDSC needs to setup an STM-64 Private Link service between R1 and R3 supported by an ODU2 end-to-end connection between S3 and S6.

As described in section 5.1.5 above, it is not clear in this case how the access links (e.g., the STM-N access links) between the transport network and the IP router, are reported by the PNC to the MDSC.

The same issues, as described in section 5.2.2, apply here:

- o the MDSC needs to understand that R1 and R3 are connected, thought STM-64 access links, with S3 and S6

- o the MDSC needs to understand which TTPs in S3 and S6 can be accessed by these access links

- o the MDSC needs to configure the private line service from these access links through the ODU2 tunnel

5.2.4. EVPL over ODU Service

[Editor's Note:] Update this section to describe the multi-domain scenario

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

As described in section 4.3.4, the CNC needs to setup EVPL services, supporting IP links, between R1 and R3, as well as between R1 and R4 and requests these services at the CMI to the MDSC.

MDSC needs to setup two EVPL services, between R1 and R3, as well as between R1 and R4, supported by ODU0 end-to-end connections between S3 and S6 and between S3 and S2 respectively.

As described in section 5.1.5 above, it is not clear in this case how the Ethernet access links between the transport network and the IP router, are reported by the PNC to the MDSC.

The same issues, as described in section 5.1.5 above, apply here:

o the MDSC needs to understand that R1, R3 and R4 are connected, thought the Ethernet access links, with S3, S6 and S2

o the MDSC needs to understand which TTPs in S3, S6 and S2 can be accessed by these access links

o the MDSC needs to configure the EVPL services from these access links through the ODU0 tunnels

In addition, the MDSC needs to get the information that the access links on S3, S6 and S2 are capable of supporting EVPL (rather than just EPL) as well as to coordinate the VLAN configuration, for each EVPL service, on these access links (this is a similar issue as the timeslot configuration on access links discussed in section 4.3.1 above).

5.3. YANG Models for Protection Configuration

5.3.1. Linear Protection (end-to-end)

To be discussed in future versions of this document.

5.3.2. Segmented Protection

To be discussed in future versions of this document.

6. Security Considerations

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

This document analyses the applicability of the YANG models being defined by the IETF to support OTN single and multi-domain scenarios There are no specific new security considerations introduced by this document.

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

7. IANA Considerations

This document requires no IANA actions.

8. References

8.1. Normative References

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8.2. Informative References

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[ONF TR-527] ONF Technical Recommendation TR-527, "Functional Requirements for Transport API", June 2016.

[ONF GitHub] ONF Open Transport (SNOWMASS) https://github.com/OpenNetworkingFoundation/Snowmass-ONFOpenTransport

9. Acknowledgments

The authors would like to thank all members of the Transport NBI Design Team involved in the definition of use cases, gap analysis and guidelines for using the IETF YANG models at the Northbound Interface (NBI) of a Transport SDN Controller.

The authors would like to thank Xian Zhang, Anurag Sharma, Sergio Belotti, Tara Cummings, Michael Scharf, Karthik Sethuraman, Oscar Gonzalez de Dios, Hans Bjursrom and Italo Busi for having initiated the work on gap analysis for transport NBI and having provided foundations work for the development of this document.

The authors would like to thank the authors of the TE Topology and Tunnel YANG models [TE-TOPO] and [TE-TUNNEL], in particular Igor Bryskin, Vishnu Pavan Beeram, Tarek Saad and Xufeng Liu, for their support in addressing any gap identified during the analysis work.

The authors would like to thank Henry Yu and Aihua Guo for their input and review of the URIs structures used within the JSON code examples.

This document was prepared using 2-Word-v2.0.template.dot.

Validating a JSON fragment against a YANG Model

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

A.1. Manipulation of JSON fragments

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

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

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

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

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

The following schema resumes these definitions:

```
                    unfold_it -->            stripper -->

          Folded-JSON          Unfolded-JSON             Naked JSON

                    <-- fold_it              <-- author edits

   <=72-chars?    MUST              MAY                     MAY

   valid JSON?     MAY            MUST                    MUST

   JSON-encoding   MAY              MAY                    MUST

   of YANG data
```

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

A.2. Comments in JSON fragments

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

- free-form descriptive comments, e.g."// COMMENT" : "refine this" to describe properties of JSON fragments.

- machine-usable directives e.g. "// __REFERENCES__DRAFTS__" : { "ietf-routing-types@2017-12-04": "rfc8294",} which can be used to automatically download from the network the relevant I-Ds or RFCs and extract from them the YANG models of interest. This is particularly useful to keep consistency when the drafting work is rapidly evolving.

A.3. Validation of JSON fragments: DSDL-based approach

The idea is to generate a JSON driver file (JTOX) from YANG, then use it to translate JSON to XML and validate it against the DSDL schemas, as shown in Figure 8.

Useful link: https://github.com/mbj4668/pyang/wiki/XmlJson

```
                        (2)
            YANG-module ---> DSDL-schemas (RNG,SCH,DSRL)
                   |                   |
                   | (1)               |
                   |                   |
   Config/state  JTOX-file             | (4)
          \        |                   |
           \       |                   |
            \      V                   V
   JSON-file------------> XML-file ----------------> Output
              (3)
```

Figure 8 - DSDL-based approach for JSON code validation

In order to allow the use of comments following the convention defined in section 3without impacting the validation process, these comments will be automatically removed from the JSON-file that will be validate.

A.4. Validation of JSON fragments: why not using a XSD-based approach

This approach has been analyzed and discarded because no longer supported by pyang.

The idea is to convert YANG to XSD, JSON to XML and validate it against the XSD, as shown in Figure 9:

```
                (1)
YANG-module ---> XSD-schema - \       (3)
                               +--> Validation
JSON-file------> XML-file ----/
                (2)
```

Figure 9 - XSD-based approach for JSON code validation

The pyang support for the XSD output format was deprecated in 1.5 and removed in 1.7.1. However pyang 1.7.1 is necessary to work with YANG 1.1 so the process shown in Figure 9 will stop just at step (1).

Detailed JSON Examples

The JSON code examples provided in this appendix have been validated using the tools in Appendix A and folded using the tool in [FOLD].

B.1. JSON Examples for Topology Abstractions

B.1.1. JSON Code: mpi1-otn-topology.json

This is the JSON code reporting the OTN Topology @ MPI:

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

{
  "// __TITLE__": "ODU Black Topology @ MPI1",
  "// __LAST_UPDATE__": "October 18, 2018",
  "// __MISSING_ATTRIBUTES__": true,
  "// __REFERENCE_DRAFTS__": {
    "ietf-routing-types@2017-12-04": "rfc8294",
    "ietf-otn-types@2017-10-30": "draft-ietf-ccamp-otn-tunnel-model-
\
\01",
    "ietf-network@2018-02-26": "rfc8345",
    "ietf-network-topology@2018-02-26": "rfc8345",
    "ietf-te-types@2018-06-12": "draft-ietf-teas-yang-te-15",
    "ietf-te-topology@2018-06-15": "draft-ietf-teas-yang-te-topo-
18",
    "ietf-otn-topology@2017-10-30": "draft-ietf-ccamp-otn-topo-yang-
\
\02"
  },
  "// __RESTCONF_OPERATION__": {
    "operation": "GET",
    "url": "http://{{PNC1-ADDR}}/restconf/data/ietf-
network:networks"
  },
  "ietf-network:networks": {
    "network": [
      {
        "network-id": "providerId/201/clientId/300/topologyId/otn-
bl\
\ack-topology",
        "network-types": {
          "ietf-te-topology:te-topology": {
            "ietf-otn-topology:otn-topology": {}
          }
        },
        "ietf-te-topology:provider-id": 201,
        "ietf-te-topology:client-id": 300,
        "ietf-te-topology:te-topology-id": "otn-black-topology",
        "// ietf-te-topology:te": "presence container requires:
prov\
\ider, client and te-topology-id",
        "ietf-te-topology:te": {
          "name": "OTN Black Topology @ MPI1"
```

```
          },
          "// ietf-network:node": "Access LTPs to be reviewed in a
   fut\
   \ure update",
          "ietf-network:node": [
            {
              "// __NODE__:__DESCRIPTION__": {
                "name": "AN1",
                "identifier": "10.0.0.1",
                "type": "Abstract Node",
                "physical node(s)": "whole network domain 1"
              },
              "node-id": "10.0.0.1",
              "ietf-te-topology:te-node-id": "10.0.0.1",
              "ietf-te-topology:te": {
                "te-node-attributes": {
                  "name": "AN11",
                  "admin-status": "up",
                  "// __DISCUSS__ is-abstract": "To be discussed with
   \
   \TE Topology authors",
                  "// __DISCUSS__ underlay-topology": "To be
   discussed\
   \ with TE Topology authors"
                },
                "oper-status": "up",
                "// __DISCUSS__ tunnel-termination-point": []
              },
              "ietf-network-topology:termination-point": [
                {
                  "// __DESCRIPTION__:__LTP__": {
                    "name": "AN1-1 LTP",
                    "link type(s)": "OTU-2",
                    "physical node": "S3",
                    "unnumberd/ifIndex": 1,
                    "port type": "tributary port",
                    "connected to": "R1"
                  },
                  "tp-id": "1",
                  "ietf-te-topology:te-tp-id": 1,
                  "ietf-te-topology:te": {
                    "name": "AN1-1 LTP",
                    "admin-status": "up",
                    "// __DISCUSS__ interface-switching-capability":
   "\
```

```
   \See Link attributes (teNodeId/10.0.0.1/teLinkId/1)",
                     "// __DISCUSS__ inter-domain-plug-id": "Access
   Lin\
   \k",
                     "// __COMMENT__ inter-layer-lock-id": "Empty: OTN
   \
   \Links are pre-configured",
                     "oper-status": "up",
                     "// __DISCUSS__ ietf-otn-topology:supported-
   payloa\
   \d-types": "List of ODU clients?",
                     "// __DISCUSS__ ietf-otn-topology:client-facing":
   \
   \true
                   }
                 },
                 {
                   "// __DESCRIPTION__:__LTP__": {
                     "name": "AN1-2 LTP",
                     "link type(s)": "OTU-4",
                     "physical node": "S2",
                     "unnumberd/ifIndex": 1,
                     "port type": "inter-domain port",
                     "connected to": "S31"
                   },
                   "tp-id": "2",
                   "ietf-te-topology:te-tp-id": 2,
                   "ietf-te-topology:te": {
                     "name": "AN1-2 LTP",
                     "admin-status": "up",
                     "// __DISCUSS__ interface-switching-capability":
   "\
   \See Link attributes (teNodeId/10.0.0.1/teLinkId/2)",
                     "// __DISCUSS__ inter-domain-plug-id": "Inter-
   doma\
   \in Link",
                     "oper-status": "up",
                     "// __DISCUSS__ ietf-otn-topology:supported-
   payloa\
   \d-types": "Empty? (inter-domain OTN link)",
                     "// __DEFAULT__ ietf-otn-topology:client-facing":
   \
   \false
                   }
                 },
```

```
                 {
                   "// __DESCRIPTION__:__LTP__": {
                     "name": "AN1-3 LTP",
                     "link type(s)": "OTU-2",
                     "physical node": "S6",
                     "unnumberd/ifIndex": 1,
                     "port type": "tributary port",
                     "connected to": "R2"
                   },
                   "tp-id": "3",
                   "ietf-te-topology:te-tp-id": 3,
                   "ietf-te-topology:te": {
                     "name": "AN1-3 LTP",
                     "admin-status": "up",
                     "// __DISCUSS__ interface-switching-capability":
   "\
   \See Link attributes (teNodeId/10.0.0.1/teLinkId/3)",
                     "// __DISCUSS__ inter-domain-plug-id": "Access
   Lin\
   \k",
                     "oper-status": "up",
                     "// __DISCUSS__ ietf-otn-topology:supported-
   payloa\
   \d-types": "List of ODU clients?",
                     "// __DISCUSS__ ietf-otn-topology:client-facing":
   \
   \true
                   }
                 },
                 {
                   "// __DESCRIPTION__:__LTP__": {
                     "name": "AN1-4 LTP",
                     "link type(s)": "OTU-4",
                     "physical node": "S8",
                     "unnumberd/ifIndex": 1,
                     "port type": "inter-domain port",
                     "connected to": "S32"
                   },
                   "tp-id": "4",
                   "ietf-te-topology:te-tp-id": 4,
                   "ietf-te-topology:te": {
                     "name": "AN1-4 LTP",
                     "admin-status": "up",
                     "// __DISCUSS__ interface-switching-capability":
   "\
```

```
   \See Link attributes (teNodeId/10.0.0.1/teLinkId/4)",
                     "// __DISCUSS__ inter-domain-plug-id": "Inter-
   doma\
   \in Link",
                     "oper-status": "up",
                     "// __DISCUSS__ ietf-otn-topology:supported-
   payloa\
   \d-types": "Empty? (inter-domain OTN link)",
                     "// __DEFAULT__ ietf-otn-topology:client-facing":
   \
   \false
                   }
                 },
                 {
                   "// __DESCRIPTION__:__LTP__": {
                     "name": "AN1-5 LTP",
                     "link type(s)": "OTU-4",
                     "physical node": "S8",
                     "unnumberd/ifIndex": 5,
                     "port type": "inter-domain port",
                     "connected to": "S12"
                   },
                   "tp-id": "5",
                   "ietf-te-topology:te-tp-id": 5,
                   "ietf-te-topology:te": {
                     "name": "AN1-5 LTP",
                     "admin-status": "up",
                     "// __DISCUSS__ interface-switching-capability":
   "\
   \See Link attributes (teNodeId/10.0.0.1/teLinkId/5)",
                     "// __DISCUSS__ inter-domain-plug-id": "Inter-
   doma\
   \in Link",
                     "oper-status": "up",
                     "// __DISCUSS__ ietf-otn-topology:supported-
   payloa\
   \d-types": "Empty? (inter-domain OTN link)",
                     "// __DEFAULT__ ietf-otn-topology:client-facing":
   \
   \false
                   }
                 },
                 {
                   "// __DESCRIPTION__:__LTP__": {
                     "name": "AN1-6 LTP",
```

```
                      "link type(s)": "OTU-4",
                      "physical node": "S7",
                      "unnumberd/ifIndex": 4,
                      "port type": "inter-domain port",
                      "connected to": "S11"
                    },
                    "tp-id": "6",
                    "ietf-te-topology:te-tp-id": 6,
                    "ietf-te-topology:te": {
                      "name": "AN1-6 LTP",
                      "admin-status": "up",
                      "// __DISCUSS__ interface-switching-capability":
   "\
   \See Link attributes (teNodeId/10.0.0.1/teLinkId/6)",
                      "// __DISCUSS__ inter-domain-plug-id": "Inter-
   doma\
   \in Link",
                      "oper-status": "up",
                      "// __DISCUSS__ ietf-otn-topology:supported-
   payloa\
   \d-types": "Empty? (inter-domain OTN link)",
                      "// __DEFAULT__ ietf-otn-topology:client-facing":
   \
   \false
                    }
                  },
                  {
                    "// __DESCRIPTION__:__LTP__": {
                      "name": "AN1-7 LTP",
                      "link type(s)": "OTU-2",
                      "physical node": "S6",
                      "unnumberd/ifIndex": 2,
                      "port type": "tributary port",
                      "connected to": "R3"
                    },
                    "tp-id": "7",
                    "ietf-te-topology:te-tp-id": 7,
                    "ietf-te-topology:te": {
                      "name": "AN1-7 LTP",
                      "admin-status": "up",
                      "// __DISCUSS__ interface-switching-capability":
   "\
   \See Link attributes (teNodeId/10.0.0.1/teLinkId/7)",
                      "// __DISCUSS__ inter-domain-plug-id": "Access
   Lin\
```

```
\k",
                  "oper-status": "up",
                  "// __DISCUSS__ ietf-otn-topology:supported-
payloa\
\d-types": "List of ODU clients?",
                  "// __DISCUSS__ ietf-otn-topology:client-facing":
\
\true
                }
              }
            ]
          }
        ],
        "// ietf-network-topology:link": "Access links to be
reviewe\
\d in a future update",
        "ietf-network-topology:link": [
          {
            "// __DESCRIPTION__:__LINK__": {
              "name": "Access Link from AN1-1",
              "type": "access link",
              "physical link": "Link from S3-1 to R1"
            },
            "link-id": "teNodeId/10.0.0.1/teLinkId/1",
            "ietf-te-topology:te": {
              "te-link-attributes": {
                "name": "Access Link from AN1-1",
                "// __DISCUSS__ access-type": "Can we assume point-
t\
\o-point as the default value?",
                "access-type": "point-to-point",
                "// __COMMENT__ external-domain": "Empty: the plug-
i\
\d is used instead of this container",
                "// __DISCUSS__ is-abstract": "To be discussed with
\
\TE Topology authors",
                "// __DISCUSS__ underlay": "To be discussed with TE
\
\Topology authors",
                "admin-status": "up",
                "interface-switching-capability": [
                  {
                    "switching-capability": "ietf-te-
types:switching\
```

```
\-otn",
                    "encoding": "ietf-te-types:lsp-encoding-oduk",
                    "max-lsp-bandwidth": [
                      {
                        "priority": 0,
                        "// __DISCUSS__ te-bandwidth": "ODU2"
                      }
                    ]
                  }
                ],
                "// __COMMENT__ label-restrictions": "Not described
\
\in this JSON example",
                "// __DISCUSS__ link-protection-type": "Can we
assum\
\e unprotected as the default value?",
                "link-protection-type": "unprotected",
                "max-link-bandwidth": {
                  "// __DISCUSS__ te-bandwidth": "1xODU2"
                },
                "max-resv-link-bandwidth": {
                  "// __DISCUSS__ te-bandwidth": "1xODU2"
                },
                "unreserved-bandwidth": [
                  {
                    "priority": 0,
                    "// __DISCUSS__ te-bandwidth": "1xODU2"
                  }
                ]
              },
              "oper-status": "up",
              "// __EMPTY__ is-transitional": "It is not a
transitio\
\nal link",
              "// __DISCUSS__ underlay ": "To be discussed with TE
T\
\opology authors"
            },
            "source": {
              "source-node": "10.0.0.1",
              "source-tp": 1
            },
            "// __EMPTY__ destination": "access link"
          },
          {
```

```
               "// __DESCRIPTION__:__LINK__": {
                 "name": "Inter-domain Link from AN1-2",
                 "type": "inter-domain link",
                 "physical link": "Link from S2-1 to S31"
               },
               "link-id": "teNodeId/10.0.0.1/teLinkId/2",
               "ietf-te-topology:te": {
                 "te-link-attributes": {
                   "name": "Inter-domain Link from AN1-2",
                   "// __DISCUSS__ access-type": "Can we assume point-
   t\
   \o-point as the default value?",
                   "access-type": "point-to-point",
                   "// __DISCUSS__ is-abstract": "To be discussed with
   \
   \TE Topology authors",
                   "// __DISCUSS__ underlay": "To be discussed with TE
   \
   \Topology authors",
                   "admin-status": "up",
                   "interface-switching-capability": [
                     {
                       "switching-capability": "ietf-te-
   types:switching\
   \-otn",
                       "encoding": "ietf-te-types:lsp-encoding-oduk",
                       "max-lsp-bandwidth": [
                         {
                           "priority": 0,
                           "// __DISCUSS__ te-bandwidth": "ODU4"
                         }
                       ],
                       "// __DISCUSS__ label-restrictions": "To be
   adde\
   \d?"
                     }
                   ],
                   "// __DISCUSS__ link-protection-type": "Can we
   assum\
   \e unprotected as the default value?",
                   "link-protection-type": "unprotected",
                   "max-link-bandwidth": {
                     "// __DISCUSS__ te-bandwidth": "1xODU4, ..."
                   },
                   "max-resv-link-bandwidth": {
```

```
                      "// __DISCUSS__ te-bandwidth": "1xODU4, ..."
                    },
                    "unreserved-bandwidth": [
                      {
                        "priority": 0,
                        "// __DISCUSS__ te-bandwidth": "1xODU4, ..."
                      }
                    ]
                  },
                  "oper-status": "up",
                  "// __EMPTY__ is-transitional": "It is not a
   transitio\
   \nal link",
                  "// __DISCUSS__ underlay ": "To be discussed with TE
   T\
   \opology authors"
                },
                "source": {
                  "source-node": "10.0.0.1",
                  "source-tp": 2
                },
                "// __EMPTY__ destination": "inter-domain link"
              },
              {
                "// __DESCRIPTION__:__LINK__": {
                  "name": "Access Link from AN1-3",
                  "type": "access link",
                  "physical link": "Link from S6-1 to R2"
                },
                "link-id": "teNodeId/10.0.0.1/teLinkId/3",
                "ietf-te-topology:te": {
                  "te-link-attributes": {
                    "name": "Access Link from AN1-3",
                    "// __DISCUSS__ access-type": "Can we assume point-
   t\
   \o-point as the default value?",
                    "access-type": "point-to-point",
                    "// __DISCUSS__ is-abstract": "To be discussed with
   \
   \TE Topology authors",
                    "// __DISCUSS__ underlay": "To be discussed with TE
   \
   \Topology authors",
                    "admin-status": "up",
                    "interface-switching-capability": [
```

```
                     {
                       "switching-capability": "ietf-te-
   types:switching\
   \-otn",
                       "encoding": "ietf-te-types:lsp-encoding-oduk",
                       "max-lsp-bandwidth": [
                         {
                           "priority": 0,
                           "// __DISCUSS__ te-bandwidth": "ODU2"
                         }
                       ],
                       "// __DISCUSS__ label-restrictions": "To be
   adde\
   \d?"
                     }
                   ],
                   "// __DISCUSS__ link-protection-type": "Can we
   assum\
   \e unprotected as the default value?",
                   "link-protection-type": "unprotected",
                   "max-link-bandwidth": {
                     "// __DISCUSS__ te-bandwidth": "1xODU2"
                   },
                   "unreserved-bandwidth": [
                     {
                       "priority": 0,
                       "// __DISCUSS__ te-bandwidth": "1xODU2"
                     }
                   ],
                   "max-resv-link-bandwidth": {
                     "// __DISCUSS__ te-bandwidth": "1xODU2"
                   }
                 },
                 "oper-status": "up",
                 "// __EMPTY__ is-transitional": "It is not a
   transitio\
   \nal link",
                 "// __DISCUSS__ underlay ": "To be discussed with TE
   T\
   \opology authors"
               },
               "source": {
                 "source-node": "10.0.0.1",
                 "source-tp": 3
               },
```

```
              "// __EMPTY__ destination": "access link"
            },
            {
              "// __DESCRIPTION__:__LINK__": {
                "name": "Inter-domain Link from AN1-4",
                "type": "inter-domain link",
                "physical link": "Link from S8-1 to S32"
              },
              "link-id": "teNodeId/10.0.0.1/teLinkId/4",
              "ietf-te-topology:te": {
                "te-link-attributes": {
                  "name": "Inter-domain Link from AN1-4",
                  "// __DISCUSS__ access-type": "Can we assume point-
t\
\o-point as the default value?",
                  "access-type": "point-to-point",
                  "// __DISCUSS__ is-abstract": "To be discussed with
\
\TE Topology authors",
                  "// __DISCUSS__ underlay": "To be discussed with TE
\
\Topology authors",
                  "admin-status": "up",
                  "interface-switching-capability": [
                    {
                      "switching-capability": "ietf-te-
types:switching\
\-otn",
                      "encoding": "ietf-te-types:lsp-encoding-oduk",
                      "max-lsp-bandwidth": [
                        {
                          "priority": 0,
                          "// __DISCUSS__ te-bandwidth": "ODU4"
                        }
                      ],
                      "// __DISCUSS__ label-restrictions": "To be
adde\
\d?"
                    }
                  ],
                  "// __DISCUSS__ link-protection-type": "Can we
assum\
\e unprotected as the default value?",
                  "link-protection-type": "unprotected",
                  "max-link-bandwidth": {
```

```
                    "// __DISCUSS__ te-bandwidth": "1xODU4, ..."
                  },
                  "unreserved-bandwidth": [
                    {
                      "priority": 0,
                      "// __DISCUSS__ te-bandwidth": "1xODU4, ..."
                    }
                  ],
                  "max-resv-link-bandwidth": {
                    "// __DISCUSS__ te-bandwidth": "1xODU4, ..."
                  }
                },
                "oper-status": "up",
                "// __EMPTY__ is-transitional": "It is not a
   transitio\
   \nal link",
                "// __DISCUSS__ underlay ": "To be discussed with TE
   T\
   \opology authors"
              },
              "source": {
                "source-node": "10.0.0.1",
                "source-tp": 4
              },
              "// __EMPTY__ destination": "inter-domain link"
            },
            {
              "// __DESCRIPTION__:__LINK__": {
                "name": "Inter-domain Link from AN1-5",
                "type": "inter-domain link",
                "physical link": "Link from S8-5 to S12"
              },
              "link-id": "teNodeId/10.0.0.1/teLinkId/5",
              "ietf-te-topology:te": {
                "te-link-attributes": {
                  "name": "Inter-domain Link from AN1-5",
                  "// __DISCUSS__ access-type": "Can we assume point-
   t\
   \o-point as the default value?",
                  "access-type": "point-to-point",
                  "// __DISCUSS__ is-abstract": "To be discussed with
   \
   \TE Topology authors",
                  "// __DISCUSS__ underlay": "To be discussed with TE
   \
```

