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

Abstract

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

To be completed

Status of This Memo

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Table of Contents

1. Introduction

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

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

1.1. Requirements Language

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

1.2. Terminology

2. Extensions for the Layer 0 Types Module

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

transceiver-capabilities:

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

standard-mode:

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

organizational-mode:

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

common-explicit-mode:

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

common-organizational-explicit-mode:

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

cd-pmd-penalty:

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

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

3. Layer0 Types Revision 2 YANG CODE

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

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

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

```
<CODE BEGINS>
module ietf-layer0-types-ext {
  namespace "urn:ietf:params:xml:ns:yang:ietf-layer0-types-ext";
  prefix "l0-types-ext";

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

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

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       <mailto:Sergio.Belotti@nokia.com>

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

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

     // Additional contacts TBA (contributors)

  description
    "Description to be added!!!

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     as authors of the code.  All rights reserved.

     Redistribution and use in source and binary forms, with
     or without modification, is permitted pursuant to, and
     subject to the license terms contained in, the Simplified
     BSD License set forth in Section 4.c of the IETF Trust's
```

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

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

     revision "2021-07-05" {
       description
         "Initial Version";
       reference
         "RFC XXXX: A YANG Data Model for Layer 0 Types - Revision 2";
     }

   /*
    * Identities
    */

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

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

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

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

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

     identity DP-QAM8 {
       base modulation;
```

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

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

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

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

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

     identity g-fec {
       base fec-type;
       description
         "G-FEC (Generic-FEC)";
     }
     identity e-fec {
       base fec-type;
       description
         "E-FEC (Enhanced-FEC)";
     }
     identity no-fec {
       base fec-type;
       description
         "No FEC";
     }

     identity reed-solomon {
```

```
    base fec-type;
    description
      "Reed-Solomon error correction";
  }

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

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

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

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

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

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

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

  identity wavelength-assignment {
```

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

     identity unspecified-wavelength-assignment {
       base wavelength-assignment;
       description
         "No method specified";
     }

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

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

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

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

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

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

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

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

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

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

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

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

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

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

     identity OTU2f {
       base otu-type;
       description
         "OTU2f (11.31G)";
     }

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

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

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

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

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

     identity type-power-mode {
       description
         "power equalization mode used within the
          OMS and its elements";
     }
```

```
     identity power-spectral-density {
       base type-power-mode;
       description
         "all elements must use power spectral density (W/Hz)";
     }

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

   /*
    * Typedefs
    */

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

     typedef standard-mode {
       type string;
       description
         "ITU-T G.698.2 standard mode that guarantees
          interoperability.
          It must be an string with the following format:
          B-DScW-ytz(v) where all these attributes
          are conformant
          to the ITU-T recomendation";
       reference "ITU-T G.698.2 (11/2018)";
     }

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

     typedef frequency-thz {
         type decimal64 {
```

```
          fraction-digits 6;
        }
        units THz;
        description
          "The DWDM frequency in THz, e.g., 193.112500";
        reference
          "RFC6205: Generalized Labels for
          Lambda-Switch-Capable (LSC) Label Switching Routers";
    }
    typedef frequency-ghz {
        type decimal64 {
          fraction-digits 3;
        }
        units GHz;
        description
          "The DWDM frequency in GHz, e.g., 193112.500";
        reference
          "RFC6205: Generalized Labels for
          Lambda-Switch-Capable (LSC) Label Switching Routers";
    }

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

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

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

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

   /*
    * Groupings
    */

    /* supported inverse multiplexing capabilities such as
       max. OTSiG:OTSi cardinality
       It is a transponder attribute not transceiver
     */

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

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

       container supported-modes {
         description
           "Transceiver's supported modes.";
         list supported-mode {
           key "mode-id";
           config false;
           description "list of supported transceiver's modes.";
           leaf mode-id {
             type string {
               length "1..255";
```

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

```
                        + "supported-mode[mode-id=current()]/"
                        + "organizational-mode" {
                       description
                         "The pointer is only for organizational modes
                          supported by transceiver.";
                     }
                     description
                       "List of pointers to the organizational modes
                        supported by the transceiver's explicit mode.";
                   }
                 }  // container supported-modes
                 uses common-explicit-mode;
                 uses common-organizational-explicit-mode;
               }  // container explicit-mode
             } // end of case explicit-mode
           } // end of choice
         }  // list supported-modes
       }  // container supported-modes
     }  // grouping transceiver-capabilities

     grouping standard-mode {
       description
         "ITU-T G.698.2 standard mode that guarantees interoperability.
          It must be an string with the following format:
          B-DScW-ytz(v) where all these attributes are conformant
          to the ITU-T recomendation";

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

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

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

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

       }
     }

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

       leaf chromatic-dispersion {
         type decimal64 {
           fraction-digits 2;
           range "0..max";
         }
         units "ps/nm";
         config false;
         mandatory true;
         description "chromatic dispersion";
       }

       leaf polarization-mode-dispersion {
         type decimal64 {
           fraction-digits 2;
           range "0..max";
         }
         units "ps";
         config false;
         mandatory true;
         description "Polarization mode dispersion";
       }

       leaf penalty {
         type decimal64 {
           fraction-digits 2;
           range "0..max";
         }
         units "dB";
         config false;
         mandatory true;
         description "Associated penalty on the receiver";
       }
     }
```

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

       leaf max-polarization-dependent-loss {
         type decimal64 {
           fraction-digits 2;
         }
         units "dB";
         config false;
         mandatory true;
         description
           "Maximum acceptable accumulate polarization dependent loss";
       }

       leaf penalty {
         type uint8;
         units "dB";
         config false;
         mandatory true;
         description "Associated penalty on the receiver";
       }
     }

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

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


       leaf line-coding-bitrate {
         type identityref {
           base line-coding;
         }
         config false;
         description "Bit rate/line coding of optical tributary signal";
         reference
           "ITU-T G.698.2 section 7.1.2";
       }
```

```
        leaf max-polarization-mode-dispersion {
          type decimal64 {
            fraction-digits 2;
            range "0..max";
          }
          units "ps";
          config false;
          description
            "Maximum acceptable accumulated polarization mode
             dispersion on the receiver";
        }

        leaf max-chromatic-dispersion {
          type decimal64 {
            fraction-digits 2;
            range "0..max";
          }
          units "ps/nm";
          config false;
          description
            "Maximum acceptable accumulated chromatic dispersion
             on the receiver";
        }

        list chromatic-and-polarization-dispersion-penalty {
          config false;
          description
            "Optional penalty associated with a given accumulated
             CD and PMD.
             This list of triplet cd, pmd, penalty can be used to
             sample the function penalty = f(CD, PMD).";
          uses cd-pmd-penalty ;
        }

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

        list max-polarization-dependent-loss-penalty {
          config false;
          description
            "Optional penalty associated with the maximum acceptable
            accumulated polarization dependent loss.
             This list of pair pdl and penalty can be used to
             sample the function pdl = f(penalty).";
```

```
          uses pdl-penalty ;
        }

        leaf available-modulation-type {
          type identityref {
          base modulation;
           }
          config false;
          description
            "Modulation type the specific transceiver in the list
             can support";
        }
        leaf otsi-carrier-bandwidth {
          type frequency-ghz;
          config false;
          description
            "Carrier bandwidth occupancy.
             The required bandwidth can be given
             by the transceiver vendor or
             can be function of the following parameters:
             baudrate, nyquist-spacing, roll-off and
             cross-talk penalty";
        }

        leaf  min-OSNR {
          type snr;
          config false;
          description "min OSNR measured over 0.1 nm
          resolution bandwidth:
          if received OSNR at minimum Rx-power is lower than MIN-OSNR,
          an increased level of bit-errors post-FEC needs
          to be expected.";
          // change resolution BW from 12.5 GHz to 0.1 nm
        }

        leaf  min-Q-factor {
          type int32;
          units "dB";
          config false;
          description "min Qfactor at FEC threshold";
        }

        leaf available-baud-rate {
          type uint32;
            units Bd;
          config false;
          description
            "Baud-rate the specific transceiver in
```

```
           the list can support.
            Baud-rate is the unit for
            symbol rate or modulation rate
            in symbols per second or
            pulses per second.
            It is the number of distinct symbol
            changes (signal events) made to the
            transmission medium
            per second in a digitally
            modulated signal or a line code";
       }

       leaf nyquist-spacing-factor {
         type decimal64 {
           fraction-digits 4;
           range "1..2";
         }
         config false;
         description
           "1.x factor to multiply the baud rate
            for Nyquist shaped signal";
       }

       leaf roll-off {
         type decimal64 {
           fraction-digits 4;
           range "0..1";
         }
         config false;
         description
           "the roll-off factor (beta with values from 0 to 1)
           identifies how the real signal shape exceed
           the baud rate. If=0 it is exactly matching
           the baud rate.If=1 the signal exceeds the
           50% of the baud rate at each side.";
       }

       leaf xtalk-penalty  {
         type int32;
         config false;
         description "";
       }

       leaf available-fec-type {
         type identityref {
           base fec-type;
         }
         config false;
```

```
          description "Available FEC";
        }

        leaf fec-code-rate {
          type decimal64 {
            fraction-digits 8;
            range "0..max";
          }
          config false;
          description "FEC-code-rate";
        }

        leaf fec-threshold {
          type decimal64 {
            fraction-digits 8;
            range "0..max";
          }
          config false;
          description
            "Threshold on the BER, for which FEC
             is able to correct errors";
        }
      } // grouping common-explicit-mode

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

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

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

    /* transmitter-tunability-grid */
```

```
       leaf minimum-channel-spacing {
         type frequency-ghz;
         config false;
         description
           "This paramenter represents the minumum difference in
            frequency between two adjacent channels
            (ref. G.698.2 sec.7.1.1).
            This free value is to permit OTSi's central frequency not
            to stay on the G.694.1 grid.";
       }

   /* supported transmitter power range [p_tx-min, p_tx_max] */

       leaf tx-channel-power-min {
         type dbm-t;
         config false;
         description "The minimum output power of this interface";
       }
       leaf tx-channel-power-max {
         type dbm-t;
         config false;
         description "The maximum output power of this interface";
       }

   /* supported receiver power range [p_rx-min, p_rx_max] */

        leaf rx-channel-power-min {
         type dbm-t;
         config false;
         description "The minimum input power of this interface";
       }
       leaf rx-channel-power-max {
         type dbm-t;
         config false;
         description "The maximum input power of this interface";
       }

       leaf rx-total-power-max {
         type dbm-t;
         config false;
         description "Maximum rx optical power for
         all the channels";
       }

     } // grouping common-organizational-explicit-mode

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

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

       leaf otsi-carrier-frequency {
           type frequency-thz;
            description
              "OTSi carrier frequency, equivalent to the
              actual configured transmitter frequency";
       }


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

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

       leaf rx-total-power {
           type dbm-t;
           config false;
           description "Current total received power";
       }

     } // grouping for configured attributes out of mode

     grouping l0-tunnel-attributes {
       description
         "Parameters for Layer0 (WSON or Flexi-Grid) Tunnels.";
       leaf fec-type {
         type identityref {
           base fec-type;
         }
         description
           "FEC type.";
       }
       leaf termination-type {
         type identityref {
           base term-type;
         }
         description
           "Termination type.";
       }
       leaf bit-stuffing {
```

```
          type boolean;
          description
            "Bit stuffing enabled/disabled.";
        }
      }

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

      grouping frequency-range {
        description
          "The parameters that define a frequency range.";
        leaf lower-frequency {
          type frequency-thz;
          mandatory true;
          description
            "The lower frequency boundary of the
            frequency range.";
        }
        leaf upper-frequency {
          type frequency-thz;
          must '. > ../lower-frequency' {
            error-message
              "The upper frequency must be greater than the lower
              frequency.";
          }
          mandatory true;
          description
            "The upper frequency boundary of the
            frequency range.";
        }
      }
    }
    <CODE ENDS>
```

Figure 1

4. Acknowledgements

To be added if any.