```
   \Topology authors",
                    "admin-status": "up",
                    "interface-switching-capability": [
                      {
                        "switching-capability": "ietf-te-
   types:switching\
   \-otn",
                        "encoding": "ietf-te-types:lsp-encoding-oduk",
                        "max-lsp-bandwidth": [
                          {
                            "priority": 0,
                            "// __DISCUSS__ te-bandwidth": "ODU4"
                          }
                        ],
                        "// __DISCUSS__ label-restrictions": "To be
   adde\
   \d?"
                      }
                    ],
                    "// __DISCUSS__ link-protection-type": "Can we
   assum\
   \e unprotected as the default value?",
                    "link-protection-type": "unprotected",
                    "max-link-bandwidth": {
                      "// __DISCUSS__ te-bandwidth": "1xODU4, ..."
                    },
                    "max-resv-link-bandwidth": {
                      "// __DISCUSS__ te-bandwidth": "1xODU4, ..."
                    },
                    "unreserved-bandwidth": [
                      {
                        "priority": 0,
                        "// __DISCUSS__ te-bandwidth": "1xODU4, ..."
                      }
                    ]
                  },
                  "oper-status": "up",
                  "// __EMPTY__ is-transitional": "It is not a
   transitio\
   \nal link",
                  "// __DISCUSS__ underlay ": "To be discussed with TE
   T\
   \opology authors"
                },
                "source": {
```

```
                 "source-node": "10.0.0.1",
                 "source-tp": 5
               },
               "// __EMPTY__ destination": "inter-domain link"
             },
             {
               "// __DESCRIPTION__:__LINK__": {
                 "name": "Inter-domain Link from AN1-6",
                 "type": "inter-domain link",
                 "physical link": "Link from S7-4 to S11"
               },
               "link-id": "teNodeId/10.0.0.1/teLinkId/6",
               "ietf-te-topology:te": {
                 "te-link-attributes": {
                   "name": "Inter-domain Link from AN1-6",
                   "// __DISCUSS__ access-type": "Can we assume point-
   t\
   \o-point as the default value?",
                   "access-type": "point-to-point",
                   "// __DISCUSS__ is-abstract": "To be discussed with
   \
   \TE Topology authors",
                   "// __DISCUSS__ underlay": "To be discussed with TE
   \
   \Topology authors",
                   "admin-status": "up",
                   "interface-switching-capability": [
                     {
                       "switching-capability": "ietf-te-
   types:switching\
   \-otn",
                       "encoding": "ietf-te-types:lsp-encoding-oduk",
                       "max-lsp-bandwidth": [
                         {
                           "priority": 0,
                           "// __DISCUSS__ te-bandwidth": "ODU4"
                         }
                       ],
                       "// __DISCUSS__ label-restrictions": "To be
   adde\
   \d?"
                     }
                   ],
                   "// __DISCUSS__ link-protection-type": "Can we
   assum\
```

```
   \e unprotected as the default value?",
                   "link-protection-type": "unprotected",
                   "max-link-bandwidth": {
                     "// __DISCUSS__ te-bandwidth": "1xODU4, ..."
                   },
                   "max-resv-link-bandwidth": {
                     "// __DISCUSS__ te-bandwidth": "1xODU4, ..."
                   },
                   "unreserved-bandwidth": [
                     {
                       "priority": 0,
                       "// __DISCUSS__ te-bandwidth": "1xODU4, ..."
                     }
                   ]
                 },
                 "oper-status": "up",
                 "// __EMPTY__ is-transitional": "It is not a
   transitio\
   \nal link",
                 "// __DISCUSS__ underlay ": "To be discussed with TE
   T\
   \opology authors"
               },
               "source": {
                 "source-node": "10.0.0.1",
                 "source-tp": 6
               },
               "// __EMPTY__ destination": "inter-domain link"
             },
             {
               "// __DESCRIPTION__:__LINK__": {
                 "name": "Access Link from AN1-7",
                 "type": "access link",
                 "physical link": "Link from S6-2 to R3"
               },
               "link-id": "teNodeId/10.0.0.1teLinkId/7",
               "ietf-te-topology:te": {
                 "te-link-attributes": {
                   "name": "Access Link from AN1-7",
                   "// __DISCUSS__ access-type": "Can we assume point-
   t\
   \o-point as the default value?",
                   "access-type": "point-to-point",
                   "// __DISCUSS__ is-abstract": "To be discussed with
   \
```

```
   \TE Topology authors",
                 "// __DISCUSS__ underlay": "To be discussed with TE
   \
   \Topology authors",
                 "admin-status": "up",
                 "interface-switching-capability": [
                   {
                     "switching-capability": "ietf-te-
   types:switching\
   \-otn",
                     "encoding": "ietf-te-types:lsp-encoding-oduk",
                     "max-lsp-bandwidth": [
                       {
                         "priority": 0,
                         "// __DISCUSS__ te-bandwidth": "ODU2"
                       }
                     ],
                     "// __DISCUSS__ label-restrictions": "To be
   adde\
   \d?"
                   }
                 ],
                 "// __DISCUSS__ link-protection-type": "Can we
   assum\
   \e unprotected as the default value?",
                 "link-protection-type": "unprotected",
                 "max-link-bandwidth": {
                   "// __DISCUSS__ te-bandwidth": "1xODU2"
                 },
                 "max-resv-link-bandwidth": {
                   "// __DISCUSS__ te-bandwidth": "1xODU2"
                 },
                 "unreserved-bandwidth": [
                   {
                     "priority": 0,
                     "// __DISCUSS__ te-bandwidth": "1xODU2"
                   }
                 ]
               },
               "oper-status": "up",
               "// __EMPTY__ is-transitional": "It is not a
   transitio\
   \nal link",
               "// __DISCUSS__ underlay ": "To be discussed with TE
   T\
```

```
   \opology authors"
               },
               "source": {
                 "source-node": "10.0.0.1",
                 "source-tp": 7
               },
               "// __EMPTY__ destination": "access link"
             }
           ]
         }
       ]
     }
   }
```


B.2. JSON Examples for Service Configuration

B.2.1. JSON Code: mpi1-odu2-service-config.json

This is the JSON code reporting the ODU2 transit service configuration @ MPI:

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

{
  "// __TITLE__": "ODU2 Service Configuration @ MPI1",
  "// __LAST_UPDATE__": "October 22, 2018",
  "// __MISSING_ATTRIBUTES__": true,
  "// __REFERENCE_DRAFTS__": {
    "ietf-routing-types@2017-12-04": "rfc8294",
    "ietf-otn-types@2018-06-07": "draft-ietf-ccamp-otn-tunnel-model-
\
\02",
    "ietf-te-types@2018-07-01": "draft-ietf-teas-yang-te-16",
    "ietf-te@2018-07-01": "draft-ietf-teas-yang-te-16",
    "ietf-otn-tunnel@2018-06-07": "draft-ietf-ccamp-otn-tunnel-
model\
\-02"
  },
  "// __RESTCONF_OPERATION__": {
    "operation": "PUT",
    "url": "http://{{PNC1-ADDR}}/restconf/data/ietf-te:te"
  },
  "ietf-te:te": {
    "tunnels": {
      "tunnel": [
        {
          "name": "mpi1-odu2-service",
          "// identifier": "ODU2-SERVICE-TUNNEL-ID @ MPI1",
          "identifier": 1,
          "description": "ODU2 Service implemented by ODU2 OTN
Tunne\
\l Segment @ MPI1",
          "// encoding and switching-type": "ODU",
          "encoding": "ietf-te-types:lsp-encoding-oduk ",
          "switching-type": "ietf-te-types:switching-otn",
          "// source": "None: transit tunnel segment",
          "// destination": "None: transit tunnel segment",
          "// src-tp-id": "None: transit tunnel segment",
          "// dst-tp-id": "None: transit tunnel segment",
          "// ietf-otn-tunnel:src-client-signal": "None: ODU
transit\
\ tunnel segment",
          "// ietf-otn-tunnel:dst-client-signal": "None: ODU
transit\
\ tunnel segment",
```

```
             "bidirectional": true,
             "// protection": "No protection",
             "// __ DEFAULT __ protection": {
               "// __ DEFAULT __ enable": false
             },
             "// restoration": "No restoration",
             "// __ DEFAULT __ restoration": {
               "// __ DEFAULT __ enable": false
             },
             "// te-topology-identifier": "ODU Black Topology @ MPI1",
             "te-topology-identifier": {
               "provider-id": 201,
               "client-id": 300,
               "topology-id": "otn-black-topology"
             },
             "te-bandwidth": {
               "ietf-otn-tunnel:odu-type": "ietf-otn-types:prot-ODU2"
             },
             "// hierarchical-link": "None: transit tunnel segment",
             "p2p-primary-paths": {
               "p2p-primary-path": [
                 {
                   "name": "mpi1-odu2-service-primary-path",
                   "path-scope": "ietf-te-types:path-scope-segment",
                   "// te-bandwidth": "None: only the tunnel bandwidth
   \
   \needs to be specified in transport applications",
                   "explicit-route-objects": {
                     "route-object-include-exclude": [
                       {
                         "// comment": "Tunnel hand-off OTU2 ingress
   in\
   \terface (S3-1)",
                         "index": 1,
                         "explicit-route-usage": "ietf-te-types:route-
   i\
   \nclude-ero",
                         "num-unnum-hop": {
                           "// node-id": "AN1 Node",
                           "node-id": "10.0.0.1",
                           "// link-tp-id": "AN1-1 LTP",
                           "link-tp-id": 1,
                           "hop-type": "STRICT",
                           "direction": "INCOMING"
                         }
```

```
                      },
                      {
                        "// comment": "Tunnel hand-off ODU2 ingress
   la\
   \bel (ODU2 over OTU2) at S3-1",
                        "index": 2,
                        "explicit-route-usage": "ietf-te-types:route-
   i\
   \nclude-ero",
                        "label-hop": {
                          "te-label": {
                            "// __ DISCUSS __ odu-label": "How are HO-
   \
   \ODU (ODUk over OTUk) label represented?",
                            "// __ DISCUSS __ direction": "Check with
   \
   \TE Tunnel authors",
                            "direction": "FORWARD "
                          }
                        }
                      },
                      {
                        "// comment": "Tunnel hand-off OTU4 egress
   int\
   \erface (S2-1)",
                        "index": 3,
                        "explicit-route-usage": "ietf-te-types:route-
   i\
   \nclude-ero",
                        "num-unnum-hop": {
                          "// node-id": "AN1 Node",
                          "node-id": "10.0.0.1",
                          "// link-tp-id": "AN1-2 LTP",
                          "link-tp-id": 1,
                          "hop-type": "STRICT",
                          "direction": "OUTGOING"
                        }
                      },
                      {
                        "// comment": "Tunnel hand-off ODU2 egress
   lab\
   \el (ODU2 over OTU4) at S2-1",
                        "index": 4,
                        "explicit-route-usage": "ietf-te-types:route-
   i\
```

```
   \nclude-ero",
                         "label-hop": {
                           "te-label": {
                             "ietf-otn-tunnel:tpn": 1,
                             "ietf-otn-tunnel:tsg": "ietf-otn-
   types:tsg\
   \-1.25G",
                             "ietf-otn-tunnel:ts-list": "1-8",
                             "// __ DISCUSS __ direction": "Check with
   \
   \TE Tunnel authors",
                             "direction": "FORWARD "
                           }
                         }
                       }
                     ]
                   }
                 }
               ]
             }
           }
         ]
       }
     }
   }
```


B.2.2. JSON Code: mpi1-odu2-tunnel-config.json

The JSON code for this use case will be added in a future version of this document

An incomplete version is located on GitHub at:

https://github.com/danielkinguk/transport-nbi

B.2.3. JSON Code: mpi1-epl-service-config.json

The JSON code for this use case will be added in a future version of this document

An incomplete version is located on GitHub at:

https://github.com/danielkinguk/transport-nbi

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Internet Draft
Intended status: Standard Track
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October 18, 2018

A Yang Data Model for WSON Tunnel

draft-ietf-ccamp-wson-tunnel-model-02

Abstract

This document provides a YANG data model for WSON TE tunnel.

Status of this Memo

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

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Table of Contents

1. Introduction

This document provides a YANG data model for WSON tunnel model. The YANG model described in this document is a WSON technology-specific Yang Tunnel model based on the information model developed in [RFC7446] and the two encoding documents [RFC7581] and [RFC7579] that developed protocol independent encodings based on [RFC7446].

This document augments the generic TE tunnel model [TE-Tunnel].

1.1. Terminology

Refer to [RFC7446] and [RFC7581] for the key terms used in this document.

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

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

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

- configuration data
- state data

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

1.2. Tree diagram

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

1.3. Prefixes in Data Node Names

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

Prefix	YANG module	Reference
layer0-types	ietf-layer0-types	[WSON-TOPO]
wson-tunnel	ietf-wson-tunnel	[RFCXXXX]
tepc	ietf-te-path-computation	[TE-PC]
te	ietf-te	[TE-Tunnel]

```
| otn-types   | ietf-otn-types           | [OTN-TOPO]      |
+-------------+--------------------------+-----------------+
```

Table 1: Prefixes and corresponding YANG modules

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

2. YANG Model (Tree Structure)

```
module: ietf-wson-tunnel
  augment /te:te/te:tunnels/te:tunnel:
    +--rw src-client-signal?   identityref
    +--rw dst-client-signal?   identityref
    +--rw fec-type?            identityref
    +--rw termination-type?    identityref
    +--rw bit-stuffing?        boolean
  augment /te:te/te:globals/te:named-path-constraints/te:named-path-
constraint/te:te-bandwidth/te:technology:
    +--:(wson)
       +--rw bandwidth-type?   identityref
  augment /te:te/te:tunnels/te:tunnel/te:te-bandwidth/te:technology:
    +--:(wson)
       +--rw bandwidth-type?   identityref
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:te-bandwidth/te:technology:
    +--:(wson)
       +--rw bandwidth-type?   identityref
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-path/te:te-bandwidth/te:technology:
    +--:(wson)
       +--rw bandwidth-type?   identityref
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:te-bandwidth/te:technology:
    +--:(wson)
       +--rw bandwidth-type?   identityref
  augment /te:te/te:globals/te:named-path-constraints/te:named-path-
constraint/te:explicit-route-objects/te:route-object-exclude-
always/te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
```

```
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  augment /te:te/te:globals/te:named-path-constraints/te:named-path-
constraint/te:explicit-route-objects/te:route-object-include-
exclude/te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  augment /te:te/te:globals/te:named-path-constraints/te:named-path-
constraint/te:path-in-segment/te:forward/te:label-restrictions/te:label-
restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
  augment /te:te/te:globals/te:named-path-constraints/te:named-path-
constraint/te:path-in-segment/te:forward/te:label-restrictions/te:label-
restriction/te:label-start/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:globals/te:named-path-constraints/te:named-path-
constraint/te:path-in-segment/te:forward/te:label-restrictions/te:label-
restriction/te:label-end/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
```

```
  augment /te:te/te:globals/te:named-path-constraints/te:named-path-
constraint/te:path-in-segment/te:reverse/te:label-restrictions/te:label-
restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
  augment /te:te/te:globals/te:named-path-constraints/te:named-path-
constraint/te:path-in-segment/te:reverse/te:label-restrictions/te:label-
restriction/te:label-start/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:globals/te:named-path-constraints/te:named-path-
constraint/te:path-in-segment/te:reverse/te:label-restrictions/te:label-
restriction/te:label-end/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:globals/te:named-path-constraints/te:named-path-
constraint/te:path-out-segment/te:forward/te:label-restrictions/te:label-
restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
  augment /te:te/te:globals/te:named-path-constraints/te:named-path-
constraint/te:path-out-segment/te:forward/te:label-restrictions/te:label-
restriction/te:label-start/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:globals/te:named-path-constraints/te:named-path-
constraint/te:path-out-segment/te:forward/te:label-restrictions/te:label-
restriction/te:label-end/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
```

```
             +--rw channel-wavelength?   uint32
  augment /te:te/te:globals/te:named-path-constraints/te:named-path-
constraint/te:path-out-segment/te:reverse/te:label-restrictions/te:label-
restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
  augment /te:te/te:globals/te:named-path-constraints/te:named-path-
constraint/te:path-out-segment/te:reverse/te:label-restrictions/te:label-
restriction/te:label-start/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:globals/te:named-path-constraints/te:named-path-
constraint/te:path-out-segment/te:reverse/te:label-restrictions/te:label-
restriction/te:label-end/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:optimizations/te:algorithm/te:metric/te:optimization-
metric/te:explicit-route-exclude-objects/te:route-object-exclude-
object/te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:optimizations/te:algorithm/te:metric/te:optimization-
metric/te:explicit-route-include-objects/te:route-object-include-
object/te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
```

```
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:explicit-route-objects/te:route-object-exclude-
always/te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:explicit-route-objects/te:route-object-include-
exclude/te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:path-in-segment/te:forward/te:label-restrictions/te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:path-in-segment/te:forward/te:label-restrictions/te:label-
restriction/te:label-start/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
```

```
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:path-in-segment/te:forward/te:label-restrictions/te:label-
restriction/te:label-end/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:path-in-segment/te:reverse/te:label-restrictions/te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:path-in-segment/te:reverse/te:label-restrictions/te:label-
restriction/te:label-start/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:path-in-segment/te:reverse/te:label-restrictions/te:label-
restriction/te:label-end/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:path-out-segment/te:forward/te:label-restrictions/te:label-
restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:path-out-segment/te:forward/te:label-restrictions/te:label-
restriction/te:label-start/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
```

```
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:path-out-segment/te:forward/te:label-restrictions/te:label-
restriction/te:label-end/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:path-out-segment/te:reverse/te:label-restrictions/te:label-
restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:path-out-segment/te:reverse/te:label-restrictions/te:label-
restriction/te:label-start/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:path-out-segment/te:reverse/te:label-restrictions/te:label-
restriction/te:label-end/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:state/te:path-properties/te:path-route-objects/te:path-computed-route-
object/te:state/te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(wson)
       +--ro (grid-type)?
          +--:(dwdm)
          |  +--ro (single-or-super-channel)?
          |     +--:(single)
          |     |  +--ro channel-freq?          frequency-thz
          |     +--:(super)
          |        +--ro subcarrier-channels*   frequency-thz
          +--:(cwdm)
```

```
             +--ro channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:state/te:lsps/te:lsp/te:lsp-record-route-subobjects/te:record-route-
subobject/te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(wson)
       +--ro (grid-type)?
          +--:(dwdm)
          |  +--ro (single-or-super-channel)?
          |     +--:(single)
          |     |  +--ro channel-freq?          frequency-thz
          |     +--:(super)
          |        +--ro subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--ro channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:state/te:lsps/te:lsp/te:path-properties/te:path-route-objects/te:path-
computed-route-object/te:state/te:type/te:label/te:label-hop/te:te-
label/te:technology:
    +--:(wson)
       +--ro (grid-type)?
          +--:(dwdm)
          |  +--ro (single-or-super-channel)?
          |     +--:(single)
          |     |  +--ro channel-freq?          frequency-thz
          |     +--:(super)
          |        +--ro subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--ro channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-
path/te:optimizations/te:algorithm/te:metric/te:optimization-
metric/te:explicit-route-exclude-objects/te:route-object-exclude-
object/te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-
```

```
path/te:optimizations/te:algorithm/te:metric/te:optimization-
metric/te:explicit-route-include-objects/te:route-object-include-
object/te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-path/te:explicit-route-objects/te:route-object-
exclude-always/te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-path/te:explicit-route-objects/te:route-object-
include-exclude/te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-path/te:path-in-segment/te:forward/te:label-
restrictions/te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
```

```
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-path/te:path-in-segment/te:forward/te:label-
restrictions/te:label-restriction/te:label-start/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-path/te:path-in-segment/te:forward/te:label-
restrictions/te:label-restriction/te:label-end/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-path/te:path-in-segment/te:reverse/te:label-
restrictions/te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-path/te:path-in-segment/te:reverse/te:label-
restrictions/te:label-restriction/te:label-start/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-path/te:path-in-segment/te:reverse/te:label-
restrictions/te:label-restriction/te:label-end/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-path/te:path-out-segment/te:forward/te:label-
restrictions/te:label-restriction:
    +--rw grid-type?   identityref
```

```
    +--rw priority?    uint8
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-path/te:path-out-segment/te:forward/te:label-
restrictions/te:label-restriction/te:label-start/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-path/te:path-out-segment/te:forward/te:label-
restrictions/te:label-restriction/te:label-end/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-path/te:path-out-segment/te:reverse/te:label-
restrictions/te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-path/te:path-out-segment/te:reverse/te:label-
restrictions/te:label-restriction/te:label-start/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-path/te:path-out-segment/te:reverse/te:label-
restrictions/te:label-restriction/te:label-end/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-path/te:state/te:path-properties/te:path-route-
```

```
objects/te:path-computed-route-object/te:state/te:type/te:label/te:label-
hop/te:te-label/te:technology:
    +--:(wson)
       +--ro (grid-type)?
          +--:(dwdm)
          |  +--ro (single-or-super-channel)?
          |     +--:(single)
          |     |  +--ro channel-freq?          frequency-thz
          |     +--:(super)
          |        +--ro subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--ro channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-path/te:state/te:lsps/te:lsp/te:lsp-record-route-
subobjects/te:record-route-subobject/te:type/te:label/te:label-hop/te:te-
label/te:technology:
    +--:(wson)
       +--ro (grid-type)?
          +--:(dwdm)
          |  +--ro (single-or-super-channel)?
          |     +--:(single)
          |     |  +--ro channel-freq?          frequency-thz
          |     +--:(super)
          |        +--ro subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--ro channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths/te:p2p-primary-
path/te:p2p-reverse-primary-path/te:state/te:lsps/te:lsp/te:path-
properties/te:path-route-objects/te:path-computed-route-
object/te:state/te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(wson)
       +--ro (grid-type)?
          +--:(dwdm)
          |  +--ro (single-or-super-channel)?
          |     +--:(single)
          |     |  +--ro channel-freq?          frequency-thz
          |     +--:(super)
          |        +--ro subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--ro channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:optimizations/te:algorithm/te:metric/te:optimization-
metric/te:explicit-route-exclude-objects/te:route-object-exclude-
object/te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(wson)
```

```
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:optimizations/te:algorithm/te:metric/te:optimization-
metric/te:explicit-route-include-objects/te:route-object-include-
object/te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:explicit-route-objects/te:route-object-exclude-
always/te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:explicit-route-objects/te:route-object-include-
exclude/te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
```

```
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:path-in-segment/te:forward/te:label-restrictions/te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:path-in-segment/te:forward/te:label-restrictions/te:label-
restriction/te:label-start/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:path-in-segment/te:forward/te:label-restrictions/te:label-
restriction/te:label-end/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:path-in-segment/te:reverse/te:label-restrictions/te:label-restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:path-in-segment/te:reverse/te:label-restrictions/te:label-
restriction/te:label-start/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:path-in-segment/te:reverse/te:label-restrictions/te:label-
restriction/te:label-end/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
```

```
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:path-out-segment/te:forward/te:label-restrictions/te:label-
restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:path-out-segment/te:forward/te:label-restrictions/te:label-
restriction/te:label-start/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:path-out-segment/te:forward/te:label-restrictions/te:label-
restriction/te:label-end/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:path-out-segment/te:reverse/te:label-restrictions/te:label-
restriction:
    +--rw grid-type?   identityref
    +--rw priority?    uint8
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:path-out-segment/te:reverse/te:label-restrictions/te:label-
restriction/te:label-start/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:path-out-segment/te:reverse/te:label-restrictions/te:label-
restriction/te:label-end/te:te-label/te:technology:
    +--:(wson)
       +--rw (grid-type)?
```

```
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:state/te:path-properties/te:path-route-objects/te:path-computed-route-
object/te:state/te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(wson)
       +--ro (grid-type)?
          +--:(dwdm)
          |  +--ro (single-or-super-channel)?
          |     +--:(single)
          |     |  +--ro channel-freq?          frequency-thz
          |     +--:(super)
          |        +--ro subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--ro channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:state/te:lsps/te:lsp/te:lsp-record-route-subobjects/te:record-route-
subobject/te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(wson)
       +--ro (grid-type)?
          +--:(dwdm)
          |  +--ro (single-or-super-channel)?
          |     +--:(single)
          |     |  +--ro channel-freq?          frequency-thz
          |     +--:(super)
          |        +--ro subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--ro channel-wavelength?    uint32
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths/te:p2p-secondary-
path/te:state/te:lsps/te:lsp/te:path-properties/te:path-route-objects/te:path-
computed-route-object/te:state/te:type/te:label/te:label-hop/te:te-
label/te:technology:
    +--:(wson)
       +--ro (grid-type)?
          +--:(dwdm)
          |  +--ro (single-or-super-channel)?
          |     +--:(single)
          |     |  +--ro channel-freq?          frequency-thz
          |     +--:(super)
          |        +--ro subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--ro channel-wavelength?    uint32
```

```
  augment /te:te/te:lsps-state/te:lsp/te:lsp-record-route-
subobjects/te:record-route-subobject/te:type/te:label/te:label-hop/te:te-
label/te:technology:
    +--:(wson)
       +--ro (grid-type)?
          +--:(dwdm)
          |  +--ro (single-or-super-channel)?
          |     +--:(single)
          |     |  +--ro channel-freq?          frequency-thz
          |     +--:(super)
          |        +--ro subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--ro channel-wavelength?    uint32
  augment /te:tunnels-rpc/te:input/te:tunnel-info/tepc:path-request:
    +---- src-client-signal?       identityref
    +---- dst-client-signal?       identityref
    +---- fec-type?                identityref
    +---- termination-type?        identityref
    +---- bit-stuffing?            boolean
    +---- wavelength-assignment?   identityref
```