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6. IANA Considerations

This memo includes no request to IANA.

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

7. Security Considerations

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

8. References

8.1. Normative References

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A YANG Data Model for Flexi-Grid Media Channels
draft-ietf-ccamp-flexigrid-media-channel-yang-03

Abstract

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

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

Copyright Notice

Table of Contents

1. Introduction

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

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

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

2. Terminology

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

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

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

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

- configuration data
- state data

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

3. 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
- 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.ietf-teas-yang-te] and augments when necessary. For instance, source address, source flexi-grid transponder, destination address and destination flexi-grid transponder attributes are directly taken from tunnel, whereas other attributes such as source flexi-grid port, destination flexi-grid port are defined, as they are specific for flexi-grid.

4. Example of Use

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

```
                                 Media channel
          <=========================================================>
                                    Path x
          <~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~>
      +-----------+                                        +-----------+
      |  Optical  |                                        |  Optical  |
      |   Edge    |                                        |   Edge    |
      |           |                                        |           |
      |   ........|        +------+        +------+        |........   |
      |   :       | Link 1 |Flexi-| Link 2 |Flexi-| Link 3 |       :   |
      |   : Flexi-|<------>|  grid|<------>|  grid|<------>|Flexi- :   |
      |   :   grid|        |node B|        |node C|        |  grid :   |
      |   : Trans-|        +------+        +------+        |Trans- :   |
      |   : ponder|                                        |ponder :   |
      |   :    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.ietf-ccamp-flexigrid-yang] we can configure the media-channel from the information we have stored in the flexi-grid topology, by querying which elements are available, and planning the resources that have to be provided on each situation. Note that every element in the flexi-grid topology has a reference, and this is the way in which they are called in the media-channel.

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

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

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

5. YANG Model for Flexi-Grid Media Channel

5.1. YANG Tree

```
module: ietf-te
  +--rw te!
     +--rw globals
     |  +--rw named-admin-groups
     |  |  +--rw named-admin-group* [name]
     |  |          {te-types:extended-admin-groups,te-types:named-extended-admin-
groups}?
     |  |     +--rw name            string
     |  |     +--rw bit-position?   uint32
     |  +--rw named-srlgs
     |  |  +--rw named-srlg* [name] {te-types:named-srlg-groups}?
     |  |     +--rw name     string
     |  |     +--rw group?   te-types:srlg
     |  |     +--rw cost?    uint32
     |  +--rw named-path-constraints
     |     +--rw named-path-constraint* [name]
     |             {te-types:named-path-constraints}?
     |        +--rw name                             string
     |        +--rw te-bandwidth
     |        |  +--rw (technology)?
     |        |     +--:(generic)
     |        |        +--rw generic?   te-bandwidth
     |        +--rw link-protection?                 identityref
     |        +--rw setup-priority?                  uint8
     |        +--rw hold-priority?                   uint8
     |        +--rw signaling-type?                  identityref
     |        +--rw path-metric-bounds
     |        |  +--rw path-metric-bound* [metric-type]
     |        |     +--rw metric-type    identityref
     |        |     +--rw upper-bound?   uint64
     |        +--rw path-affinities-values
     |        |  +--rw path-affinities-value* [usage]
     |        |     +--rw usage    identityref
     |        |     +--rw value?   admin-groups
     |        +--rw path-affinity-names
     |        |  +--rw path-affinity-name* [usage]
     |        |     +--rw usage            identityref
     |        |     +--rw affinity-name* [name]
     |        |        +--rw name    string
     |        +--rw path-srlgs-lists
     |        |  +--rw path-srlgs-list* [usage]
     |        |     +--rw usage     identityref
     |        |     +--rw values*   srlg
     |        +--rw path-srlgs-names
```

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

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

```
     |        |        |  +--rw (technology)?
     |        |        |     +--:(generic)
     |        |        |        +--rw generic?   int32
     |        |        +--rw range-bitmap?   yang:hex-string
     |        +--rw path-out-segment!
     |           +--rw label-restrictions
     |              +--rw label-restriction* [index]
     |                 +--rw restriction?    enumeration
     |                 +--rw index           uint32
     |                 +--rw label-start
     |                 |  +--rw te-label
     |                 |     +--rw (technology)?
     |                 |     |  +--:(generic)
     |                 |     |     +--rw generic?
     |                 |     |             rt-types:generalized-label
     |                 |     +--rw direction?
     |                 |             te-label-direction
     |                 +--rw label-end
     |                 |  +--rw te-label
     |                 |     +--rw (technology)?
     |                 |     |  +--:(generic)
     |                 |     |     +--rw generic?
     |                 |     |             rt-types:generalized-label
     |                 |     +--rw direction?
     |                 |             te-label-direction
     |                 +--rw label-step
     |                 |  +--rw (technology)?
     |                 |     +--:(generic)
     |                 |        +--rw generic?   int32
     |                 +--rw range-bitmap?   yang:hex-string
     +--rw tunnels
     |  +--rw tunnel* [name]
     |  |  +--ro operational-state?             identityref
     |  |  +--rw name                           string
     |  |  +--rw identifier?                    uint16
     |  |  +--rw description?                   string
     |  |  +--rw encoding?                      identityref
     |  |  +--rw switching-type?                identityref
     |  |  +--rw provisioning-state?            identityref
     |  |  +--rw preference?                    uint8
     |  |  +--rw reoptimize-timer?              uint16
     |  |  +--rw source?                        te-types:te-node-id
     |  |  +--rw destination?                   te-types:te-node-id
     |  |  +--rw src-tp-id?                     yang:hex-string
     |  |  +--rw dst-tp-id?                     yang:hex-string
     |  |  +--rw bidirectional?                 boolean
     |  |  +--rw association-objects
     |  |  |  +--rw association-object*
```

```
     |  |  |  |       [type ID source global-source]
     |  |  |  |  +--rw type             identityref
     |  |  |  |  +--rw ID               uint16
     |  |  |  |  +--rw source           te-types:te-node-id
     |  |  |  |  +--rw global-source    te-types:te-node-id
     |  |  |  +--rw association-object-extended*
     |  |  |          [type ID source global-source extended-ID]
     |  |  |     +--rw type             identityref
     |  |  |     +--rw ID               uint16
     |  |  |     +--rw source           te-types:te-node-id
     |  |  |     +--rw global-source    te-types:te-node-id
     |  |  |     +--rw extended-ID      yang:hex-string
     |  |  +--rw protection
     |  |  |  +--rw enable?                          boolean
     |  |  |  +--rw protection-type?                 identityref
     |  |  |  +--rw protection-reversion-disable?   boolean
     |  |  |  +--rw hold-off-time?                   uint32
     |  |  |  +--rw wait-to-revert?                  uint16
     |  |  |  +--rw aps-signal-id?                   uint8
     |  |  +--rw restoration
     |  |  |  +--rw enable?                           boolean
     |  |  |  +--rw restoration-type?                 identityref
     |  |  |  +--rw restoration-scheme?               identityref
     |  |  |  +--rw restoration-reversion-disable?   boolean
     |  |  |  +--rw hold-off-time?                    uint32
     |  |  |  +--rw wait-to-restore?                  uint16
     |  |  |  +--rw wait-to-revert?                   uint16
     |  |  +--rw te-topology-identifier
     |  |  |  +--rw provider-id?   te-global-id
     |  |  |  +--rw client-id?     te-global-id
     |  |  |  +--rw topology-id?   te-topology-id
     |  |  +--rw te-bandwidth
     |  |  |  +--rw (technology)?
     |  |  |     +--:(generic)
     |  |  |        +--rw generic?   te-bandwidth
     |  |  +--rw link-protection?                identityref
     |  |  +--rw setup-priority?                 uint8
     |  |  +--rw hold-priority?                  uint8
     |  |  +--rw signaling-type?                 identityref
     |  |  +--rw dependency-tunnels
     |  |  |  +--rw dependency-tunnel* [name]
     |  |  |     +--rw name
     |  |  |     |       -> ../../../../../tunnels/tunnel/name
     |  |  |     +--rw encoding?         identityref
     |  |  |     +--rw switching-type?   identityref
     |  |  +--rw hierarchical-link
     |  |  |  +--rw local-te-node-id?         te-types:te-node-id
     |  |  |  +--rw local-te-link-tp-id?      te-types:te-tp-id
```

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

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

```
     |  |  |     |     |  |           |     +--rw node-id
     |  |  |     |     |  |           |     |       te-node-id
     |  |  |     |     |  |           |     +--rw hop-type?
     |  |  |     |     |  |           |     |       te-hop-type
     |  |  |     |     |  |           |     +--rw direction?
     |  |  |     |     |  |           |             te-link-direction
     |  |  |     |     |  |           +--:(as-number)
     |  |  |     |     |  |           |  +--rw as-number-hop
     |  |  |     |     |  |           |     +--rw as-number
     |  |  |     |     |  |           |     |       inet:as-number
     |  |  |     |     |  |           |     +--rw hop-type?
     |  |  |     |     |  |           |             te-hop-type
     |  |  |     |     |  |           +--:(label)
     |  |  |     |     |  |              +--rw label-hop
     |  |  |     |     |  |                 +--rw te-label
     |  |  |     |     |  |                    +--rw (technology)?
     |  |  |     |     |  |                    |  +--:(generic)
     |  |  |     |     |  |                    |     +--rw generic?
     |  |  |     |     |  |                    |             rt-types:generalized
-label
     |  |  |     |     |  |                    +--rw direction?
     |  |  |     |     |  |                            te-label-direction
     |  |  |     |     |  +--rw tiebreakers
     |  |  |     |     |     +--rw tiebreaker* [tiebreaker-type]
     |  |  |     |     |        +--rw tiebreaker-type    identityref
     |  |  |     |     +--:(objective-function)
     |  |  |     |              {path-optimization-objective-function}?
     |  |  |     |        +--rw objective-function
     |  |  |     |           +--rw objective-function-type?
     |  |  |     |                   identityref
     |  |  |     +--rw preference?                      uint8
     |  |  |     +--rw k-requested-paths?               uint8
     |  |  |     +--rw named-path-constraint?           leafref
     |  |  |     |       {te-types:named-path-constraints}?
     |  |  |     +--rw te-bandwidth
     |  |  |     |  +--rw (technology)?
     |  |  |     |     +--:(generic)
     |  |  |     |        +--rw generic?   te-bandwidth
     |  |  |     +--rw link-protection?                 identityref
     |  |  |     +--rw setup-priority?                  uint8
     |  |  |     +--rw hold-priority?                   uint8
     |  |  |     +--rw signaling-type?                  identityref
     |  |  |     +--rw path-metric-bounds
     |  |  |     |  +--rw path-metric-bound* [metric-type]
     |  |  |     |     +--rw metric-type    identityref
     |  |  |     |     +--rw upper-bound?   uint64
     |  |  |     +--rw path-affinities-values
     |  |  |     |  +--rw path-affinities-value* [usage]
     |  |  |     |     +--rw usage    identityref
```

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

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