3. TE Tunnel Model for WSON

```
<CODE BEGINS> file "ietf-wson-tunnel@2018-10-15.yang"

module ietf-wson-tunnel {
  yang-version 1.1;

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

  import ietf-te { prefix "te"; }
  import ietf-layer0-types{ prefix "layer0-types"; }
  import ietf-te-path-computation { prefix "tepc"; }
  import ietf-otn-types { prefix "otn-types";}

  organization
    "IETF CCAMP Working Group";

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

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

     WG Chair: Daniele Ceccarelli
               <mailto:daniele.ceccarelli@ericsson.com>

     WG Chair: Fatai Zhang
               <mailto:zhangfatai@huawei.com>

     Editor: Young Lee <leeyoung@huawei.com>
     Editor: Aihua Guo <aihuaguo@huawei.com>
     Editor: Dhruv Dhody <dhruv.ietf@gmail.com>
     Editor: Ricard Vilalta <ricard.vilalta@cttc.es>";
     description
       "This module defines a model for WSON Tunnel Services.";


  revision "2018-10-15" {
    description
      "Updates to version 2";
    reference "version 2";
  }

  /* Groupings. */
  grouping wson-tunnel-attributes {
    description "Parameters for WSON tunnel.";

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

    leaf dst-client-signal {
      type identityref {
        base otn-types:client-signal;
      }
      description
        "Client signal at the destination endpoint of
         the tunnel.";
    }

    leaf fec-type {
```

```
      type identityref {
        base layer0-types:fec-type;
      }
      description
        "FEC type.";
    }

    leaf termination-type {
      type identityref {
        base layer0-types:term-type;
      }
      description
        "Termination type.";
    }

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

  grouping wson-path-constraints {
    description
      "Global named path constraints configuration
       grouping for WSON tunnel";

    leaf wavelength-assignment {
      type identityref {
        base layer0-types:wavelength-assignment;
      }
      description "Wavelength Allocation Method";
    }
  }

 /*
  * Data nodes
  */

  augment "/te:te/te:tunnels/te:tunnel" {
    description
      "Augment with additional parameters required for WSON tunnel.";
    uses wson-tunnel-attributes;
  }
```

```
/*
 * Augment TE bandwidth
 */

/* Augment bandwidth of named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
      + "te:named-path-constraint/"
      + "te:te-bandwidth/te:technology" {
  description "WSON bandwidth.";
  case wson {
    uses layer0-types:wson-path-bandwidth;
  }
}

/* Augment bandwdith of tunnel */
augment "/te:te/te:tunnels/te:tunnel/"
      + "te:te-bandwidth/te:technology" {
  description "WSON bandwidth.";
  case wson {
    uses layer0-types:wson-path-bandwidth;
  }
}

/* Augment bandwidth of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
      + "te:p2p-primary-paths/te:p2p-primary-path/"
      + "te:te-bandwidth/te:technology" {
  description "WSON bandwidth.";
  case wson {
    uses layer0-types:wson-path-bandwidth;
  }
}

/* Augment bandwidth of reverse primary path */
augment "/te:te/te:tunnels/te:tunnel/"
      + "te:p2p-primary-paths/te:p2p-primary-path/"
      + "te:p2p-reverse-primary-path/"
      + "te:te-bandwidth/te:technology" {
  description "WSON bandwidth.";
  case wson {
    uses layer0-types:wson-path-bandwidth;
  }
}

/* Augment bandwidht of secondary path */
```

```
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-secondary-paths/te:p2p-secondary-path/"
        + "te:te-bandwidth/te:technology" {
    description "WSON bandwidth.";
    case wson {
      uses layer0-types:wson-path-bandwidth;
    }
  }

  /*
   * Augment TE label.
   */

  /* Augment label hop of route-object-exclude-always of named-path-
constraints */
  augment "/te:te/te:globals/te:named-path-constraints/"
        + "te:named-path-constraint/te:explicit-route-objects/"
        + "te:route-object-exclude-always/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of route-object-include-exclude of named-path-
constraints */
  augment "/te:te/te:globals/te:named-path-constraints/"
        + "te:named-path-constraint/te:explicit-route-objects/"
        + "te:route-object-include-exclude/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label restrictions for the 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:forward/te:label-restrictions/"
        + "te:label-restriction" {
    description "WSON label.";
    uses layer0-types:layer0-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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions end for the 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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction" {
    description "WSON label.";
    uses layer0-types:layer0-label-restriction;
  }

  /* Augment label restrictions start for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
```

```
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions end for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions for the 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:forward/te:label-restrictions/"
        + "te:label-restriction" {
    description "WSON label.";
    uses layer0-types:layer0-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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions end for the 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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction" {
    description "WSON label.";
    uses layer0-types:layer0-label-restriction;
  }

  /* Augment label restrictions start for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions end for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }
```

```
  /* Augment label hop of route-exclude of primary path */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-primary-paths/te:p2p-primary-path/"
        + "te:optimizations/te:algorithm/te:metric/"
        + "te:optimization-metric/te:explicit-route-exclude-objects/"
        + "te:route-object-exclude-object/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of route-include of primary path */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-primary-paths/te:p2p-primary-path/"
        + "te:optimizations/te:algorithm/te:metric/"
        + "te:optimization-metric/te:explicit-route-include-objects/"
        + "te:route-object-include-object/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of route-object-exclude-always of primary path */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-primary-paths/te:p2p-primary-path/"
        + "te:explicit-route-objects/"
        + "te:route-object-exclude-always/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of route-object-include-exclude of primary path */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-primary-paths/te:p2p-primary-path/"
        + "te:explicit-route-objects/"
        + "te:route-object-include-exclude/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
```

```
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label restrictions for the 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:forward/te:label-restrictions/"
        + "te:label-restriction" {
    description "WSON label.";
    uses layer0-types:layer0-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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions end for the 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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction" {
    description "WSON label.";
    uses layer0-types:layer0-label-restriction;
  }

  /* Augment label restrictions start for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions end for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions for the 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:forward/te:label-restrictions/"
        + "te:label-restriction" {
    description "WSON label.";
    uses layer0-types:layer0-label-restriction;
  }

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

```
        + "te:p2p-primary-paths/te:p2p-primary-path/"
        + "te:path-out-segment/te:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions end for the 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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction" {
    description "WSON label.";
    uses layer0-types:layer0-label-restriction;
  }

  /* Augment label restrictions start for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }
```

```
  /* Augment label restrictions end for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label hop of path-route of primary path */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-primary-paths/te:p2p-primary-path/"
        + "te:state/te:path-properties/"
        + "te:path-route-objects/te:path-computed-route-object/"
        + "te:state/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of record-route of primary LSP */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-primary-paths/te:p2p-primary-path/"
        + "te:state/te:lsps/te:lsp/te:lsp-record-route-subobjects/"
        + "te:record-route-subobject/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of path-route of primary LSP */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-primary-paths/te:p2p-primary-path/"
        + "te:state/te:lsps/te:lsp/te:path-properties/"
        + "te:path-route-objects/te:path-computed-route-object/"
        + "te:state/te:type/te:label/"
```

```
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of route-exclude of reverse primary path */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-primary-paths/te:p2p-primary-path/"
        + "te:p2p-reverse-primary-path/"
        + "te:optimizations/te:algorithm/te:metric/"
        + "te:optimization-metric/te:explicit-route-exclude-objects/"
        + "te:route-object-exclude-object/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of route-include of reverse primary path */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-primary-paths/te:p2p-primary-path/"
        + "te:p2p-reverse-primary-path/"
        + "te:optimizations/te:algorithm/te:metric/"
        + "te:optimization-metric/te:explicit-route-include-objects/"
        + "te:route-object-include-object/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of route-object-exclude-always of reverse primary path
*/
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-primary-paths/te:p2p-primary-path/"
        + "te:p2p-reverse-primary-path/"
        + "te:explicit-route-objects/"
        + "te:route-object-exclude-always/"
        + "te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
```

```
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of route-object-include-exclude of reverse primary path
*/
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-primary-paths/te:p2p-primary-path/"
        + "te:p2p-reverse-primary-path/"
        + "te:explicit-route-objects/"
        + "te:route-object-include-exclude/"
        + "te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label restrictions for the 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-reverse-primary-path/"
        + "te:path-in-segment/te:forward/te:label-restrictions/"
        + "te:label-restriction" {
    description "WSON label.";
    uses layer0-types:layer0-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-reverse-primary-path/"
        + "te:path-in-segment/te:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }
```

```
  /* Augment label restrictions end for the 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-reverse-primary-path/"
        + "te:path-in-segment/te:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions for the reverse 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-reverse-primary-path/"
        + "te:path-in-segment/te:reverse/te:label-restrictions/"
        + "te:label-restriction" {
    description "WSON label.";
    uses layer0-types:layer0-label-restriction;
  }

  /* Augment label restrictions start for the reverse 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-reverse-primary-path/"
        + "te:path-in-segment/te:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions end for the reverse 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-reverse-primary-path/"
        + "te:path-in-segment/te:reverse/te:label-restrictions/"
```

```
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions for the 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-reverse-primary-path/"
        + "te:path-out-segment/te:forward/te:label-restrictions/"
        + "te:label-restriction" {
    description "WSON label.";
    uses layer0-types:layer0-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-reverse-primary-path/"
        + "te:path-out-segment/te:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions end for the 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-reverse-primary-path/"
        + "te:path-out-segment/te:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
```

```
  }

  /* Augment label restrictions for the reverse 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-reverse-primary-path/"
        + "te:path-out-segment/te:reverse/te:label-restrictions/"
        + "te:label-restriction" {
    description "WSON label.";
    uses layer0-types:layer0-label-restriction;
  }

  /* Augment label restrictions start for the reverse 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-reverse-primary-path/"
        + "te:path-out-segment/te:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions end for the reverse 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-reverse-primary-path/"
        + "te:path-out-segment/te:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label hop of path-route of reverse primary path */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-primary-paths/te:p2p-primary-path/"
        + "te:p2p-reverse-primary-path/"
```

```
        + "te:state/te:path-properties/"
        + "te:path-route-objects/te:path-computed-route-object/"
        + "te:state/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of record-route of reverse primary LSP */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-primary-paths/te:p2p-primary-path/"
        + "te:p2p-reverse-primary-path/"
        + "te:state/te:lsps/te:lsp/te:lsp-record-route-subobjects/"
        + "te:record-route-subobject/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of path-route of reverse primary LSP */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-primary-paths/te:p2p-primary-path/"
        + "te:p2p-reverse-primary-path/"
        + "te:state/te:lsps/te:lsp/te:path-properties/"
        + "te:path-route-objects/te:path-computed-route-object/"
        + "te:state/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of route-exclude of secondary path */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-secondary-paths/te:p2p-secondary-path/"
        + "te:optimizations/te:algorithm/te:metric/"
        + "te:optimization-metric/te:explicit-route-exclude-objects/"
        + "te:route-object-exclude-object/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
```

```
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of route-include of secondary path */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-secondary-paths/te:p2p-secondary-path/"
        + "te:optimizations/te:algorithm/te:metric/"
        + "te:optimization-metric/te:explicit-route-include-objects/"
        + "te:route-object-include-object/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of route-object-exclude-always of secondary path */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-secondary-paths/te:p2p-secondary-path/"
        + "te:explicit-route-objects/"
        + "te:route-object-exclude-always/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of route-object-include-exclude of secondary path */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-secondary-paths/te:p2p-secondary-path/"
        + "te:explicit-route-objects/"
        + "te:route-object-include-exclude/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label restrictions for the 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:forward/te:label-restrictions/"
        + "te:label-restriction" {
    description "WSON label.";
    uses layer0-types:layer0-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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions end for the 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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction" {
    description "WSON label.";
    uses layer0-types:layer0-label-restriction;
  }

  /* Augment label restrictions start for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions end for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions for the 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:forward/te:label-restrictions/"
        + "te:label-restriction" {
    description "WSON label.";
    uses layer0-types:layer0-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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
```

```
  }

  /* Augment label restrictions end for the 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:forward/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction" {
    description "WSON label.";
    uses layer0-types:layer0-label-restriction;
  }

  /* Augment label restrictions start for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label restrictions end for the reverse 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:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-end/"
        + "te:te-label/te:technology" {
```

```
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* Augment label hop of path-route of secondary path */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-secondary-paths/te:p2p-secondary-path/"
        + "te:state/te:path-properties/te:path-route-objects/"
        + "te:path-computed-route-object/te:state/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of record-route of secondary LSP */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-secondary-paths/te:p2p-secondary-path/"
        + "te:state/te:lsps/te:lsp/te:lsp-record-route-subobjects/"
        + "te:record-route-subobject/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of path-route of secondary LSP */
  augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-secondary-paths/te:p2p-secondary-path/"
        + "te:state/te:lsps/te:lsp/te:path-properties/"
        + "te:path-route-objects/"
        + "te:path-computed-route-object/te:state/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of record-route of LSP */
  augment "/te:te/te:lsps-state/"
```

```
        + "te:lsp/te:lsp-record-route-subobjects/"
        + "te:record-route-subobject/te:type/te:label/"
        + "te:label-hop/te:te-label/te:technology" {
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  augment "/te:tunnels-rpc/te:input/te:tunnel-info/"
        + "tepc:path-request" {
    description
       "Augment with additional constraints WSON
        tunnel.";
    uses wson-tunnel-attributes;
    uses wson-path-constraints;
  }
}
```

<CODE ENDS>

4. Security Considerations

The configuration, state, and action data defined in this document are designed to be accessed via a management protocol with a secure transport layer, such as NETCONF [RFC6241]. The NETCONF access control model [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 writable/deletable (i.e., "config true") These data nodes may be considered sensitive or vulnerable in some network environments.

5. IANA Considerations

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

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

This document registers the following YANG modules in the YANG Module

Names registry [RFC7950]:

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

6. Acknowledgments

This document was prepared using 2-Word-v2.0.template.dot.

7. References

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October 22, 2018

A Yang Data Model for WSON Optical Networks

draft-ietf-ccamp-wson-yang-15

Abstract

This document provides a YANG data model for the routing and wavelength assignment (RWA) TE topology in wavelength switched optical networks (WSONs).

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Table of Contents

1. Introduction

This document provides a YANG data model for the routing and wavelength assignment (RWA) Traffic Engineering (TE) topology in wavelength switched optical networks (WSONs). The YANG model described in this document is a WSON technology-specific Yang model based on the information model developed in [RFC7446] and the two encoding documents [RFC7581] and [RFC7579] that developed protocol independent encodings based on [RFC7446].

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

What is not in scope of this document is both impairment-aware WSON and flex-grid.

This document defines two YANG models: ietf-wson-topology (Section 3) and ietf-layer0-types (Section 4).

1.1. Terminology

Refer to [RFC7446] and [RFC7581] for the key terms used in this document.

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

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

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

- configuration data
- state data

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

1.2. Tree diagram

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

1.3. Prefixes in Data Node Names

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

Prefix	YANG module	Reference
layer0-type	ietf-layer0-types	[RFCXXXX]
wson	ietf-wson-topology	[RFCXXXX]
nw	ietf-network	[RFC8345]
nt	ietf-network-topology	[RFC8345]
tet	ietf-te-topology	[TE-TOPO]

Table 1: Prefixes and corresponding YANG modules

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

2. YANG Model (Tree Structure)

```
   module: ietf-wson-topology
     augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
       +--rw wson-topology!
     augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes:
     augment /nw:networks/nw:network/nw:node/nt:termination-point/tet:te:
       +--rw supported-payload-types* [index]
       |  +--rw index           uint16
       |  +--rw payload-type?   string
       +--rw client-facing?            boolean
     augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes:
       +--rw wson-node
          +--rw node-type?   identityref
     augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-point
:
       +--rw supported-operational-modes*    layer0-types:operational-mode
       +--rw configured-operational-modes?   layer0-types:operational-mode
       +--rw supported-fec-types*            identityref
       +--rw supported-termination-types*    identityref
       +--rw supports-bit-stuffing?          boolean
       +--rw is-tunable?                     boolean
       +--rw max-subcarrier-channel-num?     uint8
     augment /nw:networks/nw:network/nw:node/nt:termination-
   point/tet:te/tet:interface-switching-capability/tet:max-lsp-bandwidth/tet:te-
   bandwidth/tet:technology:
```

```
       +--:(wson)
          +--rw bandwidth-type?   identityref
     augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
   attributes/tet:connectivity-matrices/tet:path-constraints/tet:te-
   bandwidth/tet:technology:
       +--:(wson)
          +--rw supported-bandwidth-list*   identityref
     augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
   attributes/tet:connectivity-matrices/tet:connectivity-matrix/tet:path-
   constraints/tet:te-bandwidth/tet:technology:
       +--:(wson)
          +--rw supported-bandwidth-list*   identityref
     augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
   entry/tet:connectivity-matrices/tet:path-constraints/tet:te-
   bandwidth/tet:technology:
       +--:(wson)
          +--ro supported-bandwidth-list*   identityref
     augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
   entry/tet:connectivity-matrices/tet:connectivity-matrix/tet:path-
   constraints/tet:te-bandwidth/tet:technology:
       +--:(wson)
          +--ro supported-bandwidth-list*   identityref
     augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-
   point/tet:client-layer-adaptation/tet:switching-capability/tet:te-
   bandwidth/tet:technology:
       +--:(wson)
          +--rw supported-bandwidth-list*   identityref
     augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-
   point/tet:local-link-connectivities/tet:path-constraints/tet:te-
   bandwidth/tet:technology:
       +--:(wson)
          +--rw supported-bandwidth-list*   identityref
     augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-
   point/tet:local-link-connectivities/tet:local-link-connectivity/tet:path-
   constraints/tet:te-bandwidth/tet:technology:
       +--:(wson)
          +--rw supported-bandwidth-list*   identityref
     augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-
   attributes/tet:interface-switching-capability/tet:max-lsp-bandwidth/tet:te-
   bandwidth/tet:technology:
       +--:(wson)
          +--rw bandwidth-type?   identityref
     augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/tet:m
ax-
   link-bandwidth/tet:te-bandwidth/tet:technology:
       +--:(wson)
          +--rw supported-bandwidth-list*   identityref
     augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/tet:m
ax-
   resv-link-bandwidth/tet:te-bandwidth/tet:technology:
       +--:(wson)
```

```
          +--rw supported-bandwidth-list*   identityref
     augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-
   attributes/tet:unreserved-bandwidth/tet:te-bandwidth/tet:technology:
       +--:(wson)
          +--rw supported-bandwidth-list*   identityref
     augment /nw:networks/nw:network/nt:link/tet:te/tet:information-source-
   entry/tet:interface-switching-capability/tet:max-lsp-bandwidth/tet:te-
   bandwidth/tet:technology:
       +--:(wson)
          +--ro bandwidth-type?   identityref
     augment /nw:networks/nw:network/nt:link/tet:te/tet:information-source-
   entry/tet:max-link-bandwidth/tet:te-bandwidth/tet:technology:
       +--:(wson)
          +--ro supported-bandwidth-list*   identityref
     augment /nw:networks/nw:network/nt:link/tet:te/tet:information-source-
   entry/tet:max-resv-link-bandwidth/tet:te-bandwidth/tet:technology:
       +--:(wson)
          +--ro supported-bandwidth-list*   identityref
     augment /nw:networks/nw:network/nt:link/tet:te/tet:information-source-
   entry/tet:unreserved-bandwidth/tet:te-bandwidth/tet:technology:
       +--:(wson)
          +--ro supported-bandwidth-list*   identityref
     augment /nw:networks/tet:te/tet:templates/tet:link-template/tet:te-link-
   attributes/tet:interface-switching-capability/tet:max-lsp-bandwidth/tet:te-
   bandwidth/tet:technology:
       +--:(wson)
          +--rw bandwidth-type?   identityref
     augment /nw:networks/tet:te/tet:templates/tet:link-template/tet:te-link-
   attributes/tet:max-link-bandwidth/tet:te-bandwidth/tet:technology:
       +--:(wson)
          +--rw supported-bandwidth-list*   identityref
     augment /nw:networks/tet:te/tet:templates/tet:link-template/tet:te-link-
   attributes/tet:max-resv-link-bandwidth/tet:te-bandwidth/tet:technology:
       +--:(wson)
          +--rw supported-bandwidth-list*   identityref
     augment /nw:networks/tet:te/tet:templates/tet:link-template/tet:te-link-
   attributes/tet:unreserved-bandwidth/tet:te-bandwidth/tet:technology:
       +--:(wson)
          +--rw supported-bandwidth-list*   identityref
     augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
   attributes/tet:connectivity-matrices/tet:label-restrictions/tet:label-restric
tion:
       +--rw grid-type?   identityref
       +--rw priority?    uint8
     augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
   attributes/tet:connectivity-matrices/tet:label-restrictions/tet:label-
   restriction/tet:label-start/tet:te-label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
```

```
           |  +--rw channel-freq?         frequency-thz
           +--:(cwdm)
              +--rw channel-wavelength?   uint32
  augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
attributes/tet:connectivity-matrices/tet:label-restrictions/tet:label-
restriction/tet:label-end/tet:te-label/tet:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw channel-freq?         frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?   uint32
  augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
attributes/tet:connectivity-matrices/tet:underlay/tet:primary-path/tet:path-
element/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
attributes/tet:connectivity-matrices/tet:underlay/tet:backup-path/tet:path-
element/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
attributes/tet:connectivity-
matrices/tet:optimizations/tet:algorithm/tet:metric/tet:optimization-
metric/tet:explicit-route-exclude-objects/tet:route-object-exclude-
object/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
```

```
             |     +--:(super)
             |        +--rw subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?    uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
   attributes/tet:connectivity-
   matrices/tet:optimizations/tet:algorithm/tet:metric/tet:optimization-
   metric/tet:explicit-route-include-objects/tet:route-object-include-
   object/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw (single-or-super-channel)?
             |     +--:(single)
             |     |  +--rw channel-freq?           frequency-thz
             |     +--:(super)
             |        +--rw subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?    uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
   attributes/tet:connectivity-matrices/tet:path-properties/tet:path-route-
   objects/tet:path-route-object/tet:type/tet:label/tet:label-hop/tet:te-
   label/tet:technology:
       +--:(wson)
          +--ro (grid-type)?
             +--:(dwdm)
             |  +--ro (single-or-super-channel)?
             |     +--:(single)
             |     |  +--ro channel-freq?           frequency-thz
             |     +--:(super)
             |        +--ro subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--ro channel-wavelength?    uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
   attributes/tet:connectivity-matrices/tet:connectivity-matrix/tet:from/tet:lab
el-
   restrictions/tet:label-restriction:
       +--rw grid-type?   identityref
       +--rw priority?    uint8
     augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
   attributes/tet:connectivity-matrices/tet:connectivity-matrix/tet:from/tet:lab
el-
   restrictions/tet:label-restriction/tet:label-start/tet:te-label/tet:technolog
y:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw channel-freq?         frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?   uint32
```