```
     |  |  |     |        |     +--rw direction?
     |  |  |     |        |             te-label-direction
     |  |  |     |        +--rw label-end
     |  |  |     |        |  +--rw te-label
     |  |  |     |        |     +--rw (technology)?
     |  |  |     |        |     |  +--:(generic)
     |  |  |     |        |     |     +--rw generic?
     |  |  |     |        |     |             rt-types:generalized-label
     |  |  |     |        |     +--rw direction?
     |  |  |     |        |             te-label-direction
     |  |  |     |        +--rw label-step
     |  |  |     |        |  +--rw (technology)?
     |  |  |     |        |     +--:(generic)
     |  |  |     |        |        +--rw generic?   int32
     |  |  |     |        +--rw range-bitmap?   yang:hex-string
     |  |  |     +--rw path-out-segment!
     |  |  |     |  +--rw label-restrictions
     |  |  |     |     +--rw label-restriction* [index]
     |  |  |     |        +--rw restriction?    enumeration
     |  |  |     |        +--rw index           uint32
     |  |  |     |        +--rw label-start
     |  |  |     |        |  +--rw te-label
     |  |  |     |        |     +--rw (technology)?
     |  |  |     |        |     |  +--:(generic)
     |  |  |     |        |     |     +--rw generic?
     |  |  |     |        |     |             rt-types:generalized-label
     |  |  |     |        |     +--rw direction?
     |  |  |     |        |             te-label-direction
     |  |  |     |        +--rw label-end
     |  |  |     |        |  +--rw te-label
     |  |  |     |        |     +--rw (technology)?
     |  |  |     |        |     |  +--:(generic)
     |  |  |     |        |     |     +--rw generic?
     |  |  |     |        |     |             rt-types:generalized-label
     |  |  |     |        |     +--rw direction?
     |  |  |     |        |             te-label-direction
     |  |  |     |        +--rw label-step
     |  |  |     |        |  +--rw (technology)?
     |  |  |     |        |     +--:(generic)
     |  |  |     |        |        +--rw generic?   int32
     |  |  |     |        +--rw range-bitmap?   yang:hex-string
     |  |  |     +--ro computed-paths-properties
     |  |  |     |  +--ro computed-path-properties* [k-index]
     |  |  |     |     +--ro k-index            uint8
     |  |  |     |     +--ro path-properties
     |  |  |     |        +--ro path-metric* [metric-type]
     |  |  |     |        |  +--ro metric-type           identityref
     |  |  |     |        |  +--ro accumulative-value?   uint64
```

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

```
     |  |  |     |        |        |     +--ro hop-type?
     |  |  |     |        |        |             te-hop-type
     |  |  |     |        |        +--:(label)
     |  |  |     |        |           +--ro label-hop
     |  |  |     |        |              +--ro te-label
     |  |  |     |        |                 +--ro (technology)?
     |  |  |     |        |                 |  +--:(generic)
     |  |  |     |        |                 |     +--ro generic?
     |  |  |     |        |                 |             rt-types:generalized-la
bel
     |  |  |     |        |                 +--ro direction?
     |  |  |     |        |                         te-label-direction
     |  |  |     |        +--ro shared-resources-tunnels
     |  |  |     |           +--ro lsp-shared-resources-tunnel*
     |  |  |     |                   tunnel-ref
     |  |  |     +--ro lsps
     |  |  |     |  +--ro lsp*
     |  |  |     |          [source destination tunnel-id lsp-id extended-tunnel-
id]
     |  |  |     |     +--ro source
     |  |  |     |     |       te-types:te-node-id
     |  |  |     |     +--ro destination
     |  |  |     |     |       te-types:te-node-id
     |  |  |     |     +--ro tunnel-id
     |  |  |     |     |       uint16
     |  |  |     |     +--ro lsp-id
     |  |  |     |     |       uint16
     |  |  |     |     +--ro extended-tunnel-id
     |  |  |     |     |       yang:dotted-quad
     |  |  |     |     +--ro operational-state?
     |  |  |     |     |       identityref
     |  |  |     |     +--ro path-setup-protocol?
     |  |  |     |     |       identityref
     |  |  |     |     +--ro origin-type?
     |  |  |     |     |       enumeration
     |  |  |     |     +--ro lsp-resource-status?
     |  |  |     |     |       enumeration
     |  |  |     |     +--ro lockout-of-normal?
     |  |  |     |     |       boolean
     |  |  |     |     +--ro freeze?
     |  |  |     |     |       boolean
     |  |  |     |     +--ro lsp-protection-role?
     |  |  |     |     |       enumeration
     |  |  |     |     +--ro lsp-protection-state?
     |  |  |     |     |       identityref
     |  |  |     |     +--ro protection-group-ingress-node-id?
     |  |  |     |     |       te-types:te-node-id
     |  |  |     |     +--ro protection-group-egress-node-id?
     |  |  |     |     |       te-types:te-node-id
     |  |  |     |     +--ro lsp-shared-resources-tunnel?
```

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

```
     |  |  |     |        |     +--ro usage     identityref
     |  |  |     |        |     +--ro values*   srlg
     |  |  |     |        +--ro path-srlgs-names
     |  |  |     |        |  +--ro path-srlgs-name* [usage]
     |  |  |     |        |     +--ro usage    identityref
     |  |  |     |        |     +--ro names*   string
     |  |  |     |        +--ro path-route-objects
     |  |  |     |        |  +--ro path-computed-route-object*
     |  |  |     |        |          [index]
     |  |  |     |        |     +--ro index
     |  |  |     |        |     |       uint32
     |  |  |     |        |     +--ro (type)?
     |  |  |     |        |        +--:(numbered-node-hop)
     |  |  |     |        |        |  +--ro numbered-node-hop
     |  |  |     |        |        |     +--ro node-id     te-node-id
     |  |  |     |        |        |     +--ro hop-type?
     |  |  |     |        |        |             te-hop-type
     |  |  |     |        |        +--:(numbered-link-hop)
     |  |  |     |        |        |  +--ro numbered-link-hop
     |  |  |     |        |        |     +--ro link-tp-id    te-tp-id
     |  |  |     |        |        |     +--ro hop-type?
     |  |  |     |        |        |     |       te-hop-type
     |  |  |     |        |        |     +--ro direction?
     |  |  |     |        |        |             te-link-direction
     |  |  |     |        |        +--:(unnumbered-link-hop)
     |  |  |     |        |        |  +--ro unnumbered-link-hop
     |  |  |     |        |        |     +--ro link-tp-id    te-tp-id
     |  |  |     |        |        |     +--ro node-id
     |  |  |     |        |        |     |       te-node-id
     |  |  |     |        |        |     +--ro hop-type?
     |  |  |     |        |        |     |       te-hop-type
     |  |  |     |        |        |     +--ro direction?
     |  |  |     |        |        |             te-link-direction
     |  |  |     |        |        +--:(as-number)
     |  |  |     |        |        |  +--ro as-number-hop
     |  |  |     |        |        |     +--ro as-number
     |  |  |     |        |        |     |       inet:as-number
     |  |  |     |        |        |     +--ro hop-type?
     |  |  |     |        |        |             te-hop-type
     |  |  |     |        |        +--:(label)
     |  |  |     |        |           +--ro label-hop
     |  |  |     |        |              +--ro te-label
     |  |  |     |        |                 +--ro (technology)?
     |  |  |     |        |                 |  +--:(generic)
     |  |  |     |        |                 |     +--ro generic?
     |  |  |     |        |                 |             rt-types:generalized-la
bel
     |  |  |     |        |                 +--ro direction?
     |  |  |     |        |                         te-label-direction
```

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

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

```
     |  |  |     |  |     |  |           |     +--rw node-id
     |  |  |     |  |     |  |           |     |       te-node-id
     |  |  |     |  |     |  |           |     +--rw hop-type?
     |  |  |     |  |     |  |           |     |       te-hop-type
     |  |  |     |  |     |  |           |     +--rw direction?
     |  |  |     |  |     |  |           |             te-link-direction
     |  |  |     |  |     |  |           +--:(as-number)
     |  |  |     |  |     |  |           |  +--rw as-number-hop
     |  |  |     |  |     |  |           |     +--rw as-number
     |  |  |     |  |     |  |           |     |       inet:as-number
     |  |  |     |  |     |  |           |     +--rw hop-type?
     |  |  |     |  |     |  |           |             te-hop-type
     |  |  |     |  |     |  |           +--:(label)
     |  |  |     |  |     |  |              +--rw label-hop
     |  |  |     |  |     |  |                 +--rw te-label
     |  |  |     |  |     |  |                    +--rw (technology)?
     |  |  |     |  |     |  |                    |  +--:(generic)
     |  |  |     |  |     |  |                    |     +--rw generic?
     |  |  |     |  |     |  |                    |             rt-types:generali
zed-label
     |  |  |     |  |     |  |                    +--rw direction?
     |  |  |     |  |     |  |                            te-label-direction
     |  |  |     |  |     |  +--rw tiebreakers
     |  |  |     |  |     |     +--rw tiebreaker* [tiebreaker-type]
     |  |  |     |  |     |        +--rw tiebreaker-type
     |  |  |     |  |     |                identityref
     |  |  |     |  |     +--:(objective-function)
     |  |  |     |  |              {path-optimization-objective-function}?
     |  |  |     |  |        +--rw objective-function
     |  |  |     |  |           +--rw objective-function-type?
     |  |  |     |  |                   identityref
     |  |  |     |  +--rw named-path-constraint?           leafref
     |  |  |     |  |       {te-types:named-path-constraints}?
     |  |  |     |  +--rw te-bandwidth
     |  |  |     |  |  +--rw (technology)?
     |  |  |     |  |     +--:(generic)
     |  |  |     |  |        +--rw generic?   te-bandwidth
     |  |  |     |  +--rw link-protection?
     |  |  |     |  |       identityref
     |  |  |     |  +--rw setup-priority?                  uint8
     |  |  |     |  +--rw hold-priority?                   uint8
     |  |  |     |  +--rw signaling-type?
     |  |  |     |  |       identityref
     |  |  |     |  +--rw path-metric-bounds
     |  |  |     |  |  +--rw path-metric-bound* [metric-type]
     |  |  |     |  |     +--rw metric-type    identityref
     |  |  |     |  |     +--rw upper-bound?   uint64
     |  |  |     |  +--rw path-affinities-values
     |  |  |     |  |  +--rw path-affinities-value* [usage]
```

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

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

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

```
     |  |  |     |  +--ro computed-paths-properties
     |  |  |     |  |  +--ro computed-path-properties* [k-index]
     |  |  |     |  |     +--ro k-index            uint8
     |  |  |     |  |     +--ro path-properties
     |  |  |     |  |        +--ro path-metric* [metric-type]
     |  |  |     |  |        |  +--ro metric-type
     |  |  |     |  |        |  |       identityref
     |  |  |     |  |        |  +--ro accumulative-value?   uint64
     |  |  |     |  |        +--ro path-affinities-values
     |  |  |     |  |        |  +--ro path-affinities-value* [usage]
     |  |  |     |  |        |     +--ro usage    identityref
     |  |  |     |  |        |     +--ro value?   admin-groups
     |  |  |     |  |        +--ro path-affinity-names
     |  |  |     |  |        |  +--ro path-affinity-name* [usage]
     |  |  |     |  |        |     +--ro usage            identityref
     |  |  |     |  |        |     +--ro affinity-name* [name]
     |  |  |     |  |        |        +--ro name    string
     |  |  |     |  |        +--ro path-srlgs-lists
     |  |  |     |  |        |  +--ro path-srlgs-list* [usage]
     |  |  |     |  |        |     +--ro usage     identityref
     |  |  |     |  |        |     +--ro values*   srlg
     |  |  |     |  |        +--ro path-srlgs-names
     |  |  |     |  |        |  +--ro path-srlgs-name* [usage]
     |  |  |     |  |        |     +--ro usage    identityref
     |  |  |     |  |        |     +--ro names*   string
     |  |  |     |  |        +--ro path-route-objects
     |  |  |     |  |        |  +--ro path-computed-route-object*
     |  |  |     |  |        |          [index]
     |  |  |     |  |        |     +--ro index
     |  |  |     |  |        |     |       uint32
     |  |  |     |  |        |     +--ro (type)?
     |  |  |     |  |        |        +--:(numbered-node-hop)
     |  |  |     |  |        |        |  +--ro numbered-node-hop
     |  |  |     |  |        |        |     +--ro node-id
     |  |  |     |  |        |        |     |       te-node-id
     |  |  |     |  |        |        |     +--ro hop-type?
     |  |  |     |  |        |        |             te-hop-type
     |  |  |     |  |        |        +--:(numbered-link-hop)
     |  |  |     |  |        |        |  +--ro numbered-link-hop
     |  |  |     |  |        |        |     +--ro link-tp-id
     |  |  |     |  |        |        |     |       te-tp-id
     |  |  |     |  |        |        |     +--ro hop-type?
     |  |  |     |  |        |        |     |       te-hop-type
     |  |  |     |  |        |        |     +--ro direction?
     |  |  |     |  |        |        |             te-link-direction
     |  |  |     |  |        |        +--:(unnumbered-link-hop)
     |  |  |     |  |        |        |  +--ro unnumbered-link-hop
     |  |  |     |  |        |        |     +--ro link-tp-id
```

```
     |  |  |     |  |        |        |     |       te-tp-id
     |  |  |     |  |        |        |     +--ro node-id
     |  |  |     |  |        |        |     |       te-node-id
     |  |  |     |  |        |        |     +--ro hop-type?
     |  |  |     |  |        |        |     |       te-hop-type
     |  |  |     |  |        |        |     +--ro direction?
     |  |  |     |  |        |        |             te-link-direction
     |  |  |     |  |        |        +--:(as-number)
     |  |  |     |  |        |        |  +--ro as-number-hop
     |  |  |     |  |        |        |     +--ro as-number
     |  |  |     |  |        |        |     |       inet:as-number
     |  |  |     |  |        |        |     +--ro hop-type?
     |  |  |     |  |        |        |             te-hop-type
     |  |  |     |  |        |        +--:(label)
     |  |  |     |  |        |           +--ro label-hop
     |  |  |     |  |        |              +--ro te-label
     |  |  |     |  |        |                 +--ro (technology)?
     |  |  |     |  |        |                 |  +--:(generic)
     |  |  |     |  |        |                 |     +--ro generic?
     |  |  |     |  |        |                 |             rt-types:generalized
-label
     |  |  |     |  |        |                 +--ro direction?
     |  |  |     |  |        |                         te-label-direction
     |  |  |     |  |        +--ro shared-resources-tunnels
     |  |  |     |  |           +--ro lsp-shared-resources-tunnel*
     |  |  |     |  |                   tunnel-ref
     |  |  |     |  +--ro lsps
     |  |  |     |  |  +--ro lsp*
     |  |  |     |  |          [source destination tunnel-id lsp-id extended-tunn
el-id]
     |  |  |     |  |     +--ro source
     |  |  |     |  |     |       te-types:te-node-id
     |  |  |     |  |     +--ro destination
     |  |  |     |  |     |       te-types:te-node-id
     |  |  |     |  |     +--ro tunnel-id
     |  |  |     |  |     |       uint16
     |  |  |     |  |     +--ro lsp-id
     |  |  |     |  |     |       uint16
     |  |  |     |  |     +--ro extended-tunnel-id
     |  |  |     |  |     |       yang:dotted-quad
     |  |  |     |  |     +--ro operational-state?
     |  |  |     |  |     |       identityref
     |  |  |     |  |     +--ro path-setup-protocol?
     |  |  |     |  |     |       identityref
     |  |  |     |  |     +--ro origin-type?
     |  |  |     |  |     |       enumeration
     |  |  |     |  |     +--ro lsp-resource-status?
     |  |  |     |  |     |       enumeration
     |  |  |     |  |     +--ro lockout-of-normal?
     |  |  |     |  |     |       boolean
```

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

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

```
     |  |  |     |  |        |        |     +--ro direction?
     |  |  |     |  |        |        |             te-link-direction
     |  |  |     |  |        |        +--:(as-number)
     |  |  |     |  |        |        |  +--ro as-number-hop
     |  |  |     |  |        |        |     +--ro as-number
     |  |  |     |  |        |        |     |       inet:as-number
     |  |  |     |  |        |        |     +--ro hop-type?
     |  |  |     |  |        |        |             te-hop-type
     |  |  |     |  |        |        +--:(label)
     |  |  |     |  |        |           +--ro label-hop
     |  |  |     |  |        |              +--ro te-label
     |  |  |     |  |        |                 +--ro (technology)?
     |  |  |     |  |        |                 |  +--:(generic)
     |  |  |     |  |        |                 |     +--ro generic?
     |  |  |     |  |        |                 |             rt-types:generalized
-label
     |  |  |     |  |        |                 +--ro direction?
     |  |  |     |  |        |                         te-label-direction
     |  |  |     |  |        +--ro shared-resources-tunnels
     |  |  |     |  |           +--ro lsp-shared-resources-tunnel*
     |  |  |     |  |                   tunnel-ref
     |  |  |     |  +--rw p2p-secondary-reverse-path
     |  |  |     |     +--rw secondary-path?        leafref
     |  |  |     |     +--rw path-setup-protocol?   identityref
     |  |  |     +--rw candidate-p2p-secondary-paths
     |  |  |        +--rw candidate-p2p-secondary-path*
     |  |  |                [secondary-path]
     |  |  |           +--rw secondary-path         leafref
     |  |  |           +--rw path-setup-protocol?   identityref
     |  |  |           +--ro active?                boolean
     |  |  +--rw p2p-secondary-paths
     |  |  |  +--rw p2p-secondary-path* [name]
     |  |  |     +--rw name                             string
     |  |  |     +--rw path-setup-protocol?             identityref
     |  |  |     +--rw path-computation-method?         identityref
     |  |  |     +--rw path-computation-server?
     |  |  |     |       inet:ip-address
     |  |  |     +--rw compute-only?                    empty
     |  |  |     +--rw use-path-computation?            boolean
     |  |  |     +--rw lockdown?                        empty
     |  |  |     +--ro path-scope?                      identityref
     |  |  |     +--rw optimizations
     |  |  |     |  +--rw (algorithm)?
     |  |  |     |     +--:(metric) {path-optimization-metric}?
     |  |  |     |     |  +--rw optimization-metric* [metric-type]
     |  |  |     |     |  |  +--rw metric-type
     |  |  |     |     |  |  |       identityref
     |  |  |     |     |  |  +--rw weight?
     |  |  |     |     |  |  |       uint8
```

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

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

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

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

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

```
     |  |  |     |        |     |     +--rw generic?
     |  |  |     |        |     |             rt-types:generalized-label
     |  |  |     |        |     +--rw direction?
     |  |  |     |        |           te-label-direction
     |  |  |     |        +--rw label-end
     |  |  |     |        |  +--rw te-label
     |  |  |     |        |     +--rw (technology)?
     |  |  |     |        |     |  +--:(generic)
     |  |  |     |        |     |     +--rw generic?
     |  |  |     |        |     |             rt-types:generalized-label
     |  |  |     |        |     +--rw direction?
     |  |  |     |        |           te-label-direction
     |  |  |     |        +--rw label-step
     |  |  |     |        |  +--rw (technology)?
     |  |  |     |        |     +--:(generic)
     |  |  |     |        |        +--rw generic?   int32
     |  |  |     |        +--rw range-bitmap?   yang:hex-string
     |  |  |     +--rw protection
     |  |  |     |  +--rw enable?                            boolean
     |  |  |     |  +--rw protection-type?                   identityref
     |  |  |     |  +--rw protection-reversion-disable?   boolean
     |  |  |     |  +--rw hold-off-time?                     uint32
     |  |  |     |  +--rw wait-to-revert?                    uint16
     |  |  |     |  +--rw aps-signal-id?                     uint8
     |  |  |     +--rw restoration
     |  |  |     |  +--rw enable?                             boolean
     |  |  |     |  +--rw restoration-type?
     |  |  |     |  |       identityref
     |  |  |     |  +--rw restoration-scheme?
     |  |  |     |  |       identityref
     |  |  |     |  +--rw restoration-reversion-disable?   boolean
     |  |  |     |  +--rw hold-off-time?                      uint32
     |  |  |     |  +--rw wait-to-restore?                    uint16
     |  |  |     |  +--rw wait-to-revert?                     uint16
     |  |  |     +--ro computed-paths-properties
     |  |  |     |  +--ro computed-path-properties* [k-index]
     |  |  |     |     +--ro k-index            uint8
     |  |  |     |     +--ro path-properties
     |  |  |     |        +--ro path-metric* [metric-type]
     |  |  |     |        |  +--ro metric-type           identityref
     |  |  |     |        |  +--ro accumulative-value?   uint64
     |  |  |     |        +--ro path-affinities-values
     |  |  |     |        |  +--ro path-affinities-value* [usage]
     |  |  |     |        |     +--ro usage    identityref
     |  |  |     |        |     +--ro value?   admin-groups
     |  |  |     |        +--ro path-affinity-names
     |  |  |     |        |  +--ro path-affinity-name* [usage]
     |  |  |     |        |     +--ro usage            identityref
```