```
     augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
   attributes/tet:connectivity-matrices/tet:connectivity-matrix/tet:from/tet:lab
el-
   restrictions/tet:label-restriction/tet:label-end/tet:te-label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw channel-freq?         frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?   uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
   attributes/tet:connectivity-matrices/tet:connectivity-matrix/tet:to/tet:label
-
   restrictions/tet:label-restriction:
       +--rw grid-type?   identityref
       +--rw priority?    uint8
     augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
   attributes/tet:connectivity-matrices/tet:connectivity-matrix/tet:to/tet:label
-
   restrictions/tet:label-restriction/tet:label-start/tet:te-label/tet:technolog
y:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw channel-freq?         frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?   uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
   attributes/tet:connectivity-matrices/tet:connectivity-matrix/tet:to/tet:label
-
   restrictions/tet:label-restriction/tet:label-end/tet:te-label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw channel-freq?         frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?   uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
   attributes/tet:connectivity-matrices/tet:connectivity-
   matrix/tet:underlay/tet:primary-path/tet:path-
   element/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw (single-or-super-channel)?
             |     +--:(single)
             |     |  +--rw channel-freq?           frequency-thz
             |     +--:(super)
             |        +--rw subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?    uint32
     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:l
abel-
   hop/tet:te-label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw (single-or-super-channel)?
             |     +--:(single)
             |     |  +--rw channel-freq?          frequency-thz
             |     +--:(super)
             |        +--rw subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?    uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
   attributes/tet:connectivity-matrices/tet:connectivity-
   matrix/tet:optimizations/tet:algorithm/tet:metric/tet:optimization-
   metric/tet:explicit-route-exclude-objects/tet:route-object-exclude-
   object/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw (single-or-super-channel)?
             |     +--:(single)
             |     |  +--rw channel-freq?          frequency-thz
             |     +--:(super)
             |        +--rw subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?    uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
   attributes/tet:connectivity-matrices/tet:connectivity-
   matrix/tet:optimizations/tet:algorithm/tet:metric/tet:optimization-
   metric/tet:explicit-route-include-objects/tet:route-object-include-
   object/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw (single-or-super-channel)?
             |     +--:(single)
             |     |  +--rw channel-freq?          frequency-thz
             |     +--:(super)
             |        +--rw subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?    uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-
   attributes/tet:connectivity-matrices/tet:connectivity-matrix/tet:path-
   properties/tet:path-route-objects/tet:path-route-
   object/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(wson)
          +--ro (grid-type)?
             +--:(dwdm)
```

```
             |  +--ro (single-or-super-channel)?
             |     +--:(single)
             |     |  +--ro channel-freq?          frequency-thz
             |     +--:(super)
             |        +--ro subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--ro channel-wavelength?    uint32
  augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
 entry/tet:connectivity-matrices/tet:label-restrictions/tet:label-restriction:
    +--ro grid-type?   identityref
    +--ro priority?    uint8
  augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
 entry/tet:connectivity-matrices/tet:label-restrictions/tet:label-
 restriction/tet:label-start/tet:te-label/tet:technology:
    +--:(wson)
       +--ro (grid-type)?
          +--:(dwdm)
          |  +--ro channel-freq?         frequency-thz
          +--:(cwdm)
             +--ro channel-wavelength?   uint32
  augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
 entry/tet:connectivity-matrices/tet:label-restrictions/tet:label-
 restriction/tet:label-end/tet:te-label/tet:technology:
    +--:(wson)
       +--ro (grid-type)?
          +--:(dwdm)
          |  +--ro channel-freq?         frequency-thz
          +--:(cwdm)
             +--ro channel-wavelength?   uint32
  augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
 entry/tet:connectivity-matrices/tet:underlay/tet:primary-path/tet:path-
 element/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
    +--:(wson)
       +--ro (grid-type)?
          +--:(dwdm)
          |  +--ro (single-or-super-channel)?
          |     +--:(single)
          |     |  +--ro channel-freq?          frequency-thz
          |     +--:(super)
          |        +--ro subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--ro channel-wavelength?    uint32
  augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
 entry/tet:connectivity-matrices/tet:underlay/tet:backup-path/tet:path-
 element/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
    +--:(wson)
       +--ro (grid-type)?
          +--:(dwdm)
          |  +--ro (single-or-super-channel)?
```

```
           |      +--:(single)
           |      |  +--ro channel-freq?          frequency-thz
           |      +--:(super)
           |         +--ro subcarrier-channels*   frequency-thz
           +--:(cwdm)
              +--ro channel-wavelength?    uint32
  augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
 entry/tet:connectivity-
 matrices/tet:optimizations/tet:algorithm/tet:metric/tet:optimization-
 metric/tet:explicit-route-exclude-objects/tet:route-object-exclude-
 object/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
     +--:(wson)
        +--ro (grid-type)?
           +--:(dwdm)
           |  +--ro (single-or-super-channel)?
           |     +--:(single)
           |     |  +--ro channel-freq?          frequency-thz
           |     +--:(super)
           |        +--ro subcarrier-channels*   frequency-thz
           +--:(cwdm)
              +--ro channel-wavelength?    uint32
  augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
 entry/tet:connectivity-
 matrices/tet:optimizations/tet:algorithm/tet:metric/tet:optimization-
 metric/tet:explicit-route-include-objects/tet:route-object-include-
 object/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
     +--:(wson)
        +--ro (grid-type)?
           +--:(dwdm)
           |  +--ro (single-or-super-channel)?
           |     +--:(single)
           |     |  +--ro channel-freq?          frequency-thz
           |     +--:(super)
           |        +--ro subcarrier-channels*   frequency-thz
           +--:(cwdm)
              +--ro channel-wavelength?    uint32
  augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
 entry/tet:connectivity-matrices/tet:path-properties/tet:path-route-
 objects/tet:path-route-object/tet:type/tet:label/tet:label-hop/tet:te-
 label/tet:technology:
     +--:(wson)
        +--ro (grid-type)?
           +--:(dwdm)
           |  +--ro (single-or-super-channel)?
           |     +--:(single)
           |     |  +--ro channel-freq?          frequency-thz
           |     +--:(super)
           |        +--ro subcarrier-channels*   frequency-thz
           +--:(cwdm)
```

```
                +--ro channel-wavelength?    uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
   entry/tet:connectivity-matrices/tet:connectivity-matrix/tet:from/tet:label-
   restrictions/tet:label-restriction:
       +--ro grid-type?   identityref
       +--ro priority?    uint8
     augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
   entry/tet:connectivity-matrices/tet:connectivity-matrix/tet:from/tet:label-
   restrictions/tet:label-restriction/tet:label-start/tet:te-label/tet:technolog
y:
       +--:(wson)
          +--ro (grid-type)?
             +--:(dwdm)
             |  +--ro channel-freq?         frequency-thz
             +--:(cwdm)
                +--ro channel-wavelength?   uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
   entry/tet:connectivity-matrices/tet:connectivity-matrix/tet:from/tet:label-
   restrictions/tet:label-restriction/tet:label-end/tet:te-label/tet:technology:
       +--:(wson)
          +--ro (grid-type)?
             +--:(dwdm)
             |  +--ro channel-freq?         frequency-thz
             +--:(cwdm)
                +--ro channel-wavelength?   uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
   entry/tet:connectivity-matrices/tet:connectivity-matrix/tet:to/tet:label-
   restrictions/tet:label-restriction:
       +--ro grid-type?   identityref
       +--ro priority?    uint8
     augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
   entry/tet:connectivity-matrices/tet:connectivity-matrix/tet:to/tet:label-
   restrictions/tet:label-restriction/tet:label-start/tet:te-label/tet:technolog
y:
       +--:(wson)
          +--ro (grid-type)?
             +--:(dwdm)
             |  +--ro channel-freq?         frequency-thz
             +--:(cwdm)
                +--ro channel-wavelength?   uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
   entry/tet:connectivity-matrices/tet:connectivity-matrix/tet:to/tet:label-
   restrictions/tet:label-restriction/tet:label-end/tet:te-label/tet:technology:
       +--:(wson)
          +--ro (grid-type)?
             +--:(dwdm)
             |  +--ro channel-freq?         frequency-thz
             +--:(cwdm)
                +--ro channel-wavelength?   uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
   entry/tet:connectivity-matrices/tet:connectivity-matrix/tet:underlay/tet:prim
ary-
```

```
   path/tet:path-element/tet:type/tet:label/tet:label-hop/tet:te-
   label/tet:technology:
       +--:(wson)
          +--ro (grid-type)?
             +--:(dwdm)
             |  +--ro (single-or-super-channel)?
             |     +--:(single)
             |     |  +--ro channel-freq?          frequency-thz
             |     +--:(super)
             |        +--ro subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--ro channel-wavelength?    uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
   entry/tet:connectivity-matrices/tet:connectivity-matrix/tet:underlay/tet:back
up-
   path/tet:path-element/tet:type/tet:label/tet:label-hop/tet:te-
   label/tet:technology:
       +--:(wson)
          +--ro (grid-type)?
             +--:(dwdm)
             |  +--ro (single-or-super-channel)?
             |     +--:(single)
             |     |  +--ro channel-freq?          frequency-thz
             |     +--:(super)
             |        +--ro subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--ro channel-wavelength?    uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
   entry/tet:connectivity-matrices/tet:connectivity-
   matrix/tet:optimizations/tet:algorithm/tet:metric/tet:optimization-
   metric/tet:explicit-route-exclude-objects/tet:route-object-exclude-
   object/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(wson)
          +--ro (grid-type)?
             +--:(dwdm)
             |  +--ro (single-or-super-channel)?
             |     +--:(single)
             |     |  +--ro channel-freq?          frequency-thz
             |     +--:(super)
             |        +--ro subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--ro channel-wavelength?    uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
   entry/tet:connectivity-matrices/tet:connectivity-
   matrix/tet:optimizations/tet:algorithm/tet:metric/tet:optimization-
   metric/tet:explicit-route-include-objects/tet:route-object-include-
   object/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(wson)
          +--ro (grid-type)?
             +--:(dwdm)
```

```
             |  +--ro (single-or-super-channel)?
             |     +--:(single)
             |     |  +--ro channel-freq?          frequency-thz
             |     +--:(super)
             |        +--ro subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--ro channel-wavelength?    uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:information-source-
   entry/tet:connectivity-matrices/tet:connectivity-matrix/tet:path-
   properties/tet:path-route-objects/tet:path-route-
   object/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(wson)
          +--ro (grid-type)?
             +--:(dwdm)
             |  +--ro (single-or-super-channel)?
             |     +--:(single)
             |     |  +--ro channel-freq?          frequency-thz
             |     +--:(super)
             |        +--ro subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--ro channel-wavelength?    uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-
   point/tet:local-link-connectivities/tet:label-restrictions/tet:label-restrict
ion:
       +--rw grid-type?   identityref
       +--rw priority?    uint8
     augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-
   point/tet:local-link-connectivities/tet:label-restrictions/tet:label-
   restriction/tet:label-start/tet:te-label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw channel-freq?         frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?   uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-
   point/tet:local-link-connectivities/tet:label-restrictions/tet:label-
   restriction/tet:label-end/tet:te-label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw channel-freq?         frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?   uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-
   point/tet:local-link-connectivities/tet:underlay/tet:primary-path/tet:path-
   element/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
```

```
             |  +--rw (single-or-super-channel)?
             |     +--:(single)
             |     |  +--rw channel-freq?          frequency-thz
             |     +--:(super)
             |        +--rw subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?    uint32
  augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-
point/tet:local-link-connectivities/tet:underlay/tet:backup-path/tet:path-
element/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  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:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  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:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
```

```
                +--rw channel-wavelength?    uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-
   point/tet:local-link-connectivities/tet:path-properties/tet:path-route-
   objects/tet:path-route-object/tet:type/tet:label/tet:label-hop/tet:te-
   label/tet:technology:
       +--:(wson)
          +--ro (grid-type)?
             +--:(dwdm)
             |  +--ro (single-or-super-channel)?
             |     +--:(single)
             |     |  +--ro channel-freq?           frequency-thz
             |     +--:(super)
             |        +--ro subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--ro channel-wavelength?    uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-
   point/tet:local-link-connectivities/tet:local-link-connectivity/tet:label-
   restrictions/tet:label-restriction:
       +--rw grid-type?   identityref
       +--rw priority?    uint8
     augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-
   point/tet:local-link-connectivities/tet:local-link-connectivity/tet:label-
   restrictions/tet:label-restriction/tet:label-start/tet:te-label/tet:technolog
y:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw channel-freq?         frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?   uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-
   point/tet:local-link-connectivities/tet:local-link-connectivity/tet:label-
   restrictions/tet:label-restriction/tet:label-end/tet:te-label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw channel-freq?         frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?   uint32
     augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-
   point/tet:local-link-connectivities/tet:local-link-
   connectivity/tet:underlay/tet:primary-path/tet:path-
   element/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw (single-or-super-channel)?
             |     +--:(single)
             |     |  +--rw channel-freq?           frequency-thz
             |     +--:(super)
```

```
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-
point/tet:local-link-connectivities/tet:local-link-
connectivity/tet:underlay/tet:backup-path/tet:path-
element/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  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:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  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:
    +--:(wson)
       +--rw (grid-type)?
          +--:(dwdm)
          |  +--rw (single-or-super-channel)?
          |     +--:(single)
          |     |  +--rw channel-freq?          frequency-thz
          |     +--:(super)
          |        +--rw subcarrier-channels*   frequency-thz
          +--:(cwdm)
             +--rw channel-wavelength?    uint32
  augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-
point/tet:local-link-connectivities/tet:local-link-connectivity/tet:path-
```

```
   properties/tet:path-route-objects/tet:path-route-
   object/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(wson)
          +--ro (grid-type)?
             +--:(dwdm)
             |  +--ro (single-or-super-channel)?
             |     +--:(single)
             |     |  +--ro channel-freq?          frequency-thz
             |     +--:(super)
             |        +--ro subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--ro channel-wavelength?    uint32
     augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-
   attributes/tet:underlay/tet:primary-path/tet:path-
   element/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw (single-or-super-channel)?
             |     +--:(single)
             |     |  +--rw channel-freq?          frequency-thz
             |     +--:(super)
             |        +--rw subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?    uint32
     augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-
   attributes/tet:underlay/tet:backup-path/tet:path-
   element/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw (single-or-super-channel)?
             |     +--:(single)
             |     |  +--rw channel-freq?          frequency-thz
             |     +--:(super)
             |        +--rw subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?    uint32
     augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/tet:l
abel-
   restrictions/tet:label-restriction:
       +--rw grid-type?   identityref
       +--rw priority?    uint8
     augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/tet:l
abel-
   restrictions/tet:label-restriction/tet:label-start/tet:te-label/tet:technolog
y:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw channel-freq?         frequency-thz
             +--:(cwdm)
```

```
                +--rw channel-wavelength?   uint32
      augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/tet:l
abel-
   restrictions/tet:label-restriction/tet:label-end/tet:te-label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw channel-freq?         frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?   uint32
     augment /nw:networks/nw:network/nt:link/tet:te/tet:information-source-
   entry/tet:label-restrictions/tet:label-restriction:
       +--ro grid-type?   identityref
       +--ro priority?    uint8
     augment /nw:networks/nw:network/nt:link/tet:te/tet:information-source-
   entry/tet:label-restrictions/tet:label-restriction/tet:label-start/tet:te-
   label/tet:technology:
       +--:(wson)
          +--ro (grid-type)?
             +--:(dwdm)
             |  +--ro channel-freq?         frequency-thz
             +--:(cwdm)
                +--ro channel-wavelength?   uint32
     augment /nw:networks/nw:network/nt:link/tet:te/tet:information-source-
   entry/tet:label-restrictions/tet:label-restriction/tet:label-end/tet:te-
   label/tet:technology:
       +--:(wson)
          +--ro (grid-type)?
             +--:(dwdm)
             |  +--ro channel-freq?         frequency-thz
             +--:(cwdm)
                +--ro channel-wavelength?   uint32
     augment /nw:networks/tet:te/tet:templates/tet:link-template/tet:te-link-
   attributes/tet:underlay/tet:primary-path/tet:path-
   element/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw (single-or-super-channel)?
             |     +--:(single)
             |     |  +--rw channel-freq?          frequency-thz
             |     +--:(super)
             |        +--rw subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?    uint32
     augment /nw:networks/tet:te/tet:templates/tet:link-template/tet:te-link-
   attributes/tet:underlay/tet:backup-path/tet:path-
   element/tet:type/tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
```

```
             +--:(dwdm)
             |  +--rw (single-or-super-channel)?
             |     +--:(single)
             |     |  +--rw channel-freq?          frequency-thz
             |     +--:(super)
             |        +--rw subcarrier-channels*   frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?    uint32
     augment /nw:networks/tet:te/tet:templates/tet:link-template/tet:te-link-
   attributes/tet:label-restrictions/tet:label-restriction:
       +--rw grid-type?   identityref
       +--rw priority?    uint8
     augment /nw:networks/tet:te/tet:templates/tet:link-template/tet:te-link-
   attributes/tet:label-restrictions/tet:label-restriction/tet:label-start/tet:t
e-
   label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw channel-freq?         frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?   uint32
     augment /nw:networks/tet:te/tet:templates/tet:link-template/tet:te-link-
   attributes/tet:label-restrictions/tet:label-restriction/tet:label-end/tet:te-
   label/tet:technology:
       +--:(wson)
          +--rw (grid-type)?
             +--:(dwdm)
             |  +--rw channel-freq?         frequency-thz
             +--:(cwdm)
                +--rw channel-wavelength?   uint32
```

3. IETF-WSON-Topology YANG Model

<CODE BEGINS> file "ietf-wson-topology@2018-10-15.yang"

```
module ietf-wson-topology {

  yang-version 1.1;
```

```
  namespace "urn:ietf:params:xml:ns:yang:ietf-wson-topology";

  prefix "wson";

  import ietf-network {
    prefix "nw";
  }

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

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

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

  organization
    "IETF CCAMP Working Group";

  contact
    "Editor:   Young Lee  <leeyoung@huawei.com>
     Editor:   Aihua Guo  <aihuaguo@huawei.com>";

  description
    "This module contains a collection of YANG definitions for
    RWA WSON.

    Copyright (c) 2018 IETF Trust and the persons identified
    as authors of the code.  All rights reserved.

    Redistribution and use in source and binary forms, with
    or without modification, is permitted pursuant to, and
    subject to the license terms contained in, the Simplified BSD
    License set forth in Section 4.c of the IETF Trust's Legal
    Provisions Relating to IETF Documents
    (http://trustee.ietf.org/license-info).";

  revision 2018-10-15 {
    description
      "version 14.";

    reference
```

```
      "RFC XXX: A Yang Data Model for WSON Optical Networks ";
  }

  /*
   * Groupings
   */
  grouping wson-node-attributes {
    description "WSON node attributes";
    container wson-node {
      description "WSON node attrtibutes.";
      leaf node-type {
        type identityref {
          base layer0-types:layer0-node-type;
        }
        description "WSON node type.";
      }
    }
  }

  grouping wson-link-attributes {
    description
     "Future WSON link attributes extensions";
  }

  grouping wson-tp-attributes {
    description "wson-tp-attributes";

    list supported-payload-types {
      key "index";
      description
        "Supported payload types of a TP. The payload type is defined
         as the generalized PIDs in GMPLS.";
      leaf index {
        type uint16;
        description "payload type index";
      }
      leaf payload-type {
        type string;
        description "the payload type supported by this client tp";
        reference
          "http://www.iana.org/assignments/gmpls-sig-parameters
           /gmpls-sig-parameters.xhtml";
      }
    }
    leaf client-facing {
      type boolean;
      default 'false';
```

```
      description
        "Indicating if it is a client-facing TP.";
    }
  }

  grouping wson-ttp-attributes {
    description
     "WSON tunnel termination point (e.g.tranponder)
       attributes";

    leaf-list supported-operational-modes {
      type layer0-types:operational-mode;
      description
        "List of all supported vendor-specific
         mode identifiers";
    }

    leaf configured-operational-modes {
      type layer0-types:operational-mode;
      description
       "Vendor-specific mode identifier configured
         on the TTP.";
    }

    leaf-list supported-fec-types {
      type identityref {
        base layer0-types:fec-type;
      }
       description
        "List of all supported FEC types by this TTP.";
    }

    leaf-list supported-termination-types {
      type identityref {
        base layer0-types:term-type;
      }
        description
         "List of all supported termination types by this TTP.";
    }

    leaf supports-bit-stuffing {
       type boolean;
       description
         "Indicate whether bit stuffing is supported by this TTP.";
    }

    leaf is-tunable {
```

```
      type boolean;
      description
       "Indicates if the TTP, or transponder, is tunable. Tunable
       transponders are assumed to be fully tunable to any of the
       96 channels within DWDM C-band.";
    }

   leaf max-subcarrier-channel-num {
     type uint8 {
       range "1..max";
     }
     default 1;
     description
       "Indicate the maximum number of subcarrier channels for
       super-channel transponders. When the value equals 1 it
       represents regular single-channel transponder.";
   }
  }


  /*
   * Data nodes
   */

  augment "/nw:networks/nw:network/nw:network-types"
   + "/tet:te-topology" {
      description "wson-topology augmented";
      container wson-topology {
        presence "indicates a topology of WSON";
        description
          "Container to identify WSON topology type";
      }
  }

  augment "/nw:networks/nw:network/nt:link/tet:te"
        + "/tet:te-link-attributes"   {
    when "/nw:networks/nw:network/nw:network-types"
        +"/tet:te-topology/wson:wson-topology" {
       description "This augment is only valid for WSON.";
    }
    description "WSON Link augmentation.";
    uses wson-link-attributes;
  }

  augment "/nw:networks/nw:network/nw:node/nt:termination-point/"
        + "tet:te" {
    when "/nw:networks/nw:network/nw:network-types"
```

```
          +"/tet:te-topology/wson:wson-topology" {
         description "This augment is only valid for WSON.";
      }
      description "WSON TP attributes.";
      uses wson-tp-attributes;
    }

    augment "/nw:networks/nw:network/nw:node/tet:te"
          + "/tet:te-node-attributes" {
      when "/nw:networks/nw:network/nw:network-types"
         +"/tet:te-topology/wson:wson-topology" {
         description "This augment is only valid for WSON.";
      }
      description "WSON Node augmentation.";
      uses wson-node-attributes;
    }

    augment "/nw:networks/nw:network/nw:node/tet:te"
          + "/tet:tunnel-termination-point" {
      when "/nw:networks/nw:network/nw:network-types"
         +"/tet:te-topology/wson:wson-topology" {
        description "This augment is only valid for WSON.";
      }
      description "WSON tunnel termination point augmentation.";
      uses wson-ttp-attributes;
    }

    /*
     * Augment TE bandwidth
     */

    /* Augment 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/"
         + "wson:wson-topology" {
        description "Augment WSON TE bandwidth";
      }
      description "WSON bandwidth.";
      case wson {
        uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE bandwidth";
    }
    description "WSON bandwidth.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE bandwidth";
    }
    description "WSON bandwidth.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE bandwidth";
    }
    description "WSON bandwidth.";
    case wson {
      uses layer0-types:wson-link-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE bandwidth";
    }
    description "WSON bandwidth.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE bandwidth";
    }
    description "WSON bandwidth.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE bandwidth";
    }
    description "WSON bandwidth.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE bandwidth";
    }
    description "WSON bandwidth.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "WSON TE bandwidth.";
    }
    description "WSON bandwidth.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "WSON TE bandwidth.";
    }
    description "WSON bandwidth.";
    case wson {
      uses layer0-types:wson-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/"
```

```
         + "wson:wson-topology" {
        description "WSON TE bandwidth.";
      }
      description "WSON bandwidth.";
      case wson {
        uses layer0-types:wson-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/"
         + "wson:wson-topology" {
        description "WSON TE bandwidth.";
      }
      description "WSON bandwidth.";
      case wson {
        uses layer0-types:wson-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/"
         + "wson:wson-topology" {
        description "WSON TE bandwidth.";
      }
      description "WSON bandwidth.";
      case wson {
        uses layer0-types:wson-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/"
         + "wson:wson-topology" {
```

```
      description "WSON TE bandwidth.";
    }
    description "WSON bandwidth.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "WSON TE bandwidth.";
    }
    description "WSON bandwidth.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "WSON TE bandwidth.";
    }
    description "WSON bandwidth.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
```