```
     |  |  |     |        |     +--ro affinity-name* [name]
     |  |  |     |        |        +--ro name    string
     |  |  |     |        +--ro path-srlgs-lists
     |  |  |     |        |  +--ro path-srlgs-list* [usage]
     |  |  |     |        |     +--ro usage     identityref
     |  |  |     |        |     +--ro values*   srlg
     |  |  |     |        +--ro path-srlgs-names
     |  |  |     |        |  +--ro path-srlgs-name* [usage]
     |  |  |     |        |     +--ro usage    identityref
     |  |  |     |        |     +--ro names*   string
     |  |  |     |        +--ro path-route-objects
     |  |  |     |        |  +--ro path-computed-route-object*
     |  |  |     |        |          [index]
     |  |  |     |        |     +--ro index
     |  |  |     |        |     |       uint32
     |  |  |     |        |     +--ro (type)?
     |  |  |     |        |        +--:(numbered-node-hop)
     |  |  |     |        |        |  +--ro numbered-node-hop
     |  |  |     |        |        |     +--ro node-id     te-node-id
     |  |  |     |        |        |     +--ro hop-type?
     |  |  |     |        |        |             te-hop-type
     |  |  |     |        |        +--:(numbered-link-hop)
     |  |  |     |        |        |  +--ro numbered-link-hop
     |  |  |     |        |        |     +--ro link-tp-id    te-tp-id
     |  |  |     |        |        |     +--ro hop-type?
     |  |  |     |        |        |     |       te-hop-type
     |  |  |     |        |        |     +--ro direction?
     |  |  |     |        |        |             te-link-direction
     |  |  |     |        |        +--:(unnumbered-link-hop)
     |  |  |     |        |        |  +--ro unnumbered-link-hop
     |  |  |     |        |        |     +--ro link-tp-id    te-tp-id
     |  |  |     |        |        |     +--ro node-id
     |  |  |     |        |        |     |       te-node-id
     |  |  |     |        |        |     +--ro hop-type?
     |  |  |     |        |        |     |       te-hop-type
     |  |  |     |        |        |     +--ro direction?
     |  |  |     |        |        |             te-link-direction
     |  |  |     |        |        +--:(as-number)
     |  |  |     |        |        |  +--ro as-number-hop
     |  |  |     |        |        |     +--ro as-number
     |  |  |     |        |        |     |       inet:as-number
     |  |  |     |        |        |     +--ro hop-type?
     |  |  |     |        |        |             te-hop-type
     |  |  |     |        |        +--:(label)
     |  |  |     |        |           +--ro label-hop
     |  |  |     |        |              +--ro te-label
     |  |  |     |        |                 +--ro (technology)?
     |  |  |     |        |                 |  +--:(generic)
```

```
     |  |  |     |        |                 |     +--ro generic?
     |  |  |     |        |                 |             rt-types:generalized-la
bel
     |  |  |     |        |                 +--ro direction?
     |  |  |     |        |                         te-label-direction
     |  |  |     |        +--ro shared-resources-tunnels
     |  |  |     |           +--ro lsp-shared-resources-tunnel*
     |  |  |     |                   tunnel-ref
     |  |  |     +--ro lsps
     |  |  |        +--ro lsp*
     |  |  |                [source destination tunnel-id lsp-id extended-tunnel-
id]
     |  |  |           +--ro source
     |  |  |           |       te-types:te-node-id
     |  |  |           +--ro destination
     |  |  |           |       te-types:te-node-id
     |  |  |           +--ro tunnel-id
     |  |  |           |       uint16
     |  |  |           +--ro lsp-id
     |  |  |           |       uint16
     |  |  |           +--ro extended-tunnel-id
     |  |  |           |       yang:dotted-quad
     |  |  |           +--ro operational-state?
     |  |  |           |       identityref
     |  |  |           +--ro path-setup-protocol?
     |  |  |           |       identityref
     |  |  |           +--ro origin-type?
     |  |  |           |       enumeration
     |  |  |           +--ro lsp-resource-status?
     |  |  |           |       enumeration
     |  |  |           +--ro lockout-of-normal?
     |  |  |           |       boolean
     |  |  |           +--ro freeze?
     |  |  |           |       boolean
     |  |  |           +--ro lsp-protection-role?
     |  |  |           |       enumeration
     |  |  |           +--ro lsp-protection-state?
     |  |  |           |       identityref
     |  |  |           +--ro protection-group-ingress-node-id?
     |  |  |           |       te-types:te-node-id
     |  |  |           +--ro protection-group-egress-node-id?
     |  |  |           |       te-types:te-node-id
     |  |  |           +--ro lsp-shared-resources-tunnel?
     |  |  |           |       tunnel-ref
     |  |  |           +--ro lsp-record-route-information
     |  |  |           |  +--ro lsp-record-route-information* [index]
     |  |  |           |     +--ro index
     |  |  |           |     |       uint32
     |  |  |           |     +--ro (type)?
     |  |  |           |        +--:(numbered-node-hop)
```

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

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

```
     |  |  |     +--ro action-result?   identityref
     |  |  +---x protection-external-commands
     |  |     +---w input
     |  |        +---w protection-external-command?
     |  |        |       identityref
     |  |        +---w protection-group-ingress-node-id?
     |  |        |       te-types:te-node-id
     |  |        +---w protection-group-egress-node-id?
     |  |        |       te-types:te-node-id
     |  |        +---w path-ref?                            path-ref
     |  |        +---w traffic-type?
     |  |        |       enumeration
     |  |        +---w extra-traffic-tunnel-ref?           tunnel-ref
     |  +--rw tunnel-p2mp* [name]
     |     +--rw name                 string
     |     +--rw identifier?          uint16
     |     +--rw description?         string
     |     +--ro operational-state?   identityref
     +--ro lsps-state
        +--ro lsp*
                [source destination tunnel-id lsp-id extended-tunnel-id]
           +--ro source
           |       te-types:te-node-id
           +--ro destination
           |       te-types:te-node-id
           +--ro tunnel-id                              uint16
           +--ro lsp-id                                 uint16
           +--ro extended-tunnel-id                     yang:dotted-quad
           +--ro operational-state?                     identityref
           +--ro path-setup-protocol?                   identityref
           +--ro origin-type?                           enumeration
           +--ro lsp-resource-status?                   enumeration
           +--ro lockout-of-normal?                     boolean
           +--ro freeze?                                boolean
           +--ro lsp-protection-role?                   enumeration
           +--ro lsp-protection-state?                  identityref
           +--ro protection-group-ingress-node-id?
           |       te-types:te-node-id
           +--ro protection-group-egress-node-id?
           |       te-types:te-node-id
           +--ro lsp-record-route-information
              +--ro lsp-record-route-information* [index]
                 +--ro index                           uint32
                 +--ro (type)?
                    +--:(numbered-node-hop)
                    |  +--ro numbered-node-hop
                    |     +--ro node-id    te-node-id
                    |     +--ro flags*     path-attribute-flags
```

```
                    +--:(numbered-link-hop)
                    |  +--ro numbered-link-hop
                    |     +--ro link-tp-id    te-tp-id
                    |     +--ro flags*        path-attribute-flags
                    +--:(unnumbered-link-hop)
                    |  +--ro unnumbered-link-hop
                    |     +--ro link-tp-id    te-tp-id
                    |     +--ro node-id?      te-node-id
                    |     +--ro flags*        path-attribute-flags
                    +--:(label)
                       +--ro label-hop
                          +--ro te-label
                          |  +--ro (technology)?
                          |  |  +--:(generic)
                          |  |     +--ro generic?
                          |  |             rt-types:generalized-label
                          |  +--ro direction?
                          |          te-label-direction
                          +--ro flags*      path-attribute-flags

  rpcs:
    +---x globals-rpc
    +---x interfaces-rpc
    +---x tunnels-rpc
       +---w input
       |  +---w tunnel-info
       |     +---w (type)?
       |        +--:(tunnel-p2p)
       |        |  +---w p2p-id?    tunnel-ref
       |        +--:(tunnel-p2mp)
       |           +---w p2mp-id?   tunnel-p2mp-ref
       +--ro output
          +--ro result
             +--ro result?   enumeration

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

5.2. YANG Code

```
   <CODE BEGINS> file "ietf-flexi-grid-topology@2020-10-21.yang"
   module ietf-flexi-grid-media-channel {
     yang-version 1.1;
     namespace
```

```
       "urn:ietf:params:xml:ns:yang:ietf-flexi-grid-media-channel";
     prefix "flexi-grid-media-channel";

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

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

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

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

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

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

       Copyright (c) 2021 IETF Trust and the persons
```

```
       identified as authors of the code.  All rights reserved.
       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
       (https://trustee.ietf.org/license-info).
       This version of this YANG module is part of RFC XXXX; see
       the RFC itself for full legal notices.";

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

    /*
     * Data nodes
     */

     augment "/te:te/te:tunnels/te:tunnel" {
       description
         "Augment with additional parameters required for flexi-grid
          media channel.";
       uses l0-types-ext:l0-tunnel-attributes;
     }

     /*
      * Augment TE label.
      */

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

     /* Augment label hop of route-object-include-exclude of
```

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

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

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

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

  /* Augment label restrictions for the forwarding direction of
```

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

      /* Augment label hop of route-object-include-exclude of
```

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

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

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

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

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

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

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

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

      /* Augment label hop of path-route of reverse primary path */
      augment "/te:te/te:tunnels/te:tunnel/"
            + "te:p2p-primary-paths/te:p2p-primary-path/"
            + "te:p2p-primary-reverse-path/"
```

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

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

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

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

```
     }

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

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

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

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

```
    uses l0-types:flexi-grid-label-range-info;
  }

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

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

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

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

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

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

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

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

    /* Augment label hop of path-route of secondary LSP */
    augment "/te:te/te:tunnels/te:tunnel/"
          + "te:p2p-secondary-paths/te:p2p-secondary-path/"
          + "te:lsps/te:lsp/te:path-properties/"
          + "te:path-route-objects/"
```

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

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

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

6. Security Considerations

To Be discussed.

7. IANA Considerations

To be discussed.

8. Contributors

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

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A YANG Data Model for Flexi-Grid Optical Networks
draft-ietf-ccamp-flexigrid-yang-19

Abstract

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

About This Document

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

The latest revision of this draft can be found at https://ietf-ccamp-wg.github.io/draft-ietf-ccamp-flexigrid-yang/draft-ietf-ccamp-flexigrid-yang.html. Status information for this document may be found at https://datatracker.ietf.org/doc/draft-ietf-ccamp-flexigrid-yang/.

Discussion of this document takes place on the Common Control and Measurement Plane Working Group mailing list (mailto:ccamp@ietf.org), which is archived at https://mailarchive.ietf.org/arch/browse/ccamp/. Subscribe at https://www.ietf.org/mailman/listinfo/ccamp/.

Source for this draft and an issue tracker can be found at https://github.com/ietf-ccamp-wg/draft-ietf-ccamp-flexigrid-yang.

Status of This Memo

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Table of Contents

1. Introduction

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

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

[RFC8363] provides extensions to the OSPF-TE protocol so as to support GMPLS control of flexi-grid networks.

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

This document identifies the flexi-grid components, parameters, and their values. It characterizes the features and the performances of the flexi-grid elements. For this, it augments [RFC8795], and imports the generic Layer 0 types and use of "media-channel" defined in [I-D.ietf-ccamp-rfc9093-bis].

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

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

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

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

2. Terminology

Refer to [RFC7698] and [RFC7699] for the key terms used in this document.

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

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

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

* configuration data
* state data

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

3. Tree Diagram

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

3.1. Prefixes in Data Node Names

In this document, names of data nodes and other data model objects are prefixed using the standard prefix associated with the corresponding YANG imported modules, as shown in Table 1. It uses prefixes from [I-D.ietf-ccamp-rfc9093-bis], [RFC8345], and [RFC8795].

Prefix	YANG module	Reference
l0-types	ietf-layer0-types	[RFCYYYY]
flexgt	ietf-flexi-grid-topology	RFC XXXX
nw	ietf-network	[RFC8345]
nt	ietf-network-topology	[RFC8345]
tet	ietf-te-topology	[RFC8795]

Table 1: Prefixes and corresponding YANG modules

RFC Editor Note: Please replace XXXX with the RFC number assigned to this document. Please replace YYYY with the RFC numbers assigned to [I-D.ietf-ccamp-rfc9093-bis]. Please remove this note.

4. Example of Use

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

```
        +----------+                                        +----------+
        |  Flexi-  |                                        | Flexi-   |
        |   grid   |                                        |  grid    |
        |  node A  |                                        | node E   |
        |          |        +------+        +------+        |          |
        |          | Link 1 |Flexi-| Link 2 |Flexi-| Link 3 |          |
        |          |<------>| grid |<------>| grid |<------>|          |
        |......... |        |node B|        |node C|        | .........|
        | Trans- : |        +------+        +------+        | : Trans- |
        | ponder : |                                        | : ponder |
        |    A   : |              +----------+              | :    E   |
        |........: |     Link 4   |Flexi-grid|   Link 5     | :........|
        |          |<------------>|   node   |<------------>|          |
        |          |              |    D     |              |          |
        |          |              +----------+              |          |
        +----------+                                        +----------+
```

Figure 1: Topology Example

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

* We define the transponders within nodes A and E as tunnel termination points (TTPs) and provide their internal local link connectivity towards the node interfaces. We also provide the identifiers, addresses and interfaces of nodes A and B.

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

* Then, we also define the links 1 to 5 that interconnect nodes, indicating which flexi-grid labels are available.

* Other information, such as the slot frequency and granularity are also provided.

5. YANG Data Model for Flexi-Grid Topology

5.1. Flexi-Grid Topology Data Model Overview

This document describes the data model for flexi-grid topology. As a classic traffic engineering (TE) technology, flexi-grid provides WDM switching in transport network. Therefore the YANG module presented in this document augments from a more generic TE network topology data model, i.e., the ietf-te-topology, as specified in [RFC8795], following the guidelines provided in section 6 of [RFC8795].

Common types, identities, and groupings defined in [I-D.ietf-ccamp-rfc9093-bis] are reused in this document.

The figure below shows the augmentation relationship between YANG models.

```
                      +--------------------------+
       TE generic     |    ietf-te-topology      |
                      +--------------------------+
                                   ^
                                   |
                                   | Augments
                                   |
                      +------------+-------------+
       Flexi-Grid     | ietf-flexi-grid-topology |
                      +--------------------------+
```

Figure 2: Relationship between Flexi-Grid and TE topology models

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

The flexi-grid specific attributes and label format is defined in [RFC7699], including the grid type, nominal central frequency granularity, slot width granularity, n and m parameters. A collection of common data types have also been specified in [I-D.ietf-ccamp-rfc9093-bis], and used in this document for augmentation of the generic TE topology model.

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

5.2. Augmentations for Flexi-Grid Topology and Node

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

Following the guidelines in [RFC8795], a flexi-grid-topology network-type is specified as the indicator of flexi-grid in the topology as shown in Figure 3.

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

Figure 3: Flexi-Grid Topology Augmentation

A flexi-grid-node presence container is specified, augmenting the generic TE node attributes, to indicate that the TE node is a Flexi-Grid node as shown in Figure 4.

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

Figure 4: Flex-Grid Node Augmentation

It is assumed that all the flexi-grid nodes are reconfigurable.

5.3. Bandwidth Augmentation

No bandwidth augmentations are needed for this YANG module.

As described in Section 4.2 of [RFC7699], there is some overlap between bandwidth and label in Layer 0.

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

5.4. Label Augmentation

The model augments all the occurrences of the label-restriction list in [RFC8795] with flexi-grid technology specific attributes using the flexi-grid-label-range-info grouping defined in [I-D.ietf-ccamp-rfc9093-bis].

Moreover, following the guidelines in [RFC8795], the model augments all the occurrences of the te-label container with the flexi-grid technology specific attributes using the flexi-grid-label-start-end, flexi-grid-label-hop and flexi-grid-label-step groupings defined in [I-D.ietf-ccamp-rfc9093-bis].

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

```
module: ietf-flexi-grid-topology

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

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

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

```
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:label-restrictions/tet:label-restriction
               /tet:label-start/tet:te-label/tet:technology:
       +--:(flexi-grid)
          +--rw flexi-n?   flexi-n
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:label-restrictions/tet:label-restriction
               /tet:label-end/tet:te-label/tet:technology:
       +--:(flexi-grid)
          +--rw flexi-n?   flexi-n
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:label-restrictions/tet:label-restriction
               /tet:label-step/tet:technology:
       +--:(flexi-grid)
          o--rw flexi-grid-channel-spacing?   identityref
          +--rw flexi-ncfg?                   identityref
          +--rw flexi-n-step?                 uint8
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:underlay/tet:primary-path/tet:path-element/tet:type
               /tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(flexi-grid)
          +--rw (single-or-super-channel)?
             +--:(single)
             |  +--rw flexi-n?             flexi-n
             |  +--rw flexi-m?             flexi-m
             o--:(super)
             |  o--rw subcarrier-flexi-n* [flexi-n]
             |     +--rw flexi-n    flexi-n
             |     +--rw flexi-m?   flexi-m
             +--:(multi)
                +--rw frequency-slots
                   +--rw frequency-slot* [flexi-n]
                      +--rw flexi-n    flexi-n
                      +--rw flexi-m?   flexi-m
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:underlay/tet:backup-path/tet:path-element/tet:type
               /tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(flexi-grid)
          +--rw (single-or-super-channel)?
             +--:(single)
             |  +--rw flexi-n?             flexi-n
             |  +--rw flexi-m?             flexi-m
             o--:(super)
```

```
           |  o--rw subcarrier-flexi-n* [flexi-n]
           |     +--rw flexi-n    flexi-n
           |     +--rw flexi-m?   flexi-m
           +--:(multi)
              +--rw frequency-slots
                 +--rw frequency-slot* [flexi-n]
                    +--rw flexi-n    flexi-n
                    +--rw flexi-m?   flexi-m
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:te-node-attributes/tet:connectivity-matrices
            /tet:optimizations/tet:algorithm/tet:metric
            /tet:optimization-metric
            /tet:explicit-route-exclude-objects
            /tet:route-object-exclude-object/tet:type/tet:label
            /tet:label-hop/tet:te-label/tet:technology:
    +--:(flexi-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw flexi-n?              flexi-n
          |  +--rw flexi-m?              flexi-m
          o--:(super)
          |  o--rw subcarrier-flexi-n* [flexi-n]
          |     +--rw flexi-n    flexi-n
          |     +--rw flexi-m?   flexi-m
          +--:(multi)
             +--rw frequency-slots
                +--rw frequency-slot* [flexi-n]
                   +--rw flexi-n    flexi-n
                   +--rw flexi-m?   flexi-m
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:te-node-attributes/tet:connectivity-matrices
            /tet:optimizations/tet:algorithm/tet:metric
            /tet:optimization-metric
            /tet:explicit-route-include-objects
            /tet:route-object-include-object/tet:type/tet:label
            /tet:label-hop/tet:te-label/tet:technology:
    +--:(flexi-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw flexi-n?              flexi-n
          |  +--rw flexi-m?              flexi-m
          o--:(super)
          |  o--rw subcarrier-flexi-n* [flexi-n]
          |     +--rw flexi-n    flexi-n
          |     +--rw flexi-m?   flexi-m
          +--:(multi)
             +--rw frequency-slots
                +--rw frequency-slot* [flexi-n]
```

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

```
       +--:(flexi-grid)
          +--rw flexi-n?   flexi-n
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:to/tet:label-restrictions
               /tet:label-restriction/tet:label-end/tet:te-label
               /tet:technology:
       +--:(flexi-grid)
          +--rw flexi-n?   flexi-n
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:to/tet:label-restrictions
               /tet:label-restriction/tet:label-step/tet:technology:
       +--:(flexi-grid)
          o--rw flexi-grid-channel-spacing?   identityref
          +--rw flexi-ncfg?                   identityref
          +--rw flexi-n-step?                 uint8
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:underlay/tet:primary-path
               /tet:path-element/tet:type/tet:label/tet:label-hop
               /tet:te-label/tet:technology:
       +--:(flexi-grid)
          +--rw (single-or-super-channel)?
             +--:(single)
             |  +--rw flexi-n?             flexi-n
             |  +--rw flexi-m?             flexi-m
             o--:(super)
             |  o--rw subcarrier-flexi-n* [flexi-n]
             |     +--rw flexi-n    flexi-n
             |     +--rw flexi-m?   flexi-m
             +--:(multi)
                +--rw frequency-slots
                   +--rw frequency-slot* [flexi-n]
                      +--rw flexi-n    flexi-n
                      +--rw flexi-m?   flexi-m
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:underlay/tet:backup-path
               /tet:path-element/tet:type/tet:label/tet:label-hop
               /tet:te-label/tet:technology:
       +--:(flexi-grid)
          +--rw (single-or-super-channel)?
             +--:(single)
             |  +--rw flexi-n?             flexi-n
             |  +--rw flexi-m?             flexi-m
             o--:(super)
             |  o--rw subcarrier-flexi-n* [flexi-n]
```

```
          |     +--rw flexi-n    flexi-n
          |     +--rw flexi-m?   flexi-m
          +--:(multi)
             +--rw frequency-slots
                +--rw frequency-slot* [flexi-n]
                   +--rw flexi-n    flexi-n
                   +--rw flexi-m?   flexi-m
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:te-node-attributes/tet:connectivity-matrices
            /tet:connectivity-matrix/tet:optimizations/tet:algorithm
            /tet:metric/tet:optimization-metric
            /tet:explicit-route-exclude-objects
            /tet:route-object-exclude-object/tet:type/tet:label
            /tet:label-hop/tet:te-label/tet:technology:
    +--:(flexi-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw flexi-n?             flexi-n
          |  +--rw flexi-m?             flexi-m
          o--:(super)
          |  o--rw subcarrier-flexi-n* [flexi-n]
          |     +--rw flexi-n    flexi-n
          |     +--rw flexi-m?   flexi-m
          +--:(multi)
             +--rw frequency-slots
                +--rw frequency-slot* [flexi-n]
                   +--rw flexi-n    flexi-n
                   +--rw flexi-m?   flexi-m
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:te-node-attributes/tet:connectivity-matrices
            /tet:connectivity-matrix/tet:optimizations/tet:algorithm
            /tet:metric/tet:optimization-metric
            /tet:explicit-route-include-objects
            /tet:route-object-include-object/tet:type/tet:label
            /tet:label-hop/tet:te-label/tet:technology:
    +--:(flexi-grid)
       +--rw (single-or-super-channel)?
          +--:(single)
          |  +--rw flexi-n?             flexi-n
          |  +--rw flexi-m?             flexi-m
          o--:(super)
          |  o--rw subcarrier-flexi-n* [flexi-n]
          |     +--rw flexi-n    flexi-n
          |     +--rw flexi-m?   flexi-m
          +--:(multi)
             +--rw frequency-slots
                +--rw frequency-slot* [flexi-n]
                   +--rw flexi-n    flexi-n
```