```
      description "WSON TE bandwidth.";
    }
*/
    description "WSON bandwidth.";
    case wson {
      uses layer0-types:wson-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/"
        + "wson:wson-topology" {
      description "WSON TE bandwidth.";
    }
*/
    description "WSON bandwidth.";
    case wson {
      uses layer0-types:wson-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/"
        + "wson:wson-topology" {
      description "WSON TE bandwidth.";
    }
*/
    description "WSON bandwidth.";
    case wson {
      uses layer0-types:wson-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/"
        + "wson:wson-topology" {
      description "WSON TE bandwidth.";
    }
*/
    description "WSON bandwidth.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    uses layer0-types:layer0-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* 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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    uses layer0-types:layer0-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* 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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    uses layer0-types:layer0-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* 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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
```

```
      }
      description "WSON label.";
      case wson {
        uses layer0-types:wson-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/"
          + "tet:algorithm/tet:metric/tet:optimization-metric/"
          + "tet:explicit-route-exclude-objects/"
          + "tet:route-object-exclude-object/tet:type/"
          + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
      when "../../../../../../../../../../../../"
         + "nw:network-types/tet:te-topology/"
         + "wson:wson-topology" {
        description "Augment WSON TE label";
      }
      description "WSON label.";
      case wson {
        uses layer0-types:wson-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/"
         + "wson:wson-topology" {
        description "Augment WSON TE label";
      }
      description "WSON label.";
      case wson {
        uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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" {
    when "../../../../../../nw:network-types/tet:te-topology/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    uses layer0-types:layer0-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/"
        + "tet:label-start/tet:te-label/tet:technology" {
    when "../../../../../../../../../"
       + "nw:network-types/tet:te-topology/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
        + "tet:label-end/tet:te-label/tet:technology" {
    when "../../../../../../../../"
       + "nw:network-types/tet:te-topology/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* 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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
```

```
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    uses layer0-types:layer0-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* 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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    uses layer0-types:layer0-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/"
       + "wson:wson-topology" {
```

```
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* 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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-label;
    }
  }

  /* Augment label hop of underlay backup 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:backup-path/tet:path-element/tet:type/"
        + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
    when "../../../../../../../../../../../"
       + "nw:network-types/tet:te-topology/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-path-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    uses layer0-types:layer0-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* 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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    uses layer0-types:layer0-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* 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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
```

```
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
```

```
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    uses layer0-types:layer0-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* 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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    uses layer0-types:layer0-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
    }
  }

  /* 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/"
       + "wson:wson-topology" {
          description "Augment WSON TE label";
    }
*/
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
       + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
*/
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
        + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
*/
    description "WSON label.";
    uses layer0-types:layer0-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/"
        + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
*/
    description "WSON label.";
    case wson {
      uses layer0-types:wson-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/"
        + "wson:wson-topology" {
      description "Augment WSON TE label";
    }
*/
    description "WSON label.";
    case wson {
      uses layer0-types:wson-link-label;
```

```
    }
  }
}

<CODE ENDS>
```

4. IETF-Layer0-Types YANG Model

```
<CODE BEGINS> file "ietf-layer0-types@2018-10-22.yang"

module ietf-layer0-types {
  namespace "urn:ietf:params:xml:ns:yang:ietf-layer0-types";
  prefix "layer0-types";

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

     Editor: Young Lee <mailto:leeyoung@huawei.com>
     Editor: Aihua Guo <mailto:aihuaguo@huawei.com>";

  description
    "This module defines Optical Layer 0 types.";

  revision "2018-10-22" {
    description
      "Revision 1";
    reference "TBD";
  }

  typedef operational-mode {
    type string;
    description
      "Vendor-specific 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";
    reference "ITU-T G.698.2 (11/2009) Section 5.3";
  }

  typedef vendor-identifier {
    type string;
    description
      "vendor identifier that uses vendor-specific mode";
    reference "TBD";
  }

  typedef frequency-thz {
    type decimal64 {
```

```
      fraction-digits 5;
    }
    units THz;
    description
      "The DWDM frequency in THz, e.g. 193.12500";
    reference
      "RFC6205";
  }

  typedef frequency-ghz {
    type decimal64 {
      fraction-digits 5;
    }
    units GHz;
    description
      "The DWDM frequency in GHz, e.g. 193125.00";
    reference
      "RFC6205";
  }


  identity layer0-node-type {
    description
      "layer0 node type.";
    reference
      "RFC6163";
  }

  identity flex-grid-node {
    base layer0-node-type;
    description
      "Flex Grid node.";
  }

  identity wson-node-foadm {
    base layer0-node-type;
    description
      "Fixed OADM node.";
  }

  identity wson-node-roadm {
    base layer0-node-type;
    description
      "ROADM or OXC node.";
  }
```

```
  identity wson-node-ila {
    base layer0-node-type;
    description
      "ILA (In-Line Amplifier) node.";
  }

  identity wavelength-assignment {
    description
    "Wavelength selection base";
  }

  identity unspecified-wavelength-assignment {
    base wavelength-assignment;
    description
      "No method specified";
  }

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

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

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

  identity layer0-grid-type {
    description
      "Layer0 grid type.";
  }
```

```
  identity flex-grid-dwdm {
    base layer0-grid-type;
    description
      "Flex grid.";
  }

  identity wson-grid-dwdm {
    base layer0-grid-type;
    description
      "DWDM grid.";
  }

  identity wson-grid-cwdm {
    base layer0-grid-type;
    description
      "CWDM grid.";
  }

  identity layer0-bandwidth-type {
    description
      "Bandwidth type carried by a single wavelength channel.";
  }

  identity bw-otu1 {
    base layer0-bandwidth-type;
    description
      "OTU1 (2.66G)";
  }

  identity bw-otu1e {
    base layer0-bandwidth-type;
    description
      "OTU1e(11.04G)";
  }

  identity bw-otu1f {
    base layer0-bandwidth-type;
    description
      "OTU1f(11.27G)";
  }

  identity bw-otu2 {
    base layer0-bandwidth-type;
    description
```

```
      "OTU2 (10.70G)";
  }

  identity bw-otu2e {
    base layer0-bandwidth-type;
    description
      "OTU2e (11.09G)";
  }

  identity bw-otu2f {
    base layer0-bandwidth-type;
    description
      "OTU2f (11.31G)";
  }

  identity bw-otu3 {
    base layer0-bandwidth-type;
    description
      "OTU3 (43.01G)";
  }

  identity bw-otu3e1 {
    base layer0-bandwidth-type;
    description
      "OTU3e1 (44.57G)";
  }

  identity bw-otu3e2 {
    base layer0-bandwidth-type;
    description
      "OTU3e2 (44.58G)";
  }

  identity bw-otu4 {
    base layer0-bandwidth-type;
    description
      "OTU4 (111.80G)";
  }

  identity bw-otucn {
    base layer0-bandwidth-type;
    description
      "OTUCn (beyond 100G)";
  }
```

```
  identity dwdm-ch-spc-type {
    description
      "DWDM channel spacing type.";
  }

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

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

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

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

  identity dwdm-6p25ghz {
    base dwdm-ch-spc-type;
    description
      "6.25GHz channel spacing";
  }

  identity cwdm-ch-spc-type {
    description
      "CWDM channel spacing type.";
  }

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

```
  identity fec-type {
    description
      "FEC type.";
  }

  identity g-fec {
    base fec-type;
    description
      "G-FEC.";
  }
  identity e-fec {
    base fec-type;
    description
      "E-FEC.";
  }
  identity no-fec {
    base fec-type;
    description
      "No FEC.";
  }

  identity term-type {
    description
      "Termination type.";
  }

  identity term-phys {
    base term-type;
    description
      "PHYS.";
  }
  identity term-otu {
    base term-type;
    description
      "OTU.";
  }
  identity term-odu {
    base term-type;
    description
      "ODU.";
  }
  identity term-opu {
    base term-type;
    description
```

```
      "OPU.";
  }
  identity term-section {
    base term-type;
    description
      "Section.";
  }

  /* Groupings. */
  grouping wson-path-bandwidth {
    description "WSON path bandwidth attributes";
    leaf bandwidth-type {
      type identityref {
        base layer0-bandwidth-type;
      }
      description "WSON bandwidth type";
    }
  }

  grouping wson-link-bandwidth {
    description "WSON link bandwidth attributes";
    leaf-list supported-bandwidth-list {
      type identityref {
        base layer0-bandwidth-type;
      }
      description "WSON bandwidth type";
    }
  }

  grouping wson-link-label {
    description
      "Generic label for WSON links.";
    choice grid-type {
      description
        "Label for DWDM or CWDM grid";
      case dwdm {
        leaf channel-freq {
        type frequency-thz;
          description
            "The DWDM fixed-grid channel frequency in THz,
          e.g. 193.12500";
          reference
            "RFC6205";
        }
      }
```

```
      case cwdm {
        leaf channel-wavelength {
          type uint32;
          units nm;
          description
            "The CWDM wavelength in nanometer, e.g. 1511";
          reference
            "RFC6205";
        }
      }
    }
  }

  grouping wson-path-label {
    description
      "Generic label for WSON paths";
    choice grid-type {
      description
        "Label for DWDM or CWDM grid";
      case dwdm {
       choice single-or-super-channel {
        description "single of super channel";
        case single {
            leaf channel-freq {
              type frequency-thz;
           description
             "The DWDM fixed-grid channel frequency in THz,
              e.g. 193.12500";
            }
        }
        case super {
          leaf-list subcarrier-channels {
              type frequency-thz;
              description
                "List of subcarrier channels for super channel.";
            }
        }
      }

      }
      case cwdm {
        leaf channel-wavelength {
          type uint32;
          units nm;
          description
```

```
            "The CWDM wavelength in nanometer, e.g. 1511";
          reference
            "RFC6205";
        }
      }
    }
  }

  grouping layer0-label-restriction {
    description
      "layer0 label restriction.";

    leaf grid-type {
      type identityref {
        base layer0-grid-type;
      }
      description "Grid type";
    }
    leaf priority {
      type uint8;
      description "priority.";
    }
  }

  grouping wson-label-step {
    description "Label step information for WSON";
    choice layer0-grid-type {
      description
        " WSON grid-type: DWDM, CWDM, etc.";
      case dwdm {
        leaf wson-dwdm {
          type identityref {
            base dwdm-ch-spc-type;
          }
          description
            "Label-step is the channel-spacing (GHz), e.g.,
             100, 50, 25, or 12.5 GHz for DWDM.";
          reference
            "RFC6205";
        }
      }
      case cwdm {
        leaf wson-cwdm {
          type identityref {
            base cwdm-ch-spc-type;
```

```
          }
          description
            "label-step is the channel-spacing (nm), i.e.,
             20 nm for CWDM, which is the only value defined for CWDM.";
          reference
            "RFC6205.";
        }
      }
    }
  }

    grouping flex-grid-node-attributes {
    description "Flex-grid node attributes.";

    container flex-grid-node {
      description "Flex-grid node attrtibutes.";
      leaf node-type {
        type identityref {
          base layer0-node-type;
        }
        description "Flex-grid node type.";
      }
    }
  }

  grouping flex-grid-path-bandwidth {
    description "Flex-grid path bandwidth attributes";
    leaf bandwidth-type {
      type identityref {
        base layer0-bandwidth-type;
      }
      description "Flex-grid bandwidth type";
    }
  }

  grouping flex-grid-link-bandwidth {
    description "flex-grid link bandwidth attributes";
    leaf-list supported-bandwidth-list {
      type identityref {
        base layer0-bandwidth-type;
      }
      description "Flex-grid bandwidth type";
    }
  }
```

```
  grouping flex-grid-link-label {
    description "Flex-grid link label.";
    leaf central-frequency {
      type frequency-thz;
      description
        "The DWDM flex-grid channel central frequency
         in THz, e.g. 193.12500.";
      reference
        "RFC7698";
    }
  }

  grouping flex-grid-channel {
    description "Flex-grid channel grouping.";
    leaf central-frequency {
      type frequency-thz;
      description
        "Flex-grid central frequency in THz, e.g. 193.12500.";
      reference
        "RFC7698";
    }

    leaf slot-width {
      type frequency-ghz;
      description
        "Flex-grid The DWDM slot width in GHz, e.g. 50, 100, 150.";
      reference
        "RFC7698";
    }
  }

  grouping flex-grid-path-label {
    description "Flex-grid path label.";
      choice single-or-super-channel {
       description "single of super channel";
        case single {
          uses flex-grid-channel;
       }
       case super {
         list subcarrier-channels {
           key central-frequency;
           uses flex-grid-channel;
         description
              "List of subcarrier channels for flex-grid
             super channel.";
```

```
          }
        }
      }

  }

  grouping flex-grid-label-restriction {
    description
     "Flex Grid-specific label restriction.";
   uses layer0-label-restriction;

    container flex-grid {
     description "flex-grid definition";
      leaf nominal-central-frequency-granularity {
        type frequency-ghz;
        default 6.25;
        description
          "It is the spacing between allowed nominal central
           frequencies and it is set to 6.25 GHz";
        reference
         "RFC7698";
      }

      leaf slot-width-granularity {
        type frequency-ghz;
        default 12.5;
        description
         "Minimum space between slot widths";
        reference
         "RFC7698";
      }
    }

  }

  grouping flex-grid-label-step {
    description "Label step information for flex grid";
    leaf flex {
      type identityref {
        base dwdm-ch-spc-type;
      }
      description
        "Label-step is the nominal central frequency granularity (GHz), e.g.,
         6.25 GHz.";
      reference
```

```
        "RFC7698";
    }
  }
}

<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 writable/deletable (i.e., "config true") These data nodes may be considered sensitive or vulnerable in some network environments.

6. IANA Considerations

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

```
--------------------------------------------------------------------
   URI: urn:ietf:params:xml:ns:yang: ietf-wson-topology
   Registrant Contact: The IESG.
   XML: N/A, the requested URI is an XML namespace.
--------------------------------------------------------------------
   URI: urn:ietf:params:xml:ns:yang: ietf-layer0-types
   Registrant Contact: The IESG.
   XML: N/A, the requested URI is an XML namespace.
--------------------------------------------------------------------
```

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

```
--------------------------------------------------------------------
   name:         ietf-wson-topology
```

```
      namespace:    urn:ietf:params:xml:ns:yang:ietf-wson-topology
      reference:    RFC XXXX (TDB)
   ---------------------------------------------------------------------
      name:         ietf-layer0-types
      namespace:    urn:ietf:params:xml:ns:yang: ietf-layer0-types
      reference:    RFC XXXX (TDB)
   ---------------------------------------------------------------------
```

7. Acknowledgments

This document was prepared using 2-Word-v2.0.template.dot.

8. References

8.1. Normative References

[TE-TOPO] X. Liu, et al., "YANG Data Model for TE Topologies", work in progress: draft-ietf-teas-yang-te-topo.

8.2. Informative References

[RFC3688] M. Mealling, "The IETF XML Registry", RFC 3688, January 2004.

[RFC7446] Y. Lee, G. Bernstein, D. Li, W. Imajuku, "Routing and Wavelength Assignment Information Model for Wavelength Switched Optical Networks", RFC 7446, Feburary 2015.

[RFC7579] G. Bernstein, Y. Lee, D. Li, W. Imajuku, "General Network Element Constraint Encoding for GMPLS Controlled Networks", RFC 7579, June 2015.

[RFC7581] G. Bernstein, Y. Lee, D. Li, W. Imajuku, "Routing and Wavelength Assignment Information Encoding for Wavelength Switched Optical Networks", RFC 7581, June 2015.

[RFC7950] Bjorklund, M., Ed., "The YANG 1.1 Data Modeling Language", RFC 7950, August 2016.

[RFC8340] M. Bjorklund and L. Berger, Ed., "YANG Tree Diagrams", RFC 8340, March 2018.

[RFC8345] A. Clemm, et al, "A YANG Data Model for Network Topologies", RFC 8345, March 2018.

9. Contributors

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Intended status: Standard Track
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October 22, 2018

A Yang Data Model for Optical Impairment-aware Topology

draft-lee-ccamp-optical-impairment-topology-yang-00

Abstract

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

Status of this Memo

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Table of Contents

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

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

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

1.1. Terminology

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

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

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

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

- configuration data

o state data

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

1.2. Tree diagram

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

1.3. Prefixes in Data Node Names

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

Prefix	YANG module	Reference
optical-imp-topo	ietf-optical-impairment-topology	[RFC XXXX]
layer0-types	ietf-layer0-types	[WSON-topo]
nw	ietf-network	[RFC8345]
nt	ietf-network-topology	[RFC8345]
tet	ietf-te-topology	[TE-TOPO]

Table 1: Prefixes and corresponding YANG modules

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

2. 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 fiber-type?   fiber-type
    +--ro power?        int32
    +--ro pmd?          decimal64
    +--ro cd?           decimal64
    +--ro osnr?         decimal64
```

```
     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:
       +--:(optical-imp-topo)
          +--rw (grid-type)?
          |  +--:(flexi-grid)
          |  |  +--ro central-channel-freq?   decimal64
          |  |  +--ro slot-width?             decimal64
          |  +--:(dwdm)
          |  |  +--ro channel-freq?           decimal64
          |  +--:(cwdm)
          |     +--ro channel-wavelength?     uint32
          +--ro bit-rate?                     decimal64
          +--ro BER?                          decimal64
          +--ro pmd?                          decimal64
          +--ro cd?                           decimal64
          +--ro osnr?                         decimal64
          +--ro q-factor?                     decimal64
     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:
       +--:(optical-imp-topo)
          +--rw (grid-type)?
          |  +--:(flexi-grid)
          |  |  +--ro central-channel-freq?   decimal64
          |  |  +--ro slot-width?             decimal64
          |  +--:(dwdm)
          |  |  +--ro channel-freq?           decimal64
          |  +--:(cwdm)
          |     +--ro channel-wavelength?     uint32
          +--ro bit-rate?                     decimal64
          +--ro BER?                          decimal64
          +--ro pmd?                          decimal64
          +--ro cd?                           decimal64
          +--ro osnr?                         decimal64
          +--ro q-factor?                     decimal64
     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:
       +--:(optical-imp-topo)
          +--rw (grid-type)?
          |  +--:(flexi-grid)
          |  |  +--ro central-channel-freq?   decimal64
          |  |  +--ro slot-width?             decimal64
          |  +--:(dwdm)
          |  |  +--ro channel-freq?           decimal64
          |  +--:(cwdm)
          |     +--ro channel-wavelength?     uint32
          +--ro bit-rate?                     decimal64
```

```
          +--ro BER?                          decimal64
          +--ro pmd?                          decimal64
          +--ro cd?                           decimal64
          +--ro osnr?                         decimal64
          +--ro q-factor?                     decimal64
     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:
       +--:(optical-imp-topo)
          +--rw (grid-type)?
          |  +--:(flexi-grid)
          |  |  +--ro central-channel-freq?   decimal64
          |  |  +--ro slot-width?             decimal64
          |  +--:(dwdm)
          |  |  +--ro channel-freq?           decimal64
          |  +--:(cwdm)
          |     +--ro channel-wavelength?     uint32
          +--ro bit-rate?                     decimal64
          +--ro BER?                          decimal64
          +--ro pmd?                          decimal64
          +--ro cd?                           decimal64
          +--ro osnr?                         decimal64
          +--ro q-factor?                     decimal64
     augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-point
:
       +--rw available-operational-mode*   layer0-types:operational-mode
       +--rw operational-mode?             layer0-types:operational-mode
       +--rw vendor-identifier?            layer0-types:vendor-identifier
       +--rw transponder-id?               uint32
       +--ro available-modulation*         identityref
       +--rw modulation-enabled?           boolean
       +--rw modulation-type?              identityref
       +--ro available-FEC*                identityref
       +--rw FEC-enabled?                  boolean
       +--rw FEC-type?                     identityref
       +--ro FEC-code-rate?                decimal64
       +--rw 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
```

3. Optical Impairment Topology YANG Model

```
<CODE BEGINS> file ietf-optical-impairment-topology@2018-10-22.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 <leeyoung@huawei.com>
     Editor:   Haomian Zheng <zhenghaomian@huawei.com>
     Editor:   Nicola Sambo <nicosambo@gmail.com>
     Editor:   Victor Lopez <victor.lopezalvarez@telefonica.com>
     Editor:   Gabriele Galimberti <ggalimbe@cisco.com>";

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

   Copyright (c) 2018 IETF Trust and the persons identified as
   authors of the code.  All rights reserved.

   Redistribution and use in source and binary forms, with or
   without modification, is permitted pursuant to, and subject
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   License set forth in Section 4.c of the IETF Trust's Legal
   Provisions Relating to IETF Documents
   (http://trustee.ietf.org/license-info).";

  revision 2018-10-22 {
   description
      "version 0.";
```

```
      reference
        "RFC XXX: 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 optical-label {
```

```
    description
      "Generic label for optical links and paths";
    choice grid-type {
      description
        "Label for Flexigrid, DWDM or CWDM grid";
      case flexi-grid {
        leaf central-channel-freq {
          type decimal64 {
            fraction-digits 5;
          }
          units THz;
          config false;
          description
            "The Flexi-grid central frequency in THz, e.g. 193.12500";
          reference
            "RFC7698";
        }
        leaf slot-width {
          type decimal64 {
            fraction-digits 5;
          }
          units GHz;
          config false;
          description
            "The Flexi-grid slot width in GHz, e.g. 50, 100, 150.";
          reference
            "RFC7698";
   }
      }
      case dwdm {
        leaf channel-freq {
          type decimal64 {
            fraction-digits 5;
          }
          units THz;
          config false;
          description
            "The DWDM frequency in THz, e.g. 193.12500";
          reference
            "RFC6205";
        }
      }
      case cwdm {
        leaf channel-wavelength {
          type uint32;
          units nm;
     config false;
          description
            "The CWDM wavelength in nanometer, e.g. 1511";
```

```
          reference
            "RFC6205";
        }
      }
    }
  }


  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-enabled {
     type boolean;
     description
       "Determines whether the modulation is enabled or not";
   }
   leaf modulation-type {
     type identityref {
       base modulation;
     }
     description
       "Modulation type of the transponder";
   }
   leaf-list available-FEC {
     type identityref {
       base FEC;
     }
     config false;
          description "List determining all the available FEC";
   }
   leaf FEC-enabled {
     type boolean;
          description
         "Determines whether the FEC is enabled or not";
   }
   leaf FEC-type {
     type identityref {
       base FEC;
     }
     description
       "FEC type of 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";
     }
     description "Threshold on the BER, for which FEC is able to correct errors"
;
   }
   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";
        }
  }

  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 wson-node-attributes {
   description "WSON node attributes";
   container wson-node {
      description "WSON node attrtibutes.";
      leaf node-type {
       type identityref {
         base te-wson-types:wson-node-type;
       }
       description "WSON node type.";
      }
   }
  }
*/

  grouping optical-fiber-data {
      description "optical link (fiber) attributes with impairment data";

      leaf fiber-type {
    type fiber-type;
    config false;
    description "fiber-type";
      }

      leaf power {
         type int32;
    units "dBm";
         config false;
         description "Total Input Power Level at the line port 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 "osnr";
      }
/*    leaf sigma {
    type decimal64 {
            fraction-digits 5;
    }
    units "dB";
    config false;
       description "sigma in the Gausian Noise Model";
      }
     */
  }

  grouping optical-impairment-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";
     }
     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 "osnr";
      }
      leaf q-factor {
        type decimal64 {
         fraction-digits 5;
        }
        units "dB";
        config false;
        description "q-factor";
      }
  }

  grouping wson-ttp-attributes {
    description
      "WSON tunnel termination point (e.g.tranponder) attributes";
      leaf-list available-operational-mode {
        type layer0-types:operational-mode;
        description "List of all vendor-specific supported
        mode identifiers";
      }

      leaf operational-mode {
        type layer0-types:operational-mode;
        description "Vendor-specific mode identifier";
      }

      leaf vendor-identifier {
          type layer0-types:vendor-identifier;
          description "vendor identifier that uses vendor-specific mode";
        }
  }

/* 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.";
    uses optical-fiber-data;
  }

    /* 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/"
       + "optical-imp-topo:optical-impairment-topology" {
      description "Augment optical TE label";
    }
    description "optical label.";
    case optical-imp-topo {
      uses optical-label;
     uses optical-impairment-data;
    }
  }

  /* 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/"
       + "optical-imp-topo:optical-impairment-topology" {
      description "Augment optical TE label";
    }
    description "optical label.";
    case optical-imp-topo {
      uses optical-label;
     uses optical-impairment-data;
```

```
    }
  }
    /* 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/"
       + "optical-imp-topo:optical-impairment-topology" {
          description "Augment Optical TE label";
    }
*/
    description "optical label.";
    case optical-imp-topo {
      uses optical-label;
     uses optical-impairment-data;
    }
  }

  /* 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/"
       + "optical-imp-topo:optical-impairment-topology" {
      description "Augment Optical TE label";
    }
*/
    description "optical label.";
    case optical-imp-topo {
      uses optical-label;
     uses optical-impairment-data;
    }
  }



/*
  augment "/nw:networks/nw:network/nw:node/tet:te"
    + "/tet:te-node-attributes" {
    when "/nw:networks/nw:network/nw:network-types"
      +"/tet:te-topology/optical-imp-topo:optical-impairment-topology" {
      description
        "This augment is only valid for WSON.";
```

```
    }
    description "WSON Node augmentation.";
    uses wson-node-attributes;
  }
*/

  augment "/nw:networks/nw:network/nw:node/tet:te"
    + "/tet:tunnel-termination-point" {
    when "/nw:networks/nw:network/nw:network-types"
      +"/tet:te-topology/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.";

        uses wson-ttp-attributes;

        leaf transponder-id {
          type uint32;
          description "transponder identifier";
        }
    uses transponder-attributes;
  }

  augment "/nw:networks/nw:network/nw:node/tet:te"
    + "/tet:tunnel-termination-point" {
    when "/nw:networks/nw:network/nw:network-types"
      +"/tet:te-topology/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>
```

4. Security Considerations

The configuration, state, and action data defined in this document are designed to be accessed via a management protocol with a secure transport layer, such as NETCONF [RFC6241]. The NETCONF access control model [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).