```
                  +--rw flexi-m?   flexi-m
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:path-properties
               /tet:path-route-objects/tet:path-route-object/tet:type
               /tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(flexi-grid)
          +--ro (single-or-super-channel)?
             +--:(single)
             |  +--ro flexi-n?             flexi-n
             |  +--ro flexi-m?             flexi-m
             o--:(super)
             |  o--ro subcarrier-flexi-n* [flexi-n]
             |     +--ro flexi-n    flexi-n
             |     +--ro flexi-m?   flexi-m
             +--:(multi)
                +--ro frequency-slots
                   +--ro frequency-slot* [flexi-n]
                      +--ro flexi-n    flexi-n
                      +--ro flexi-m?   flexi-m
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:label-restrictions/tet:label-restriction
               /tet:label-start/tet:te-label/tet:technology:
       +--:(flexi-grid)
          +--ro flexi-n?   flexi-n
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:label-restrictions/tet:label-restriction
               /tet:label-end/tet:te-label/tet:technology:
       +--:(flexi-grid)
          +--ro flexi-n?   flexi-n
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:label-restrictions/tet:label-restriction
               /tet:label-step/tet:technology:
       +--:(flexi-grid)
          o--ro flexi-grid-channel-spacing?   identityref
          +--ro flexi-ncfg?                   identityref
          +--ro flexi-n-step?                 uint8
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:underlay/tet:primary-path/tet:path-element/tet:type
               /tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(flexi-grid)
          +--ro (single-or-super-channel)?
             +--:(single)
             |  +--ro flexi-n?             flexi-n
```

```
           |  +--ro flexi-m?              flexi-m
           o--:(super)
           |  o--ro subcarrier-flexi-n* [flexi-n]
           |     +--ro flexi-n    flexi-n
           |     +--ro flexi-m?   flexi-m
           +--:(multi)
              +--ro frequency-slots
                 +--ro frequency-slot* [flexi-n]
                    +--ro flexi-n    flexi-n
                    +--ro flexi-m?   flexi-m
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:information-source-entry/tet:connectivity-matrices
            /tet:underlay/tet:backup-path/tet:path-element/tet:type
            /tet:label/tet:label-hop/tet:te-label/tet:technology:
    +--:(flexi-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro flexi-n?              flexi-n
          |  +--ro flexi-m?              flexi-m
          o--:(super)
          |  o--ro subcarrier-flexi-n* [flexi-n]
          |     +--ro flexi-n    flexi-n
          |     +--ro flexi-m?   flexi-m
          +--:(multi)
             +--ro frequency-slots
                +--ro frequency-slot* [flexi-n]
                   +--ro flexi-n    flexi-n
                   +--ro flexi-m?   flexi-m
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:information-source-entry/tet:connectivity-matrices
            /tet:optimizations/tet:algorithm/tet:metric
            /tet:optimization-metric
            /tet:explicit-route-exclude-objects
            /tet:route-object-exclude-object/tet:type/tet:label
            /tet:label-hop/tet:te-label/tet:technology:
    +--:(flexi-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro flexi-n?              flexi-n
          |  +--ro flexi-m?              flexi-m
          o--:(super)
          |  o--ro subcarrier-flexi-n* [flexi-n]
          |     +--ro flexi-n    flexi-n
          |     +--ro flexi-m?   flexi-m
          +--:(multi)
             +--ro frequency-slots
                +--ro frequency-slot* [flexi-n]
                   +--ro flexi-n    flexi-n
```

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

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

```
          |  o--ro subcarrier-flexi-n* [flexi-n]
          |     +--ro flexi-n    flexi-n
          |     +--ro flexi-m?   flexi-m
          +--:(multi)
             +--ro frequency-slots
                +--ro frequency-slot* [flexi-n]
                   +--ro flexi-n    flexi-n
                   +--ro flexi-m?   flexi-m
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:information-source-entry/tet:connectivity-matrices
            /tet:connectivity-matrix/tet:underlay/tet:backup-path
            /tet:path-element/tet:type/tet:label/tet:label-hop
            /tet:te-label/tet:technology:
    +--:(flexi-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro flexi-n?              flexi-n
          |  +--ro flexi-m?              flexi-m
          o--:(super)
          |  o--ro subcarrier-flexi-n* [flexi-n]
          |     +--ro flexi-n    flexi-n
          |     +--ro flexi-m?   flexi-m
          +--:(multi)
             +--ro frequency-slots
                +--ro frequency-slot* [flexi-n]
                   +--ro flexi-n    flexi-n
                   +--ro flexi-m?   flexi-m
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:information-source-entry/tet:connectivity-matrices
            /tet:connectivity-matrix/tet:optimizations/tet:algorithm
            /tet:metric/tet:optimization-metric
            /tet:explicit-route-exclude-objects
            /tet:route-object-exclude-object/tet:type/tet:label
            /tet:label-hop/tet:te-label/tet:technology:
    +--:(flexi-grid)
       +--ro (single-or-super-channel)?
          +--:(single)
          |  +--ro flexi-n?              flexi-n
          |  +--ro flexi-m?              flexi-m
          o--:(super)
          |  o--ro subcarrier-flexi-n* [flexi-n]
          |     +--ro flexi-n    flexi-n
          |     +--ro flexi-m?   flexi-m
          +--:(multi)
             +--ro frequency-slots
                +--ro frequency-slot* [flexi-n]
                   +--ro flexi-n    flexi-n
                   +--ro flexi-m?   flexi-m
```

```
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:optimizations/tet:algorithm
               /tet:metric/tet:optimization-metric
               /tet:explicit-route-include-objects
               /tet:route-object-include-object/tet:type/tet:label
               /tet:label-hop/tet:te-label/tet:technology:
       +--:(flexi-grid)
          +--ro (single-or-super-channel)?
             +--:(single)
             |  +--ro flexi-n?             flexi-n
             |  +--ro flexi-m?             flexi-m
             o--:(super)
             |  o--ro subcarrier-flexi-n* [flexi-n]
             |     +--ro flexi-n    flexi-n
             |     +--ro flexi-m?   flexi-m
             +--:(multi)
                +--ro frequency-slots
                   +--ro frequency-slot* [flexi-n]
                      +--ro flexi-n    flexi-n
                      +--ro flexi-m?   flexi-m
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:path-properties
               /tet:path-route-objects/tet:path-route-object/tet:type
               /tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(flexi-grid)
          +--ro (single-or-super-channel)?
             +--:(single)
             |  +--ro flexi-n?             flexi-n
             |  +--ro flexi-m?             flexi-m
             o--:(super)
             |  o--ro subcarrier-flexi-n* [flexi-n]
             |     +--ro flexi-n    flexi-n
             |     +--ro flexi-m?   flexi-m
             +--:(multi)
                +--ro frequency-slots
                   +--ro frequency-slot* [flexi-n]
                      +--ro flexi-n    flexi-n
                      +--ro flexi-m?   flexi-m
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:tunnel-termination-point
               /tet:local-link-connectivities/tet:label-restrictions
               /tet:label-restriction/tet:label-start/tet:te-label
               /tet:technology:
       +--:(flexi-grid)
          +--rw flexi-n?   flexi-n
     augment /nw:networks/nw:network/nw:node/tet:te
```

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

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

```
              /tet:local-link-connectivities/tet:path-properties
              /tet:path-route-objects/tet:path-route-object/tet:type
              /tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(flexi-grid)
          +--ro (single-or-super-channel)?
             +--:(single)
             |  +--ro flexi-n?              flexi-n
             |  +--ro flexi-m?              flexi-m
             o--:(super)
             |  o--ro subcarrier-flexi-n* [flexi-n]
             |     +--ro flexi-n    flexi-n
             |     +--ro flexi-m?   flexi-m
             +--:(multi)
                +--ro frequency-slots
                   +--ro frequency-slot* [flexi-n]
                      +--ro flexi-n    flexi-n
                      +--ro flexi-m?   flexi-m
     augment /nw:networks/nw:network/nw:node/tet:te
              /tet:tunnel-termination-point
              /tet:local-link-connectivities
              /tet:local-link-connectivity/tet:label-restrictions
              /tet:label-restriction/tet:label-start/tet:te-label
              /tet:technology:
       +--:(flexi-grid)
          +--rw flexi-n?   flexi-n
     augment /nw:networks/nw:network/nw:node/tet:te
              /tet:tunnel-termination-point
              /tet:local-link-connectivities
              /tet:local-link-connectivity/tet:label-restrictions
              /tet:label-restriction/tet:label-end/tet:te-label
              /tet:technology:
       +--:(flexi-grid)
          +--rw flexi-n?   flexi-n
     augment /nw:networks/nw:network/nw:node/tet:te
              /tet:tunnel-termination-point
              /tet:local-link-connectivities
              /tet:local-link-connectivity/tet:label-restrictions
              /tet:label-restriction/tet:label-step/tet:technology:
       +--:(flexi-grid)
          o--rw flexi-grid-channel-spacing?   identityref
          +--rw flexi-ncfg?                   identityref
          +--rw flexi-n-step?                 uint8
     augment /nw:networks/nw:network/nw:node/tet:te
              /tet:tunnel-termination-point
              /tet:local-link-connectivities
              /tet:local-link-connectivity/tet:underlay
              /tet:primary-path/tet:path-element/tet:type/tet:label
              /tet:label-hop/tet:te-label/tet:technology:
```

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

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

```
                   +--ro flexi-n    flexi-n
                   +--ro flexi-m?   flexi-m
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:te-link-attributes/tet:underlay/tet:primary-path
               /tet:path-element/tet:type/tet:label/tet:label-hop
               /tet:te-label/tet:technology:
       +--:(flexi-grid)
          +--rw (single-or-super-channel)?
             +--:(single)
             |  +--rw flexi-n?              flexi-n
             |  +--rw flexi-m?              flexi-m
             o--:(super)
             |  o--rw subcarrier-flexi-n* [flexi-n]
             |     +--rw flexi-n    flexi-n
             |     +--rw flexi-m?   flexi-m
             +--:(multi)
                +--rw frequency-slots
                   +--rw frequency-slot* [flexi-n]
                      +--rw flexi-n    flexi-n
                      +--rw flexi-m?   flexi-m
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:te-link-attributes/tet:underlay/tet:backup-path
               /tet:path-element/tet:type/tet:label/tet:label-hop
               /tet:te-label/tet:technology:
       +--:(flexi-grid)
          +--rw (single-or-super-channel)?
             +--:(single)
             |  +--rw flexi-n?              flexi-n
             |  +--rw flexi-m?              flexi-m
             o--:(super)
             |  o--rw subcarrier-flexi-n* [flexi-n]
             |     +--rw flexi-n    flexi-n
             |     +--rw flexi-m?   flexi-m
             +--:(multi)
                +--rw frequency-slots
                   +--rw frequency-slot* [flexi-n]
                      +--rw flexi-n    flexi-n
                      +--rw flexi-m?   flexi-m
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:te-link-attributes/tet:label-restrictions
               /tet:label-restriction/tet:label-start/tet:te-label
               /tet:technology:
       +--:(flexi-grid)
          +--rw flexi-n?   flexi-n
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:te-link-attributes/tet:label-restrictions
               /tet:label-restriction/tet:label-end/tet:te-label
               /tet:technology:
```

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