5. IANA Considerations

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

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

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

```
--------------------------------------------------------------------
name:      ietf-optical-impairment-topology
namespace: urn:ietf:params:xml:ns:yang:ietf-optical-impairment-
topology

reference: RFC XXXX (TDB)
--------------------------------------------------------------------
```

6. Acknowledgments

We thank Dieter Bella and Sergio Belotti for useful discussions and motivation for this work.

7. References

7.1. Normative References

7.2. Informative References

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Internet Engineering Task Force
Internet-Draft
Intended status: Informational
Expires: January 3, 2019

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July 2, 2018

Applicability of GMPLS for B100G Optical Transport Network
draft-merge-ccamp-gmpls-otn-b100g-applicability-00

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.

Status of This Memo

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Table of Contents

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 x 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 Structrure 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*100G. 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 >=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.

```
    ==================================================================

          +---------------------------------------------------------+
          |                   OTUCn signal                          |
          +---------------------------------------------------------+
          |  Inter+Domain      |  Intra+Domain      |  Intra+Domain  |
          |  Interface (IrDI)|  Interface (IaDI)|  Interface       |
          |  FlexO (G.709.1)  |  FlexO (G.709.x)  |  Proprietary     |
          |                    |  (Future)          |  Encap, FEC etc. |
          +---------------------------------------------------------+

    ==================================================================
```

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 x 239/226 x 99,532,800 kbit/s = n x 105,258,138.053 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.

```
   ==================================================================


+--------+           +--------+                 +--------+           +--------+
|        +-----------+        |                 |        +-----------+        |
| OTN    |-----------| OTN    |                 | OTN    |-----------| OTN    |
| DXC    +-----------+ WXC    +-----------------+ WXC    +-----------+ DXC    |
|        |           | 3R     |                 | 3R     |           |        |
+--------+           +--------+                 +--------+           +--------+
    <--------------------------------ODUCn------------------------------->
     <------------------->  <----------------------> <------------------->
             OTUCn                   OTUCn                   OTUCn


   ==================================================================
```

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 X 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*n tributary slots (of 5Gbps capacity). It is worthwhile considering that the range of tributary port number (TPN) is 10*n, and not 20*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*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*n bytes and indicates the availability of each TS. Two bytes are used for each of the 20*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 illstrates 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 x 2,488,320 Kbps
ODU2	239/237 x 9,953,280 Kbps
ODU2e	239/237 x 10,312,500 Kbps
ODU3	239/236 x 39,813,120 Kbps
ODU4	239/227 x 99,532,800 Kbps
ODUflex for CBR client signals	239/238 x Client signal Bit rate
ODUflex for GFP-F mapped packet traffic	Configured bit rate
ODUflex for IMP mapped packet traffic	s x 239/238 x 5 156 250 kbit/s: s=2,8,5*n, n >= 1
ODUflex for FlexE aware transport	103 125 000 x 240/238 x 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

```
    ==================================================================

                     Clients (e.g. SONET/SDH, Ethernet)
                          +       +      +
                          |       |      |
          +-------------------+-------+------+------------------------+
          |                    OPUk                                   |
          +-----------------------------------------------------------+
          |                    ODUk                                   |
          +-----------------------+----------------------------+------+
          | OTUk, OTUk.V, OTUkV   |          OPUk              |      |
          +----------+-----------------------------------------+      |
          | OTLk.n   |            |          ODUk              |      |
          +----------+            +---------------------+------+      |
                                  | OTUk, OTUk.V, OTUkV |   OPUCn     |
                                  +----------+-----------------------+
                                  | OTLk.n   |          |   ODUCn     |
                                  +----------+          +-------------+
                                                        |   OTUCn     |
                                                        +-------------+

    ==================================================================
```

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.

```
==================================================================


              +--------+                      +--------+
              |        +----------------------+        |
              | OTN    |----------------------| OTN    |
              |  XC    +----------------------+  XC    |
              |        |                      |        |
              +--------+                      +--------+
                <---------- ODUk/ODUflex ----------->
                 <------------ ODUCn -------------->
                  <------- OTUCn/OTUCn-M --------->
                   <--------OTSi(G)/OTSiA--------->


==================================================================
```

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.

```
   ===================================================================

                    +--------------------------------------+
     A              |                B                     |          A or C
     |              |                                      |             |
+--------+          | +--------+                +--------+ |        +--------+
|        +----------|-+        |                |        +-|--------+        |
| OTN    |----------|-| Transp |                | Transp |-|--------| OTN    |
|  XC    +----------|-+ onder  +----------------+ onder  +-|--------+  XC    |
|        |          | |        |                |        | |        |        |
+--------+          | +--------+                +--------+ |        +--------+
                    |                                      |
                    +--------------------------------------+

     <-----------------------------ODUk/ODUflex---------------------------->
      <----------------------------- ODUCn ------------------------------->
       <-------OTUCn-------><-----OTUCn/OTUCn-M-----><-------OTUCn------->
        <--OTSi(G)/OTSiA-->  <----OTSi(G)/OTSiA---->  <--OTSi(G)/OTSiA-->

   ===================================================================
```

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. 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.

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.

```
=================================================================


    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |       TPN = 3           |   Reserved    |    Length = 200       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0 1 1 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0 0 0 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0 0 0 0 0 0 0 0|               Padding Bits(0)                   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+


=================================================================
```

Figure 6: Label format

4.2.2. 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

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8. IANA Considerations

This memo includes no request to IANA.

9. Security Considerations

None.

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Internet Engineering Task Force X. Niu, Ed.
Internet-Draft Q. Wang, Ed.
Intended status: Informational ZTE
Expires: April 25, 2019 October 22, 2018

A YANG Data Model for Flex Ethernet(FlexE)
draft-xiaobn-flexe-yang-mod-00

Abstract

Flex Ethernet(FlexE) implementation agreement have been published by OIF. FlexE provides a generic mechanism for supporting a variety of Ethernet MAC rates that may or may not correspond to any existing Ethernet PHY rate.

This document describes a YANG data model for FlexE. It can be used to manage and control devices supporting FlexE functions.

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Table of Contents

1. Introduction

Flex Ethernet (FlexE) implementation agreement version 1.0 [OIFFLEXE1] and 2.0 [OIFFLEXE2] have been published by OIF. FlexE provides a generic mechanism for supporting a variety of Ethernet MAC rates that may or may not correspond to any existing Ethernet PHY rate. This includes MAC rates that are both greater than (through bonding) and less than (through sub-rate and channelization) the Ethernet PHY rates used to carry FlexE.

This document defines a date model of FlexE, using YANG[RFC7950]. This model mainly deals with the data model of the FlexE Group and the FlexE client. It can be used by an application to configure and modify the parameters of the FlexE Group and the FlexE client, and to receive notifications, e.g. mismatch errors, from devices supporting FlexE functions.

Requirements for the FlexE YANG model are considered. And FlexE YANG tree and YANG files are given.

2. Terminology

A simplified graphical representation of the data model is used in this document. The meaning of the symbols in the YANG data tree presented later in this document is defined in [RFC8340]. They are provided below for reference.

- o Brackets "[" and "]" enclose list keys.
- o Abbreviations before data node names: "rw" means configuration (read-write) and "ro" state data (read-only).
- o Symbols after data node names: "?" means an optional node, "!" means a presence container, and "*" denotes a list and leaf-list.
- o Parentheses enclose choice and case nodes, and case nodes are also marked with a colon (":").
- o Ellipsis ("...") stands for contents of subtrees that are not shown.
- o Some of the key terms used in this document are listed as follow.

2.1. Requirements Language

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

2.2. FlexE terminology used in this document

a. CSG: Calendar Slot Granularity. It can be 5G or 25G.

b. FlexE Calendar: In FlexE IA v1.0, the total capacity of a FlexE Group is represented as a collection of slots which have a granularity of 5G. The calendar for a FlexE Group composed of n 100G PHYs is represented as an array of 20n slots (each representing 5G of bandwidth). This calendar is partitioned into sub-calendars, with 20 slots per 100G PHY. Each FlexE client is mapped into one or more calendar slots (based on the bandwidth the FlexE client flow will need). In FlexE IA v2.0[OIFFLEXE2], the total capacity of a FlexE Group is represented as a collection of slots which may have a granularity of 5G or 25G. The calendar for a FlexE Group composed of n 100G FlexE instances from m 100G/200G/400G PHYs is represented as an array of 20n slots (each representing 5G of bandwidth) or 4n slots (25G granularity).

c. FlexE Client: An Ethernet flow based on a MAC data rate that may or may not correspond to any Ethernet PHY rate.

d. FlexE Group: A FlexE Group is composed of from 1 to n 100G FlexE Instances that are carried by a group of from 1 to m bonded Ethernet PHYs.

e. FlexE instance: A 100G FlexE Instance is a unit of information consisting of 100G of capacity able to carry FlexE Client data, together with its associated overhead.

Detailed description of these terms can be found in [OIFFLEXE1] and [OIFFLEXE2] .

3. FlexE Reference Configuration Model

FlexE can be implemented between the FlexE mux and demux in two end devices connected directly by the FlexE links. In this case, FlexE is just a link connection technology.

FlexE can also be transported by transport networks. There are three kinds of transport network mapping mechanisms for FlexE signals, that is, FlexE unaware transport, FlexE termination in the transport network and FlexE aware transport.

How to configure the ingress or egress of transport network about FlexE mapping relationship may be application specific. In this document, the part of YANG data model for the transport network mapping for FlexE is not included at present.

4. Requirements

4.1. Requirements

This section summarizes the management requirements for the FlexE Group and the FlexE Client.

Req-1 The model SHALL support the management of the FlexE Group, consisting of one or more 100G FlexE instances which carried by one or more 100GE, 200GE, 400GE Ethernet PHY(s).

The detailed management covers the CURD functions (create, update, read and delete), and lock/unlock.

Req-2 The model SHOULD be able to verify that the collection of Ethernet PHY(s) included in a FlexE Group have the same characteristics (e.g. number of PHYs, rate of PHYs, etc.) at the local FlexE shims. If inconsistency exists, notifications (e.g. errors) SHOULD be invoked.

Req-3 The model SHOULD be able to verify that the collection of FlexE instances included in a FlexE Group have the same characteristics (e.g. calendar slot granularity, unequipped slots, etc.) at the local FlexE shims. If inconsistency exists, notifications (e.g. errors) SHOULD be invoked.

Req-4 The model SHALL allow the addition (or removal) of one or more FlexE clients on a FlexE Group. The addition (or removal) of a FlexE client flow SHALL NOT affect the services for the other FlexE client signals.

Req-5 The model SHALL allow FlexE client signals to flexibly span the set of FlexE instances which comprise the FlexE Group.

Req-6 The model SHALL support a FlexE client flow resizing without affecting any existing FlexE clients within the same FlexE Group.

Req-7 The model SHALL support the switching of a calendar configuration. There are two calendar configurations, A and B.

5. YANG Data Model for FlexE (Tree Structure)

```
module: ietf-flexe-yang
  +--rw flexe-configuration
  |  +--rw flexe-groups
  |  |  +--rw flexe-group* [group-name]
  |  |     +--rw group-name          string
  |  |     +--rw group-attributes
  |  |        +--rw group-number?                 uint32
  |  |        +--rw calendar-slot-granularity?   calendar-slot-granularity
  |  |        +--rw flexe-phy-type?              flexe-phy-type
  |  |        +--rw bonded-phys
  |  |        |  +--rw flexe-phys* [phy-number-in-group]
  |  |        |     +--rw phy-number-in-group    uint8
  |  |        |     +--rw local-phy-number?      uint16
  |  |        +--rw flexe-instances
  |  |        |  +--rw flexe-instance* [flexe-instance-number]
  |  |        |  |  +--rw flexe-instance-number    uint8
  |  |        |  +--rw uneqipped-flexe-instance* [flexe-instance-number]
  |  |        |     +--rw flexe-instance-number    uint8
  |  |        +--rw rx-calendar?                 calendar-AorB
  |  |        +--rw tx-calendar?                 calendar-AorB
  |  |        +--rw tx-calendar-neg?             enumeration
  |  |        +--rw reply-ca-mode?               enumeration
  |  +--rw flexe-clients
  |     +--rw flexe-client* [client-name]
  |        +--rw client-name             string
  |        +--rw client-attribute
  |        |  +--rw client-number?   uint32
  |        |  +--rw bandwidth
  |        |     +--rw signal-type?   flexe-client-signal-rate
  |        |     +--rw mac-rate?      rt-types:bandwidth-ieee-float32
  |        +--rw used-flexe-resources
  |           +--rw used-rsc* [calendar flexe-group]
  |              +--rw calendar          calendar-AorB
  |              +--rw flexe-group       string
  |              +--rw flexe-instance?   uint8
  +--ro flexe-group-state
     +--ro port-group
        +--ro port-group* [port-group-id]
           +--ro port-group-id    uint32
           +--ro intf-state?      intf-state
```

Figure 1

6. YANG Module

```
<CODE BEGINS> file "ietf-flexe-yang@2018-10-12.yang"
module ietf-flexe-yang {
  yang-version 1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-flexe-yang";
  prefix "flexe";
  import ietf-routing-types {
    prefix rt-types;
  }
  organization
    "Internet Engineering Task Force (IETF) CCAMP WG";
  contact
    "WG List: <mailto:ccamp@ietf.org>
  ID-draft editor:
    Xiaobing Niu (niu.xiaobing@zte.com.cn);
    Qilei Wang (wang.qilei@zte.com.cn); ";
  description
    "This module defines a YANG data model for FlexE.";
  revision 2018-10-12 {
    description
      "Initial version.";
    reference
          "draft-xiaobn-flexe-yang-mod-00.txt";
  }

  /* typedefs */
  typedef calendar-slot-granularity {
    type enumeration {
      enum csg-5G {
        value 1;
        description "Calendar slot with a 5G granularity";
      }
      enum csg-25G {
        value 2;
        description "Calendar slot with a 25G granularity";
      }
    }
    description
      "Defines a type representing the granularity of a calendar slot.";
  }

  typedef flexe-client-signal-rate {
    type enumeration {
      enum flexe-client-signal-10Gbps{
        value 1;
        description
          "FlexE Client signal rate of 10Gbps";
```

```
      }
      enum flexe-client-signal-40Gbps{
        value 2;
        description
          "FlexE Client signal rate of 40Gbps";
      }
      enum flexe-client-signal-25mGbps{
        value 3;
        description
          "FlexE Client signal rate of m*25Gbps";
      }
    }
    description
      "Defines FlexE Client signal rate, including 10, 40, m*25Gbps.";
  }
  typedef flexe-phy-type {
    type enumeration {
      enum flexe-phy-100GBASE-R {
        value 1;
        description "100GBASE-R PHY";
      }
      enum flexe-phy-200GBASE-R {
        value 2;
        description "200GBASE-R PHY";
      }
      enum flexe-phy-400GBASE-R {
        value 3;
        description "400GBASE-R PHY";
      }
    }
    description
      "Defines types of PHYs in a FlexE group";
  }
  typedef calendar-AorB {
    type enumeration {
      enum calendar-A {
        value 0 ;
        description
          "Set the A calendar configuration.";
      }
      enum calendar-B {
        value 1 ;
        description
          "Set the B calendar configuration.";
      }
    }
    description
      "Calendar configuration A or B";
```

```
  }
  /* interface states: OK, SF, SD */
  typedef intf-state {
    type enumeration {
      enum ok {
        value 0 ;
        description
          "The interface state of the FlexE Group is OK.";
      }
      enum sf {
        value 1 ;
        description
          "The interface state of the FlexE Group is SF."      ;
      }
      enum sd {
        value 2 ;
        description
          "The interface state of the FlexE Group is SD.";
      }
    }
    description
      "Interface state of port group.";
  }
  /* grouping */
  grouping flexe-client-bandwidth{
    leaf signal-type{
      type flexe-client-signal-rate;
      description
        "Client signal types: 10, 40, m*25 Gbps.";
    }
    leaf mac-rate {
      type rt-types:bandwidth-ieee-float32;
        description
          "Bandwidth of clients.";
    }
    description
      "The bandwidth of a FlexE client.";
  }

  /* Configuration of FlexE */
  container flexe-configuration{
    description
      "FlexE configuration, including configuration of FlexE groups and FlexE cl
ients.";
    container flexe-groups {
      description
        "Container for the FlexE Group";
      list flexe-group {
        key group-name;
```

```
        description
          "List of FlexE Group";
        leaf group-name {
          type string ;
          description
            "The name of a FlexE Group";
        }
        container group-attributes {
          description
            "The attributes of a FlexE Group";
          leaf group-number {
            type uint32 {
              range 1..1048574 ;
            }
            description
              "The FlexE Group number is selected from the range 1~0xFFFFE.
               The value of 0x00000 and 0xFFFFF may not be used to designate
               a FlexE Group.";
          }
          leaf calendar-slot-granularity{
            type calendar-slot-granularity;
              description
                "The granularity of calendar slot is 5G or 25G";
              reference
                "OIF FlexE IA 2.0";
          }
          leaf flexe-phy-type{
            type 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 ;
                description
                  "Refer to the clause 6.1 in FlexE IA 2.0.
                   For 100GBASE-R, the FlxeE PHY number and the 100G FlexE insta
nce
                   number are the same and in the range [1-254];
                   For 200GBASE-R, each PHY number is in the range [1-126].
                   For 400GBASE-R, each PHY number is in the range [1-62].";
```

```
              }
              leaf local-phy-number{
                type uint16 ;
                description
                  "Local PHY number related to the PHY number
                   in a FlexE group.( with uint16 while not uint8 )";
              }
            }
          }

          container flexe-instances {
            description
              "FlexE instances in a FlexE Group";
            list flexe-instance {
              key flexe-instance-number;
              description
                "List of a FlexE instance in a FlexE Group";
              leaf flexe-instance-number{
                type uint8 ;
                description
                  "Logical FlexE instance number";
                reference
                  "Clause 6.1 FlexE Group in FlexE IA 2.0.
                   For 100G, instance num=PHY num;
                   For 200G, 8-bit instance num consists of the PHY num in the u
pper
                   seven bits, and 0 or 1 in the lower order bit.
                   For 400G, 8-bit instance num consists of the PHY num in the u
pper
                   six bits, and 0,1,2, or 3 in the two lower order bits.  ";
              }
            }
            list uneqipped-flexe-instance {
              key flexe-instance-number;
              description
                "Unquipped FlexE instance in a FlexE Group";
              leaf flexe-instance-number{
                type uint8 ;
                description
                  "Clause 6.1 FlexE Group in FlexE IA 2.0";
              }
            }
          }
          leaf rx-calendar {
            type calendar-AorB;
            description
              "Calendar configuration in the receive direction";
          }
          leaf tx-calendar {
            type calendar-AorB;
```

```
            description
              "Calendar configuration in the transmit direction";
          }
          leaf tx-calendar-neg {
            type enumeration {
              enum manual {
                value 1 ;
                description
                  "Manually configured";
              }
              enum protocol-force {
                value 2 ;
                description
                  "Protocol forced";
              }
              enum protocol-normal {
                value 3 ;
                description
                  "Protocol normal";
              }
            }
            description
              "TX calendar negotiation methods";
          }
          leaf reply-ca-mode {
            type enumeration {
              enum never {
                value 1 ;
                description
                  "never reply CA (Configuration Ack)";
              }
              enum immediately {
                value 2 ;
                description
                  "immediately reply CA (Configuration Ack)";
              }
              enum ask-controller {
                value 3 ;
                description
                  "Ask controller for more control";
              }
            }
            description
              "Reply CA mode";
          }
        }
      }
    }
```

```
    container flexe-clients {
      description
        "FlexE clients information";
      list flexe-client {
        key client-name ;
        description
          "Attributes of FlexE client" ;
        leaf client-name {
          type string ;
          description
            "FlexE client name";
        }
        container client-attribute {
          description
            "Attributes for specific client.";
          leaf client-number {
            type uint32 {
              range 1..65534 ;
            }
            description
              "Client number in the range of 1~0xFFFF";
          }
          container bandwidth {
            description "Client bandwidth";
            uses flexe-client-bandwidth;
          }
        }
        container used-flexe-resources {
          description
            "Used FlexE resources to carry the FlexE client";
          list used-rsc {
            key "calendar flexe-group" ;
            description
              "List of used resources";
            leaf calendar {
              type calendar-AorB;
              description
                "Calendar configuration";
            }
            leaf flexe-group {
              type string ;
              description
                "FlexE Group";
            }
            leaf flexe-instance {
              type uint8 ;
              description
                "FlexE Instance";
```

```
            }
          }
        }
      }
    }     /* end of FlexE client */
  }

  /* states of FlexE Group */
  container flexe-group-state {
    config false ;
    description "State info." ;
    container port-group {
      description "Port group state information.";
      list port-group {
        key port-group-id ;
        description "The state information of port-group.";
        leaf port-group-id {
          type uint32 {
            range 1..65536 {
              description "Port group id.";
            }
          }
          description "Port group id of port group.";
        }
        leaf intf-state {
          type intf-state ;
          description "Port state of port group.";
        }
      }
    }
  }
}
```

<CODE ENDS>

7. Acknowledgements

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9. Contributors

10. IANA Considerations

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

URI: urn:ietf:params:xml:ns:yang:ietf-flexe-yang

Registrant Contact: The IESG.

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

This document registers the following YANG modules in the YANG Module Names registry[RFC6020] :

name: ietf-flexe-yang

namespace: urn:ietf:params:xml:ns:yang:ietf-flexe-yang

reference: RFC XXXX (TDB)

11. Security Considerations

The YANG module specified in this document defines a schema for data that is designed to be accessed via network management protocols such as NETCONF[RFC6241]. Proper standardized security measures should be implemented.

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

12. References

12.1. Normative References

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CCAMP Working Group M. Ye, Ed.
Internet-Draft A. Guo
Intended status: Standards Track Huawei Technologies
Expires: January 1, 2019 J. Ahlberg
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June 30, 2018

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

Abstract

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

Requirements Language

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

Status of This Memo

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Table of Contents

1. Terminology and Definitions

The following acronyms are used in this document:

PNC Provisioning Network Controller

MDSC Multi Domain Service Coordinator

2. Introduction

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

The microwave topology model is expected to be used between a Provisioning Network Controller(PNC) and a Multi Domain Service

Coordinator(MDSC)([I-D.ietf-teas-actn-framework]). Possible use cases of microwave topology models include:

1. The microwave link frequency could be used to understand the current frequency usage, enabling a whole view of the network topology information, and as an input for network frequency planning.

2. The microwave radio link could change its bandwidth according to the environments under the adaptive modulation mode, e.g., the bandwidth will degrade when there's a heavy rain. To get to know of current microwave link bandwidth is important for path computation and service provisioning across different technologies/networks.

3. Due to bandwidth changing feature, availability is normally used to describe the microwave radio link characteristic. [RFC8330] defines a mechanism to report bandwidth-availability information through OSPF-TE. It's also necessary to include the information in the YANG data model to optimize the path/route computation.

3. YANG Data Model (Tree Structure)

3.1. The YANG Tree

```
module: ietf-microwave-topology
  augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
    +--rw mw-topology!
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes:
        +--rw mw-link-frequency?            uint32
        +--rw mw-link-channel-separation?    uint32
        +--ro mw-link-nominal-bandwidth? rt-types:bandwidth-ieee-float32
        +--ro mw-link-current-bandwidth? rt-types:bandwidth-ieee-float32
        +--rw mw-unreserved-bandwidth    rt-types:bandwidth-ieee-float32
        +--rw mw-link-availability* [availability]
           +--rw mw-link-availability    rt-types:percentage
           +--ro mw-link-bandwidth       rt-types:bandwidth-ieee-float32
  augment /nw:networks/nw:network/nw:node/nt:termination-point /tet:te:
    +-- mp interface-root
```

3.2. Relationship with microwave interface YANG model

The microwave topology model is expected to be used between a PNC and a MDSC. [I-D.ietf-ccamp-mw-yang] defines an interface YANG model for microwave radio link which is used between the PNC and the physical device for device configuration. The PNC is able to convert the information received from the topology model into the interface model. For example, the link frequency in the topology model is mapped to the tx-frequency of the carrier termination in the interface model.

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

4. YANG Module

```
<CODE BEGINS> file "ietf-microwave-topology.yang"

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

  prefix "mwtopo";

  import ietf-network {
    prefix "nw";
  }

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

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

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

  import ietf-yang-schema-mount {
       prefix yangmnt;
       reference "draft-ietf-netmod-schema-mount: YANG Schema Mount";
     }
```

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

     ID-draft authors:
      Min Ye (amy.yemin@huawei.com);
      Aihua Guo (aihuaguo@huawei.com);
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      Daniela Spreafico (daniela.spreafico@nokia.com)
     ";

    description
     "This is a module for microwave topology.";

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

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


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

            leaf mw-link-frequency {
              type uint32;
              units "kHz";
              description "Frequency of the link";
              }

            leaf mw-link-channel-separation {
              type uint32;
              units "kHz";
              description "The distance
               between adjacent channels in a radio frequency channel
               arrangement used in this link";
```

```
              reference "ETSI EN 302 217-1";
              }

             leaf mw-link-nominal-bandwidth {
               type rt-types:bandwidth-ieee-float32;
                   units "Mbps";
                   config false;
                   description "The nominal bandwidth of the link";
             }

             leaf mw-link-current-bandwidth {
              type rt-types:bandwidth-ieee-float32;
              units "Mbps";
              config false;
              description "The current bandwidth of the link";
              }

             leaf mw-unreserved-bandwidth {
              type rt-types:bandwidth-ieee-float32;
              units "Mbps";
              description "the unreserved bandwidth of the link";
              }


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

                   leaf availability {
                     type rt-types:percentage;
                     description "availability level of the link";
                   }

                   leaf mw-link-bandwidth {
                     type rt-types:bandwidth-ieee-float32;
                     units "Mbps";
                     config false;
                     description "The link bandwidth corresponding
                                  to the availability level";
                     }
        }

         container "interface-root" {
              description
                "Container for mount point.";
              yangmnt:mount-point "interface-root" {
                description
```

```
                  "Root for microwave rado interface model.
                               It could contain an interface instance.";
              }
            }

           }

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

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

       uses mw-link-attributes;
     }

    }
   <CODE ENDS>
```

5. Security Considerations

The YANG module specified in this document defines a schema for data that is designed to be accessed via network management protocols such as NETCONF [RFC6241] or RESTCONF [RFC8040][RFC8040]. The lowest NETCONF layer is the secure transport layer, and the mandatory-to-implement secure transport is Secure Shell (SSH) [RFC6242]. The lowest RESTCONF layer is HTTPS, and the mandatory-to-implement secure transport is TLS [RFC5246].

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

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

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

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

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

6. IANA Considerations

IANA has assigned a new URI from the "IETF XML Registry" [RFC3688].

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

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

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

7. References

7.1. Normative References

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Appendix A. Appendix A Examples of microwave topology

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

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

```
      Node 1                                Node 2
+---------------+                     +---------------+
|               |                     |               |
| +-----------+ |                     | +-----------+ |
| |    LTP11  | |                     | |   LTP21   | | --ETH topo
| +-------o---+ |  ETH-TE-Link-1      | +---o-------+ |
|         |---------------------------------|         |
|               |                     |               |
| +-----------+ |                     | +-----------+ |
| | TTP-1 __  | | microwave tunnel-11 | |  __ TTP-1 | |
| |       \/@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@\/       | |
| |        *  | |                     | |  *        | | --Microwave topo
| |         * | | microwave link 12   | | *         | |
| |    LTP-1 *o ------------------------o* LTP-1    | |
| |           | |                     | |           | |
| +-----------+ |                     | +-----------+ |
|               |                     |               |
+---------------+                     +---------------+
```

Figure 3: ETH transported on a single microwave radio link

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

```
...
"ietf-network-topology:link": [
  {
    "link-id": "N1,LTP11,N2,LTP21",
    "source": {
      "source-node": "N1",
      "source-tp": "LTP11"
    }
    "destination": {
      "dest-node": "N2",
      "dest-tp": "LTP21"
    }
  }
]
"ietf-te-topology:link/te/te-link-attributes/": [
  {
    "enabled": ture,
        "primary-path":{
         "path-element": {
           "path-element-id": "MW-11"
               //no backup-path
               //no protection-type
         }
        }
        "tunnel-termination-points": {
          "source": "N1/TTP-1",
              "destination": "N2/TTP-1"
        }
        "tunnels" : {
         "sharing": "false",
         "tunnel":{
           "tunnel-name": "MW-11",
               "sharing": "false"
         }
        }
      }
]
```


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

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

```
     ...
     "ietf-network-topology:link": [
       {
         "link-id": "N1,LTP1,N2,LTP1",
         "source": {
           "source-node": "N1",
           "source-tp": "LTP1"
         }
         "destination": {
           "dest-node": "N2",
           "dest-tp": "LTP1"
         }
       }
     ]
     "ietf-te-topology:link/te/te-link-attributes/underlay": [
       {
            "mw-link-frequency":  10728000,
            "mw-link-channel-separation": "28000",
            "mw-link-actual-tx-cm":"qam-512",
            "mw-link-nominal-bandwidth": "1000",
            "mw-link-current-bandwidth": "1000",
            "mw-link-availability":{
             "mw-link-availability":"0.9999",
             "mw-link-bandwidth": "1000"
            }
           }
     ]
```


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

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

```
      Node 1                                Node 2
+----------------+                     +----------------+
|                |                     |                |
| +------------+ |                     | +------------+ |
| |    LTP11   | |                     | |    LTP21   | | --ETH topo
| +-------o---+ |  ETH-TE-Link-1      | +---o-------+ |
|          |---------------------------------|          |
|                |                     |                |
| +------------+ |                     | +------------+ |
| | TTP-1 __   | | microwave tunnel-11 | |  __ TTP-1 | |
| |       \/@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@\/        | |
| |         *  | |                     | |  *         | | --Microwave topo
| |          * | | mw bundled link 33  | | *          | |
| |    LTP-3 *o ------------------------o* LTP-3    | |
| |            | |                     | |            | |
| |    LTP-2  o |                      | o  LTP-2    | |
| |    LTP-1  o |                         | o  LTP-1    | |
| +------------+ |                     | +------------+ |
|                |                     |                |
+----------------+                     +----------------+
```

Figure 4: ETH transported on single microwave radio links

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

```
...
"ietf-network-topology:link": [
  {
    "link-id": "N1,LTP11,N2,LTP21",
    "source": {
      "source-node": "N1",
      "source-tp": "LTP11"
    }
    "destination": {
      "dest-node": "N2",
      "dest-tp": "LTP21"
    }
  }
]
"ietf-te-topology:link/te/te-link-attributes/": [
  {
    "enabled": ture,
        "primary-path":{
         "path-element": {
           "path-element-id": "MW-33"
               //no backup-path
               //no protection-type
         }
        }
        "tunnel-termination-points": {
          "source": "N1/TTP-1",
              "destination": "N2/TTP-1"
        }
        "tunnels" : {
         "sharing": "false",
         "tunnel":{
           "tunnel-name": "MW-11",
               "sharing": "false"
         }
        }
      }
]
```

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

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

```
...
"ietf-network-topology:link": [
  {
    "link-id": "N1,LTP1,N2,LTP1",
    "source": {
      "source-node": "N1",
      "source-tp": "LTP3"
    }
    "destination": {
      "dest-node": "N2",
      "dest-tp": "LTP3"
    }
  }
]
"ietf-te-topology:link/te/te-link-config": [
  {
       "bundle-stack-level":{
         "component" {
           "component-links-1": {
         "sequence": "mw-11",
         "src-tp-ref": "N1-LTP1",
         "des-tp-ref" : "N2-LTP1"
               }
                "component-links-2": {
         "sequence": "mw-22",
         "src-tp-ref": "N1-LTP2"
         "des-tp-ref" : "N2-LTP2"
               }
         }
       }
      }
]
```

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

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A YANG Data Model for Transport Network Client Signals
draft-zheng-ccamp-client-signal-yang-03

Abstract

A transport network is a server-layer network to provide connectivity services to its client. The topology and tunnel information in the transport layer has already been defined by Traffic-engineered models and OTN models, however, the access to the network has not been described. These information is useful to both client and provider.

This draft describe how the client signals are carried over transport network and defined corresponding YANG data model which is required during configuration procedure. More specifically, several client signal (of transport network) models including ETH, STM-n, FC and so on, are defined in this draft.

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Table of Contents

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. Currently there has been topology and tunnel model defined for transport network, such as [I-D.ietf-ccamp-otn-topo-yang] and [I-D.ietf-ccamp-otn-tunnel-model], which has described the network model between PEs. However, there is a missing piece for the mapping between the PE and the CE, which is expected to be solved in this document.

This document defines a data model of all transport network client signals, using YANG language defined in [RFC7950]. The model can be used by applications exposing to a transport controller via a REST interface. Furthermore, it can be used by an application for the following purposes (but not limited to):

o To request/update an end-to-end service by driving a new tunnel to be set up to support this service;

o To request/update an end-to-end service by using an existing tunnel;

o To receive notification with regard to the information change of the given service;

The YANG model defined in this document is independent of control plane protocols and captures topology related information. 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].

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 [I-D.ietf-netmod-yang-tree-diagrams]. They are provided below for reference.

o Brackets "[" and "]" enclose list keys.

o Abbreviations before data node names: "rw" means configuration (read-write) and "ro" state data (read-only).

o Symbols after data node names: "?" means an optional node, "!" means a presence container, and "*" denotes a list and leaf-list.

o Parentheses enclose choice and case nodes, and case nodes are also marked with a colon (":").

o Ellipsis ("...") stands for contents of subtrees that are not shown.

3. Transport Network Client Signal Overview

The transport network is usually a server-layer network designed to provide connectivity services for a client-layer network to carry the client traffic opaquely across the server-layer network resources. A transport network may be constructed from equipments utilizing any of a number of different transport technologies such as the evolving optical transport infrastructure (SONET/SDH and OTN) or packet transport as epitomized by the MPLS Transport Profile (MPLS-TP).

In the example of OTN as the transport network, a full list of G-PID was summarized in [RFC7139], which can be divided into a few categories. The G-PID signals can be categorized into transparent and non-transparent. Examples of transparent signals may include Ethernet, ODU, STM-n and so on. In this approach the OTN devices do not is not aware of the client signal type, and this information is only necessary among the controllers. Once OTN tunnel is set up, there is no switching requested on the client layer, and therefore only signal mapping is needed, without a client tunnel set up. The other category would be non-transparent, such as Carrier Ethernet and MPLS-TP, with a switching request on the client layer. Once the OTN tunnel is set up, a corresponding tunnel in the client layer has to be set up to carry services. The models in this draft are applicable for both of the two above categories.

It is also worth noting that some client signal can be carried over multiple types of transport networks. For example, the Ethernet services can be carried over either OTN or Ethernet TE tunnels (over optical or microwave networks). The model specified in this document allows the support from networks with different technologies.

4. YANG Model for Transport Network Client Signal

4.1. YANG Tree for Ethernet Service

```
module: ietf-eth-tran-service
    +--rw etht-svc
       +--rw globals
       |  +--rw named-bandwidth-profiles* [bandwidth-profile-name]
       |     +--rw bandwidth-profile-name    string
       |     +--rw bandwidth-profile-type?   etht-types:bandwidth-profile-type
       |     +--rw CIR?                      uint64
       |     +--rw CBS?                      uint64
       |     +--rw EIR?                      uint64
       |     +--rw EBS?                      uint64
       |     +--rw color-aware?              boolean
       |     +--rw coupling-flag?            boolean
```

```
       +--rw etht-svc-instances* [etht-svc-name]
          +--rw etht-svc-name             string
          +--rw etht-svc-id?              yang:uuid
          +--rw etht-svc-descr?           string
          +--rw etht-svc-customer?        string
          +--rw etht-svc-type?            etht-types:service-type
          +--rw etht-svc-lifecycle?       etht-types:lifecycle-status
          +--rw te-topology-identifier
          |  +--rw provider-id?   te-types:te-global-id
          |  +--rw client-id?     te-types:te-global-id
          |  +--rw topology-id?   te-types:te-topology-id
          +--rw etht-svc-access-ports* [access-port-id]
          |  +--rw access-port-id                     uint16
          |  +--rw access-node-id?                    te-types:te-node-id
          |  +--rw access-ltp-id?                     te-types:te-tp-id
          |  +--rw service-classification-type?       identityref
          |  +--rw (service-classification)?
          |  |  +--:(port-classification)
          |  |  +--:(vlan-classification)
          |  |     +--rw outer-tag!
          |  |     |  +--rw tag-type?     etht-types:eth-tag-classify
          |  |     |  +--rw (individual-bundling-vlan)?
          |  |     |     +--:(individual-vlan)
          |  |     |     |  +--rw vlan-value?   etht-types:vlanid
          |  |     |     +--:(vlan-bundling)
          |  |     |        +--rw vlan-range?   etht-types:vid-range-type
          |  |     +--rw second-tag!
          |  |        +--rw tag-type?     etht-types:eth-tag-classify
          |  |        +--rw (individual-bundling-vlan)?
          |  |           +--:(individual-vlan)
          |  |           |  +--rw vlan-value?   etht-types:vlanid
          |  |           +--:(vlan-bundling)
          |  |              +--rw vlan-range?   etht-types:vid-range-type
          |  +--rw split-horizon-group?                string
          |  +--rw (direction)?
          |  |  +--:(symmetrical)
          |  |  |  +--rw ingress-egress-bandwidth-profile
          |  |  |     +--rw (style)?
          |  |  |        +--:(named)
          |  |  |        |  +--rw bandwidth-profile-name?   string
          |  |  |        +--:(value)
          |  |  |           +--rw bandwidth-profile-type?   etht-types:bandwidth
-profile-type
          |  |  |           +--rw CIR?                      uint64
          |  |  |           +--rw CBS?                      uint64
          |  |  |           +--rw EIR?                      uint64
          |  |  |           +--rw EBS?                      uint64
          |  |  |           +--rw color-aware?              boolean
          |  |  |           +--rw coupling-flag?            boolean
```

```
          |  |  +--:(asymmetrical)
          |  |     +--rw ingress-bandwidth-profile
          |  |     |  +--rw (style)?
          |  |     |     +--:(named)
          |  |     |     |  +--rw bandwidth-profile-name?   string
          |  |     |     +--:(value)
          |  |     |        +--rw bandwidth-profile-type?   etht-types:bandwidth
-profile-type
          |  |     |        +--rw CIR?                      uint64
          |  |     |        +--rw CBS?                      uint64
          |  |     |        +--rw EIR?                      uint64
          |  |     |        +--rw EBS?                      uint64
          |  |     |        +--rw color-aware?              boolean
          |  |     |        +--rw coupling-flag?            boolean
          |  |     +--rw egress-bandwidth-profile
          |  |        +--rw (style)?
          |  |           +--:(named)
          |  |           |  +--rw bandwidth-profile-name?   string
          |  |           +--:(value)
          |  |              +--rw bandwidth-profile-type?   etht-types:bandwidth
-profile-type
          |  |              +--rw CIR?                      uint64
          |  |              +--rw CBS?                      uint64
          |  |              +--rw EIR?                      uint64
          |  |              +--rw EBS?                      uint64
          |  |              +--rw color-aware?              boolean
          |  |              +--rw coupling-flag?            boolean
          |  +--rw vlan-operations
          |     +--rw (direction)?
          |        +--:(symmetrical)
          |        |  +--rw symmetrical-operation
          |        |     +--rw pop-tags?    uint8
          |        |     +--rw push-tags
          |        |        +--rw outer-tag!
          |        |        |  +--rw tag-type?      etht-types:eth-tag-type
          |        |        |  +--rw vlan-value?    etht-types:vlanid
          |        |        |  +--rw default-pcp?   uint8
          |        |        +--rw second-tag!
          |        |           +--rw tag-type?      etht-types:eth-tag-type
          |        |           +--rw vlan-value?    etht-types:vlanid
          |        |           +--rw default-pcp?   uint8
          |        +--:(asymmetrical)
          |           +--rw asymmetrical-operation
          |              +--rw ingress
          |              |  +--rw pop-tags?    uint8
          |              |  +--rw push-tags
          |              |     +--rw outer-tag!
          |              |     |  +--rw tag-type?      etht-types:eth-tag-type
          |              |     |  +--rw vlan-value?    etht-types:vlanid
          |              |     |  +--rw default-pcp?   uint8
```

```
          |               |     +--rw second-tag!
          |               |        +--rw tag-type?      etht-types:eth-tag-type
          |               |        +--rw vlan-value?    etht-types:vlanid
          |               |        +--rw default-pcp?   uint8
          |               +--rw egress
          |                  +--rw pop-tags?    uint8
          |                  +--rw push-tags
          |                     +--rw outer-tag!
          |                     |  +--rw tag-type?      etht-types:eth-tag-type
          |                     |  +--rw vlan-value?    etht-types:vlanid
          |                     |  +--rw default-pcp?   uint8
          |                     +--rw second-tag!
          |                        +--rw tag-type?      etht-types:eth-tag-type
          |                        +--rw vlan-value?    etht-types:vlanid
          |                        +--rw default-pcp?   uint8
          +--rw etht-svc-tunnels* [tunnel-name]
          |  +--rw tunnel-name                string
          |  +--rw (svc-multiplexing-tag)?
          |  |  +--:(other)
          |  |  +--:(none)
          |  |  +--:(vlan-tag)
          |  |  +--:(pw)
          |  +--rw src-split-horizon-group?   string
          |  +--rw dst-split-horizon-group?   string
          +--rw pm-config
          |  +--rw pm-enable?             boolean
          |  +--rw sending-rate-high?     uint64
          |  +--rw sending-rate-low?      uint64
          |  +--rw receiving-rate-high?   uint64
          |  +--rw receiving-rate-low?    uint64
          +--rw admin-status?             identityref
          +--ro state
             +--ro operational-state?         identityref
             +--ro provisioning-state?        identityref
             +--ro creation-time?             yang:date-and-time
             +--ro last-updated-time?         yang:date-and-time
             +--ro sending-rate-too-high?     uint32
             +--ro sending-rate-too-low?      uint32
             +--ro receiving-rate-too-high?   uint32
             +--ro receiving-rate-too-low?    uint32
```

4.2. YANG Tree for other Transport Network Client Signal Model

```
   module: ietf-trans-client-service
       +--rw client-svc
          +--rw client-svc-instances* [client-svc-name]
             +--rw client-svc-name           string
             +--rw client-svc-descr?         string
             +--rw te-topology-identifier
             |  +--rw provider-id?   te-types:te-global-id
             |  +--rw client-id?     te-types:te-global-id
             |  +--rw topology-id?   te-types:te-topology-id
             +--rw src-access-ports
             |  +--rw access-node-id?   te-types:te-node-id
             |  +--rw access-ltp-id?    te-types:te-tp-id
             |  +--rw client-signal?    identityref
             +--rw dst-access-ports
             |  +--rw access-node-id?   te-types:te-node-id
             |  +--rw access-ltp-id?    te-types:te-tp-id
             |  +--rw client-signal?    identityref
             +--rw svc-tunnels* [tunnel-name]
             |  +--rw tunnel-name    string
             +--rw admin-status?             identityref
             +--ro operational-state?        identityref
             +--ro provisioning-state?       identityref
```

5. YANG Code for Transport Network Client Signal

5.1. The ETH Service YANG Code

```
<CODE BEGINS> file "ietf-eth-tran-service@2018-10-18.yang"

module ietf-eth-tran-service {

  namespace "urn:ietf:params:xml:ns:yang:ietf-eth-tran-service";

  prefix "ethtsvc";

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

  import ietf-te-types {
    prefix "te-types";
```

```
  }

  import ietf-eth-tran-types {
    prefix "etht-types";
  }

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

  description
    "This module defines a YANG data model for describing
     the Ethernet transport services.";

  revision 2018-10-18 {
    description
      "Initial revision";
    reference
      "draft-zheng-ccamp-otn-client-signal-yang";
  }

  /*
   * Groupings
   */

  grouping vlan-classification {
    description
      "A grouping which represents classification on an 802.1Q VLAN tag.";

    leaf tag-type {
      type etht-types:eth-tag-classify;
      description
        "The tag type used for VLAN classification.";
    }
    choice individual-bundling-vlan {
      description
```

```
        "VLAN based classification can be individual
         or bundling.";

      case individual-vlan {
        leaf vlan-value {
          type etht-types:vlanid;
          description
            "VLAN ID value.";
        }
      }

      case vlan-bundling {
        leaf vlan-range {
          type etht-types:vid-range-type;
          description
            "List of VLAN ID values.";
        }
      }
    }
  }

  grouping vlan-write {
    description
      "A grouping which represents push/pop operations
       of an 802.1Q VLAN tag.";

    leaf tag-type {
      type etht-types:eth-tag-type;
      description
        "The VLAN tag type to push/swap.";
    }
    leaf vlan-value {
      type etht-types:vlanid;
      description
        "The VLAN ID value to push/swap.";
    }
/*
 * To be added: this attribute is used when:
 * a) the ETH service has only one CoS (as in current version)
 * b) as a default when a mapping between a given CoS value
 *    and the PCP value is not defined (in future versions)
 */
    leaf default-pcp {
      type uint8 {
        range "0..7";
      }
      description
        "The default Priority Code Point (PCP) value to push/swap";
```

```
    }
  }

  grouping vlan-operations {
    description
      "A grouping which represents VLAN operations.";

      leaf pop-tags {
      type uint8 {
        range "1..2";
      }
      description
        "The number of VLAN tags to pop (or swap if used in
         conjunction with push-tags)";
    }
    container push-tags {
      description
        "The VLAN tags to push (or swap if used in
         conjunction with pop-tags)";

      container outer-tag {
        presence
          "Indicates existence of the outermost VLAN tag to
           push/swap";

        description
          "The outermost VLAN tag to push/swap.";

        uses vlan-write;
      }
      container second-tag {
        must
          '../outer-tag/tag-type = "etht-types:s-vlan-tag-type" and ' +
          'tag-type = "etht-types:c-vlan-tag-type"'
        {

          error-message
            "
              When pushing/swapping two tags, the outermost tag must
              be specified and of S-VLAN type and the second
              outermost tag must be of C-VLAN tag type.
            ";
          description
            "
              For IEEE 802.1Q interoperability, when pushing/swapping
              two tags, it is required that the outermost tag exists
              and is an S-VLAN, and the second outermost tag is a
              C-VLAN.
```

```
            ";
        }

        presence
          "Indicates existence of a second outermost VLAN tag to
           push/swap";

        description
          "The second outermost VLAN tag to push/swap.";

        uses vlan-write;
      }
    }
  }

  grouping named-or-value-bandwidth-profile {
    description
      "A grouping to configure a bandwdith profile either by
       referencing a named bandwidth profile or by
       configuring the values of the bandwidth profile attributes.";
    choice style {
      description
        "Whether the bandwidth profile is named or defined by value";

      case named {
        description
          "Named bandwidth profile.";
        leaf bandwidth-profile-name {
          type "string";
          description
            "Name of the bandwidth profile.";
        }
      }
      case value {
        description
          "Bandwidth profile configured by value.";
        uses etht-types:etht-bandwidth-profiles;
      }
    }
  }

  grouping bandwidth-profiles {
    description
      "A grouping which represent bandwidth profile configuration.";

    choice direction {
      description
        "Whether the bandwidth profiles are symmetrical or
```

```
         asymmetrical";
      case symmetrical {
        description
          "The same bandwidth profile is used to describe both
           the ingress and the egress bandwidth profile.";
        container ingress-egress-bandwidth-profile {
          description
            "The bandwdith profile used in both directions.";
          uses named-or-value-bandwidth-profile;
        }
      }
      case asymmetrical {
        description
          "Ingress and egress bandwidth profiles can be specified.";
        container ingress-bandwidth-profile {
          description
            "The bandwdith profile used in the ingress direction.";
          uses named-or-value-bandwidth-profile;
        }
        container egress-bandwidth-profile {
          description
            "The bandwdith profile used in the egress direction.";
          uses named-or-value-bandwidth-profile;
        }
      }
    }
  }

  grouping etht-svc-access-parameters {
    description
      "ETH transport services access parameters";

    leaf access-node-id {
      type te-types:te-node-id;
      description
        "The identifier of the access node in
         the ETH transport topology.";
    }
    leaf access-ltp-id {
      type te-types:te-tp-id;
      description
        "The TE link termination point identifier, used
         together with access-node-id to identify the
         access LTP.";
    }
    leaf service-classification-type {
      type identityref {
        base etht-types:service-classification-type;
```

```
      }
      description
        "Service classification type.";
    }

    choice service-classification {
      description
        "Access classification can be port-based or
         VLAN based.";

      case port-classification {
        /* no additional information */
      }

      case vlan-classification {
        container outer-tag {
          presence "The outermost VLAN tag exists";
          description
            "Classifies traffic using the outermost VLAN tag.";

          uses vlan-classification;
        }
        container second-tag {
          must
            '../outer-tag/tag-type = "etht-types:classify-s-vlan" and ' +
            'tag-type = "etht-types:classify-c-vlan"'
          {

            error-message
              "
                When matching two tags, the outermost tag must be
                specified and of S-VLAN type and the second
                outermost tag must be of C-VLAN tag type.
              ";
            description
              "
                For IEEE 802.1Q interoperability, when matching two
                tags, it is required that the outermost tag exists
                and is an S-VLAN, and the second outermost tag is a
                C-VLAN.
              ";
          }
          presence "The second outermost VLAN tag exists";

          description
            "Classifies traffic using the second outermost VLAN tag.";

          uses vlan-classification;
```

```
        }
      }
    }

/*
 * Open issue: can we constraints it to be used only with mp services?
 */
    leaf split-horizon-group {
      type string;
      description "Identify a split horizon group";
    }

    uses bandwidth-profiles;

    container vlan-operations {
      description
        "Configuration of VLAN operations.";
      choice direction {
        description
          "Whether the VLAN operations are symmetrical or
           asymmetrical";
        case symmetrical {
          container symmetrical-operation {
            uses vlan-operations;
            description
              "Symmetrical operations.
               Expressed in the ingress direction, but
               the reverse operation is applied to egress traffic";
          }
        }
        case asymmetrical {
          container asymmetrical-operation {
            description "Asymmetrical operations";
            container ingress {
              uses vlan-operations;
              description "Ingress operations";
            }
            container egress {
              uses vlan-operations;
              description "Egress operations";
            }
          }
        }
      }
    }
  }

  grouping etht-svc-tunnel-parameters {
```

```
    description
      "ETH transport services tunnel parameters";

    leaf tunnel-name {
      type string;
      description
        "TE service tunnel instance name.";
    }
    choice svc-multiplexing-tag {
      description
        "Service multiplexing is optional and flexible.";

      case other {
        /*
         placeholder to support proprietary multiplexing
         (for further discussion)
        */
      }

      case none {
        /* no additional information is needed */
      }

      case vlan-tag {
        /*
          No additional information is needed
          The C-Tag or S-Tag used for service mulitplexing is defined
          by the VLAN classification and operations configured in the
          etht-svc-access-parameters grouping
        */
      }

      case pw {
        /* to be completed (for further discussion) */
      }
    }

/*
 * Open issue: can we constraints it to be used only with mp services?
 */
    leaf src-split-horizon-group {
      type string;
      description "Identify a split horizon group at the Tunnel source TTP";
    }
    leaf dst-split-horizon-group {
      type string;
      description "Identify a split horizon group at the Tunnel destination TTP"
;
    }
```

```
  }

  grouping  etht-svc-pm-threshold_config {
    description
      "Configuraiton parameters for Ethernet service PM thresholds.";

    leaf sending-rate-high {
      type uint64;
      description
        "High threshold of packet sending rate in kbps.";
    }
    leaf sending-rate-low {
      type uint64;
      description
        "Low threshold of packet sending rate in kbps.";
    }
    leaf receiving-rate-high {
      type uint64;
      description
        "High threshold of packet receiving rate in kbps.";
    }
    leaf receiving-rate-low {
      type uint64;
      description
        "Low threshold of packet receiving rate in kbps.";
    }
  }

  grouping  etht-svc-pm-stats {
    description
      "Ethernet service PM statistics.";

    leaf sending-rate-too-high {
      type uint32;
      description
        "Counter that indicates the number of times the sending rate is above th
e high threshold";
    }
    leaf sending-rate-too-low {
      type uint32;
      description
        "Counter that indicates the number of times the sending rate is below th
e low threshold";
    }
    leaf receiving-rate-too-high {
      type uint32;
      description
        "Counter that indicates the number of times the receiving rate is above
the high threshold";
    }
    leaf receiving-rate-too-low {
```

```
      type uint32;
      description
        "Counter that indicates the number of times the receiving rate is below
the low threshold";
    }
  }

  grouping  etht-svc-instance_config {
    description
      "Configuraiton parameters for Ethernet services.";

    leaf etht-svc-name {
      type string;
      description
        "Name of the ETH transport service.";
    }

    leaf etht-svc-id {
      type yang:uuid;
      description
        "Universally Unique IDentifier (UUID) of the ETH transport service.";
    }

    leaf etht-svc-descr {
      type string;
      description
        "Description of the ETH transport service.";
    }

    leaf etht-svc-customer {
      type string;
      description
        "Customer of the ETH transport service.";
    }

     leaf etht-svc-type {
      type etht-types:service-type;
      description
        "Type of ETH transport service (p2p, mp2mp or rmp).";
      /* Add default as p2p */
    }

     leaf etht-svc-lifecycle {
      type etht-types:lifecycle-status;
      description
        "Lifecycle state of ETH transport service.";
      /* Add default as installed  */
    }
```

```
    uses te-types:te-topology-identifier;

    list etht-svc-access-ports {
      key access-port-id;
      min-elements "1";
/*
  Open Issue:
    Is it possible to limit the max-elements only for p2p services?

      max-elements "2";
*/
      description
        "List of the ETH trasport services access port instances.";

      leaf access-port-id {
        type uint16;
        description
          "ID of the service access port instance";
      }
        uses etht-svc-access-parameters;
    }
    list etht-svc-tunnels {
      key tunnel-name;
      description
        "List of the TE Tunnels supporting the ETH
        transport service.";

      uses etht-svc-tunnel-parameters;
    }
    container pm-config {
      description
        "ETH service performance monitoring";

      leaf pm-enable {
        type boolean;
        description
          "Boolean value indicating whether PM is enabled.";
      }
      uses etht-svc-pm-threshold_config;
    }
    leaf admin-status {
      type identityref {
        base te-types:tunnel-state-type;
      }
      default te-types:tunnel-state-up;
      description "ETH service administrative state.";
    }
  }
```

```
  grouping  etht-svc-instance_state {
    description
      "State parameters for Ethernet services.";

    leaf operational-state {
    type identityref {
        base te-types:tunnel-state-type;
      }
      default te-types:tunnel-state-up;
    description "ETH service operational state.";
    }
    leaf provisioning-state {
      type identityref {
        base te-types:lsp-state-type;
      }
      description "ETH service provisioning state.";
    }
    leaf creation-time {
      type yang:date-and-time;
      description
        "Time of ETH service creation.";
    }
    leaf last-updated-time {
      type yang:date-and-time;
      description
        "Time of ETH service last update.";
    }
    uses etht-svc-pm-stats;
  }

  /*
   * Data nodes
   */

  container etht-svc {
    description
      "ETH transport services.";

    container globals {
      description
        "Globals Ethernet configuration data container";
      list named-bandwidth-profiles {
        key bandwidth-profile-name;
        description
          "List of named bandwidth profiles used by
           Ethernet services.";

        leaf bandwidth-profile-name {
```

```
          type string;
          description
            "Name of the bandwidth profile.";
        }
        uses etht-types:etht-bandwidth-profiles;
      }
    }

    list etht-svc-instances {
      key etht-svc-name;
      description
        "The list of p2p ETH transport service instances";

      uses etht-svc-instance_config;

      container state {
        config false;
        description
          "Ethernet Service states.";

        uses etht-svc-instance_state;
      }
    }
  }
}

<CODE ENDS>
```

5.2. YANG Code for ETH transport type

```
<CODE BEGINS> file "ietf-eth-tran-types@2018-10-18.yang"
module ietf-eth-tran-types {

  namespace "urn:ietf:params:xml:ns:yang:ietf-eth-tran-types";

  prefix "etht-types";

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

      ID-draft editor:
        Haomian Zheng (zhenghaomian@huawei.com);
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        Xufeng Liu (Xufeng_Liu@jabil.com);
        Giuseppe Fioccola (giuseppe.fioccola@huawei.com);
    ";

  description
    "This module defines the ETH transport types.";

  revision 2018-10-18 {
    description
      "Initial Revision";
    reference
      "draft-zheng-ccamp-client-signal-yang";
  }

  /*
   * Identities
   */

  identity eth-vlan-tag-type {
    description
      "ETH VLAN tag type.";
  }

  identity c-vlan-tag-type {
    base eth-vlan-tag-type;
    description
      "802.1Q Customer VLAN";
  }

  identity s-vlan-tag-type {
    base eth-vlan-tag-type;
    description
      "802.1Q Service VLAN (QinQ)";
  }

  identity service-classification-type {
    description
      "Service classification.";
  }

  identity port-classification {
    base service-classification-type;
    description
      "Port classification.";
```

```
  }

  identity vlan-classification {
    base service-classification-type;
    description
      "VLAN classification.";
  }

  identity eth-vlan-tag-classify {
    description
      "VLAN tag classification.";
  }

  identity classify-c-vlan {
    base eth-vlan-tag-classify;
    description
      "Classify 802.1Q Customer VLAN tag.
       Only C-tag type is accepted";
  }

  identity classify-s-vlan {
    base eth-vlan-tag-classify;
    description
      "Classify 802.1Q Service VLAN (QinQ) tag.
       Only S-tag type is accepted";
  }

  identity classify-s-or-c-vlan {
    base eth-vlan-tag-classify;
    description
      "Classify S-VLAN or C-VLAN tag-classify.
       Either tag is accepted";
  }

  identity bandwidth-profile-type {
    description
      "Bandwidth Profile Types";
  }

  identity mef-10-bwp {
    base bandwidth-profile-type;
    description
      "MEF 10 Bandwidth Profile";
  }

  identity rfc-2697-bwp {
    base bandwidth-profile-type;
    description
```

```
      "RFC 2697 Bandwidth Profile";
  }

  identity rfc-2698-bwp {
    base bandwidth-profile-type;
    description
      "RFC 2698 Bandwidth Profile";
  }

  identity rfc-4115-bwp {
    base bandwidth-profile-type;
    description
      "RFC 4115 Bandwidth Profile";
  }

  identity service-type {
    description
      "Type of Ethernet service.";
  }

  identity p2p-svc {
    base service-type;
    description
      "Ethernet point-to-point service (EPL, EVPL).";
  }

  identity rmp-svc {
    base service-type;
    description
      "Ethernet rooted-multitpoint service (E-TREE, EP-TREE).";
  }

  identity mp2mp-svc {
    base service-type;
    description
      "Ethernet multipoint-to-multitpoint service (E-LAN, EP-LAN).";
  }

  identity lifecycle-status {
    description
      "Lifecycle Status.";
  }

  identity installed {
    base lifecycle-status;
    description
      "Installed.";
  }
```

```
  identity planned {
    base lifecycle-status;
    description
      "Planned.";
  }

  identity pending-removal {
    base lifecycle-status;
    description
      "Pending Removal.";
  }

  /*
   * Type Definitions
   */

  typedef eth-tag-type {
    type identityref {
      base eth-vlan-tag-type;
    }
    description
      "Identifies a specific ETH VLAN tag type.";
  }

  typedef eth-tag-classify {
    type identityref {
      base eth-vlan-tag-classify;
    }
    description
      "Identifies a specific VLAN tag classification.";
  }

  typedef vlanid {
    type uint16 {
      range "1..4094";
    }
    description
      "The 12-bit VLAN-ID used in the VLAN Tag header.";
  }

  typedef vid-range-type {
    type string {
      pattern "([1-9][0-9]{0,3}(-[1-9][0-9]{0,3})?" +
              "(,[1-9][0-9]{0,3}(-[1-9][0-9]{0,3})?)*)";
    }
    description
      "A list of VLAN Ids, or non overlapping VLAN ranges, in
       ascending order, between 1 and 4094.
```

```
       This type is used to match an ordered list of VLAN Ids, or
       contiguous ranges of VLAN Ids. Valid VLAN Ids must be in the
       range 1 to 4094, and included in the list in non overlapping
       ascending order.

       For example: 1,10-100,50,500-1000";
  }

  typedef bandwidth-profile-type {
    type identityref {
      base bandwidth-profile-type;
    }
    description
      "Identifies a specific Bandwidth Profile type.";
  }

  typedef service-type {
    type identityref {
      base service-type;
    }
    description
      "Identifies the type of Ethernet service.";
  }

  typedef lifecycle-status {
    type identityref {
      base lifecycle-status;
    }
    description
      "Identifies the lLifecycle Status .";
  }

  /*
   * Grouping Definitions
   */

  grouping etht-bandwidth-profiles {
    description
      "Bandwidth profile configuration paramters.";

    leaf bandwidth-profile-type {
      type etht-types:bandwidth-profile-type;
      description
        "The type of bandwidth profile.";
    }
    leaf CIR {
      type uint64;
      description
```

```
        "Committed Information Rate in Kbps";
    }
    leaf CBS {
      type uint64;
      description
        "Committed Burst Size in in KBytes";
    }
    leaf EIR {
      type uint64;
      /* Need to indicate that EIR is not supported by RFC 2697

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

      must
        '../bw-profile-type != "rfc-2697-bwp"'
      */
      description
        "Excess Information Rate in Kbps
         In case of RFC 2698, PIR = CIR + EIR";
    }
    leaf EBS {
      type uint64;
      description
        "Excess Burst Size in KBytes.
          In case of RFC 2698, PBS = CBS + EBS";
    }
    leaf color-aware {
      type boolean;
      description
        "Indicates weather the color-mode is color-aware or color-blind.";
    }
    leaf coupling-flag {
      type boolean;
      /* Need to indicate that Coupling Flag is defined only for MEF 10

      must
        '../bw-profile-type = "mef-10-bwp"'
      */
      description
        "Coupling Flag.";
    }
  }
}
```

<CODE ENDS>

5.3. Other Transport Network client signal YANG Code

```
 <CODE BEGINS> file "ietf-trans-client-service@2018-10-19.yang"
 module ietf-trans-client-service {
   /* TODO: FIXME */
   //yang-version 1.1;

   namespace "urn:ietf:params:xml:ns:yang:ietf-trans-client-service";
   prefix "clntsvc";

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

   import ietf-l1-service-types {
     prefix "l1-svc-types";
   }

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

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         Xufeng Liu (Xufeng_Liu@jabil.com);
         Giuseppe Fioccola (giuseppe.fioccola@telecomitalia.it);
     ";

   description
     "This module defines a YANG data model for describing
      simple transport client services.";

   revision 2018-10-19 {
     description
       "Initial version";
     reference
       "draft-zheng-ccamp-client-signal-yang";
   }
```

```
   /*
    * Groupings
    */

   grouping client-svc-access-parameters {
     description
       "Transport client services access parameters";

     leaf access-node-id {
       type te-types:te-node-id;
       description
         "The identifier of the access node in the underlying
          transport topology.";
     }
     leaf access-ltp-id {
       type te-types:te-tp-id;
       description
         "The TE link termination point identifier, used together with
          access-node-id to identify the access LTP.";
     }
     leaf client-signal {
       type identityref {
         base l1-svc-types:protocol-type;
       }
       description
         "Identifiies the client signal type associated with this port";
     }
   }

   grouping client-svc-tunnel-parameters {
     description
       "Transport client services tunnel parameters";

     leaf tunnel-name {
       type string;
       description
         "TE service tunnel instance name.";
     }
   }

   grouping  client-svc-instance_config {
     description
       "Configuraiton parameters for client services.";

     leaf client-svc-name {
       type string;
       description
         "Name of the p2p transport client service.";
```

```
     }
     leaf client-svc-descr {
       type string;
       description
         "Description of the transport client service.";
     }
     uses te-types:te-topology-identifier;
     container src-access-ports {
       description
         "Source access port of a client service.";
       uses client-svc-access-parameters;
     }
     container dst-access-ports {
       description
         "Destination access port of a client service.";
       uses client-svc-access-parameters;
     }
     list svc-tunnels {
       key tunnel-name;
       description
         "List of the TE Tunnels supporting the client service.";
       uses client-svc-tunnel-parameters;
     }
     leaf admin-status {
       type identityref {
         base te-types:tunnel-state-type;
       }
       default te-types:tunnel-state-up;
       description "Client service administrative state.";
     }
   }

   grouping  client-svc-instance_state {
         description
           "State parameters for client services.";
         leaf operational-state {
           type identityref {
                 base te-types:tunnel-state-type;
           }
           config false;
           description "Client service operational state.";
         }
         leaf provisioning-state {
           type identityref {
                 base te-types:lsp-state-type;
           }
           config false;
           description "Client service provisioning state.";
```

```
         }
   }

   /*
    * Data nodes
    */

   container client-svc {
     description
       "Transport client services.";

     list client-svc-instances {
       key client-svc-name;
       description
         "The list of p2p transport client service instances";

           uses client-svc-instance_config;
           uses client-svc-instance_state;
     }
   }
 }

 <CODE ENDS>
```

6. Considerations and Open Issue

Editor Notes: This section is used to note temporary discussion/ conclusion that to be fixed in the future version, and will be removed before publication. We currently categorize all the client signal types into transparent and non-transparent, with separate models. There was consensus that no common model is needed for these two categories.

7. IANA Considerations

TBD.

8. Manageability Considerations

TBD.

9. Security Considerations

The data following the model defined in this document is exchanged via, for example, the interface between an orchestrator and a 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.

10. Acknowledgements

We would like to thank Igor Bryskin and Daniel King for their comments and discussions.

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12. References

12.1. Normative References

[I-D.ietf-ccamp-otn-topo-yang]
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Category: Informational   Ruiquan Jing
Expires: April 22, 2019   China Telecom
                                                           October 22, 2018

Framework on Customer Premises Equipment Control in Optical Transport Networks

draft-zheng-ccamp-cpe-otn-fwk-00

Abstract

The term Customer Premises Equipment (CPE) describes the terminals that are associated with a carrier's telecommunication network. The CPE provides access between a customer's devices and the network.

This document describes the framework for control of CPEs in optical transport networks. Gap analysis is also included as guidance for potential solutions such as protocol extensions.

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1. Introduction

Carriers are providing leased line business-to-business (B2B) services to their customers. These kinds of service have special requests on bandwidth, latency, and other performance features. As the leased line services start at the Customer Premises Equipment (CPEs), the end-to-end (E2E) services need to be coordinated over heterogeneous networks with the support of CPE control mechanisms.

The Generalized Multi-Protocol Label Switching (GMPLS) techniques [RFC3945] have been widely applied in metro and backbone network,

providing effective deployment and efficient recovery mechanisms. A detailed summary is provided in Section 4 of this document.

The YANG models specified by the IETF can also be applied to satisfy the requirement of CPE control. The models' applicability is analyzed in Section 5.

This document describes the framework for control of the CPE in optical transport networks. Gap analysis is also included as guidance for potential solutions such as protocol extensions.

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. CPE Terminology

TBD.

2. CPE Scenarios and Framework

This section provides overviews of the GMPLS control plane and centralized controller systems as well as the interactions between the GMPLS control plane and centralized controllers.

2.1. B2B Leased Line Services in OTN context

```
      +--------------------------------------------------+
      |            Carrier Orchestrator System           |
      +---+-----------+----------+------------------+---+
          |           |          |                  |
   .......|...........|..........|..................|.......
   :      |           | +--------+--------+         |      :
   :      |           | | CPE Ctrl& Mgmt  |         |      :
   : +----+----+    +-+---------------+   |    +----+----+ :
   : | EMS/NMS |    |  CPE Control    |--+-+    | EMS/NMS | :
   : | VendorA |    | and Management  |  |      | VendorB | :
```

```
    : +----+----+    +-------+--------+   |      +----+----+ :
    :......|................|...........|...........|.......:
           |                |           |           |
          _|________________|_         _|___________|__
         /                    \       /                \
        /     Vendor A DCN     \     /   Vendor B DCN   \
        \                      /     \                  /
         \____________________/       \________________/
                    |                          |
             _______|_______            _______|_______
            /               \          /               \
    +---+  |       OTN       |        |       OTN       |    +---+
    |CPE|---+   Domain A     |-------|     Domain B    +---|CPE|
    +---+  |                 |        |                 |    +---+
            \_______________/          \_______________/
```

Figure 1: Architecture for OTN CPE Scenario

In the Figure 1, a two-domain example of OTN network is used with CPE devices accessed to respective OTN domains. This architecture is an extension of existing one with controller hierarchies. The dashed line shows a logical of controller that directly controls the OTN domain via DCN. More specifically, besides traditional NMS/EMS, there is another CPE control/Management functional block in the system, to accomplish the control function of CPE devices. This logical system is further connected to carrier orchestration system.

3. Requirement Analysis for CPE Control

In order to support the above scenarios, the following functionalities need to be satisfied.

Interaction between CPE and NMS/EMS:

- Report and Query the basic information from the CPE;

- Configuration of CPE and OTN Access;

- Management of the Connections/CPEs;

Interaction between CPE and OTN Access:

- Discovery and mapping to the right OTN access;

- Set up of connection between CPE and OTN via access protocol;

The above interactions are should be automatically processed rather than manually. The main challenges are the limited resources (storage/memory/computation) on the CPE are not as good as on core nodes, so the solution may be different with core networks. If there are potential different protocols for the CPE, the interworking between the CPE and the core network would also need to be investigated.

4. GMPLS Applicability

GMPLS [RFC3945] is capable of three different kind of functionality: discovery, routing, and signaling.

The Link Management Protocol (LMP) [RFC4204] runs between a pair of physically or virtually adjacent nodes and is used to manage TE links. In addition to setting up and maintaining control channels, LMP can be used to discover and verify data link connectivity and to correlate the properties of the link. LMP is also applicable to the CPE scenario.

Routing protocols, especially OSPF-TE [RFC4203], have been extended to provide link state capabilities for GMPLS. The same characteristics may be used for CPE control.

In GMPLS, the signaling function is basically accomplished via RSVP-TE [RFC3473], with the definition of generalized label request and label set.

Even if the current solution set is complete, it is challenging in the CPE scenario to support all the functions with limited resources on a simple CPE device. In order to support the automation of control in CPE environments, it is necessary to specify a simplified version of control protocols, to satisfy specific requirements in CPE control.

5. YANG Model Applicability

[RFC7895] describes a YANG library that provides information about all the YANG modules used by a network management server. The NETCONF protocol defined in [RFC6241] can be used to support these YANG modules with the XML based data encoding.

[RFC7407] defines the usage of YANG data models for the configuration of SNMP engines, which can also be applied for CPE configuration. A set of YANG submodules that share the same

namespace have been specified to add configuration support for SNMP features. These submodules include a common session, together with configurations to SNMP engine, target, notification, proxy, community and so on. These functions are required in CPE control, and these submodules can be applied in the system.

[RFC8343] defines a YANG data model for the management of network interfaces, including the definitions for configuration and system state (status information and counters for the collection of statistics), satisfying the Network Management Datastore Architecture (NMDA), as a fundamental model. A few interface-type-specific models augment to this model, to support the interface management in tech-specific network scenarios, such as [RFC8344] for IP interfaces and [draft-ietf-netmod-intf-ext-yang] for Ethernet.

Other functions have also been modeled in various other documents. Routing functions and DHCP have also been supported in [RFC8349]. [draft-ietf-ccamp-alarm-module] provides a module for alarm management, [draft-ietf-netconf-ssh-client-server] and [draft-ietf-netconf-tls-client-server] specify the usage of communication protocols.

Potential gaps in the current set of models for CPE control may include performance monitoring and management, fault diagnosis and management, configuration and collection on device port and so on. These modules need to be covered in future documents for a complete CPE control solution.

6. Other Control Plane Requirement

TBD.

7. Network Management

TBD.

8. Security Considerations

TBD.

9. IANA Considerations

TBD.

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