```
               /tet:path-element/tet:type/tet:label/tet:label-hop
               /tet:te-label/tet:technology:
       +--:(flexi-grid)
          +--rw (single-or-super-channel)?
             +--:(single)
             |  +--rw flexi-n?             flexi-n
             |  +--rw flexi-m?             flexi-m
             o--:(super)
             |  o--rw subcarrier-flexi-n* [flexi-n]
             |     +--rw flexi-n    flexi-n
             |     +--rw flexi-m?   flexi-m
             +--:(multi)
                +--rw frequency-slots
                   +--rw frequency-slot* [flexi-n]
                      +--rw flexi-n    flexi-n
                      +--rw flexi-m?   flexi-m
     augment /nw:networks/tet:te/tet:templates/tet:link-template
               /tet:te-link-attributes/tet:label-restrictions
               /tet:label-restriction/tet:label-start/tet:te-label
               /tet:technology:
       +--:(flexi-grid)
          +--rw flexi-n?   flexi-n
     augment /nw:networks/tet:te/tet:templates/tet:link-template
               /tet:te-link-attributes/tet:label-restrictions
               /tet:label-restriction/tet:label-end/tet:te-label
               /tet:technology:
       +--:(flexi-grid)
          +--rw flexi-n?   flexi-n
     augment /nw:networks/tet:te/tet:templates/tet:link-template
               /tet:te-link-attributes/tet:label-restrictions
               /tet:label-restriction/tet:label-step/tet:technology:
       +--:(flexi-grid)
          o--rw flexi-grid-channel-spacing?   identityref
          +--rw flexi-ncfg?                   identityref
          +--rw flexi-n-step?                 uint8
```

Figure 5

7. The YANG Code for Flexi-grid topology

```
<CODE BEGINS> file "ietf-flexi-grid-topology@2023-12-15.yang"
module ietf-flexi-grid-topology {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-flexi-grid-topology";
  prefix "flexgt";

  import ietf-network {
    prefix "nw";
```

```
       reference
         "RFC 8345: A YANG Data Model for Network Topologies";
     }

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

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

     import ietf-layer0-types {
       prefix "l0-types";
       reference
         "RFC YYYY: A YANG Data Model for Layer 0 Types";
     }
     /* Note: The RFC Editor will replace YYYY with the number assigned
        to the RFC once draft-ietf-ccamp-rfc9093-bis becomes an RFC.*/

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

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

        Editor: Jorge E. Lopez de Vergara
                <mailto:jorge.lopez_vergara@uam.es>

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        Editor: Daniel King
                <mailto:d.king@lancaster.ac.uk>

        Editor: Young Lee
                <mailto:younglee.tx@gmail.com>";

     description
```

```
    "This YANG module defines a topology model for flexi-grid
     optical networks. The model augments the technology-agnostic
     TE topology model with flexi-grid technology specific
     definitions, based on RFC 7698 and RFC 7699.

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

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     as authors of the code.  All rights reserved.

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     or without modification, is permitted pursuant to, and
     subject to the license terms contained in, the Revised
     BSD License set forth in Section 4.c of the IETF Trust's
     Legal Provisions Relating to IETF Documents
     (https://trustee.ietf.org/license-info).

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

     The key words 'MUST', 'MUST NOT', 'REQUIRED', 'SHALL', 'SHALL
     NOT', 'SHOULD', 'SHOULD NOT', 'RECOMMENDED', 'NOT RECOMMENDED',
     'MAY', and 'OPTIONAL' in this document are to be interpreted as
     described in BCP 14 (RFC 2119) (RFC 8174) when, and only when,
     they appear in all capitals, as shown here.";
    reference
      "RFC 7698: Framework and Requirements for GMPLS-Based Control
        of Flexi-Grid Dense Wavelength Division Multiplexing
        (DWDM) Networks;
      RFC 7699: Generalized Labels for the Flexi-Grid in Lambda
        Switch Capable (LSC) Label Switching Routers.";

  revision 2023-12-15 {
    description
      "Initial Version";
    reference
      "RFC XXXX: A YANG Data Model for Flexi-Grid Optical Networks";
    // RFC Ed.: replace XXXX with actual RFC number, update date
    // information and remove this note
  }

  /*
   * Groupings
   */

  grouping label-range-info {
    description
```

```
         "Flexi-grid-specific label range related information with a
         presence container indicating whether the label range is a
         flexi-grid label range.";
       container flexi-grid-label-range {
         presence
           "Indicates the label range is a flexi-grid label range.

           This container MUST NOT be present if there are other
           presence containers or attributes indicating another type
           of label range.";
         description
           "Flexi-grid-specific label range related information.";
         uses l0-types:flexi-grid-label-range-info;
       }
     }

     /*
      * Data nodes
      */

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

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

```
   /*
    * Augment TE label range information
    */

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

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

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

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

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

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

```
     }

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

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

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

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

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

   /*
    * Augment TE label
    */

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

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

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

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

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

```
       description
         "Augment TE label hop for the underlay primary path of the
          TE node connectivity matrices.";
       case flexi-grid {
         uses l0-types:flexi-grid-label-hop;
       }
     }

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

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

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

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

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

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

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

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:connectivity-matrix/tet:from/"
           + "tet:label-restrictions/tet:label-restriction/"
           + "tet:label-step/"
           + "tet:technology" {
```

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

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

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

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

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

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

```
       }
     }

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

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

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

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

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

      augment "/nw:networks/nw:network/nw:node/tet:te/"
            + "tet:information-source-entry/"
            + "tet:connectivity-matrices/tet:label-restrictions/"
            + "tet:label-restriction/"
            + "tet:label-start/tet:te-label/tet:technology" {
        when "../../../../../../../../../../"
           + "nw:network-types/tet:te-topology/"
```

```
          + "flexgt:flexi-grid-topology" {
         description
           "Augmentation parameters apply only for networks with
            flexi-grid topology type.";
       }
       description
         "Augment TE label range start for the TE node connectivity
          matrices information source.";
       case flexi-grid {
         uses l0-types:flexi-grid-label-start-end;
       }
     }

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

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

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

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

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

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

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

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

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:information-source-entry/tet:connectivity-matrices/"
           + "tet:path-properties/tet:path-route-objects/"
           + "tet:path-route-object/tet:type/"
           + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
```

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

     augment "/nw:networks/nw:network/nw:node/tet:te/"
```

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

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

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

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

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

      augment "/nw:networks/nw:network/nw:node/tet:te/"
            + "tet:tunnel-termination-point/"
            + "tet:local-link-connectivities/"
            + "tet:optimizations/tet:algorithm/tet:metric/"
            + "tet:optimization-metric/"
            + "tet:explicit-route-include-objects/"
            + "tet:route-object-include-object/tet:type/"
            + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
        when "../../../../../../../../../../../"
           + "nw:network-types/tet:te-topology/"
           + "flexgt:flexi-grid-topology" {
          description
```

```
            "Augmentation parameters apply only for networks with
             flexi-grid topology type.";
        }
        description
          "Augment TE label hop for the explicit route objects included
           by the path computation of the TTP Local Link
           Connectivities.";
        case flexi-grid {
          uses l0-types:flexi-grid-label-hop;
        }
      }

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

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

```
           Local Link Connectivity entry.";
        case flexi-grid {
          uses l0-types:flexi-grid-label-start-end;
        }
      }

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

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

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

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

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:tunnel-termination-point/"
           + "tet:local-link-connectivities/"
           + "tet:local-link-connectivity/"
           + "tet:optimizations/tet:algorithm/tet:metric/"
           + "tet:optimization-metric/"
```

```
            + "tet:explicit-route-exclude-objects/"
            + "tet:route-object-exclude-object/tet:type/"
            + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
        when "../../../../../../../../../../../../"
           + "nw:network-types/tet:te-topology/"
           + "flexgt:flexi-grid-topology" {
          description
            "Augmentation parameters apply only for networks with
             flexi-grid topology type.";
        }
        description
          "Augment TE label hop for the explicit route objects excluded
           by the path computation of the TTP Local Link
           Connectivity entry.";
        case flexi-grid {
          uses l0-types:flexi-grid-label-hop;
        }
      }

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

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

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

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

```
         "Augment TE label hop for the underlay backup path
          of the TE link.";
       case flexi-grid {
         uses l0-types:flexi-grid-label-hop;
       }
     }

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

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

     augment "/nw:networks/nw:network/nt:link/tet:te/"
           + "tet:te-link-attributes/"
           + "tet:label-restrictions/tet:label-restriction/"
           + "tet:label-step/tet:technology" {
       when "../../../../../../nw:network-types/tet:te-topology/"
          + "flexgt:flexi-grid-topology" {
         description
```

```
           "Augmentation parameters apply only for networks with
            flexi-grid topology type.";
       }
       description
         "Augment TE label range step for the TE link.";
       case flexi-grid {
         uses l0-types:flexi-grid-label-step;
       }
     }

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

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

     augment "/nw:networks/nw:network/nt:link/tet:te/"
           + "tet:information-source-entry/"
```

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

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

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

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

```
        }
      }

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

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

Figure 6

8. Security Considerations

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

The NETCONF access control model [RFC8341] provides the means to restrict access for particular NETCONF users to a preconfigured subset of all available NETCONF protocol operations and content. The NETCONF Protocol SSH [RFC6242] describes a method for invoking and running NETCONF within a SSH session as an SSH subsystem. The Network Configuration Access Control Model (NACM) [RFC8341] provides the means to restrict access for particular NETCONF or RESTCONF users to a preconfigured subset of all available NETCONF or RESTCONF protocol operations and content.

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

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

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

9. IANA Considerations

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

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

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

```
Name: ietf-flexi-grid-topology
Namespace: urn:ietf:params:xml:ns:yang:ietf-flexi-grid-topology
Prefix: flexgt
Reference: RFC XXXX
```

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12 April 2024

A YANG Data Model for L1 Connectivity Service Model (L1CSM)
draft-ietf-ccamp-l1csm-yang-26

Abstract

This document provides a YANG Layer 1 Connectivity Service Model (L1CSM).

This model can be utilized by a customer network controller to initiate a connectivity service request as well as to retrieve service states for a Layer 1 network controller communicating with its customer network controller. This YANG model is in compliance of Network Management Datastore Architecture (NMDA).

Status of This Memo

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Table of Contents

1. Introduction

This document provides a YANG Layer 1 (L1) Connectivity Service Model (L1CSM) which can be classified as Network Service YANG module per [RFC8199]. This model can be utilized by a customer network controller to initiate a connectivity service request as well as to retrieve service states for a Layer 1 network controller communicating with its customer network 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 the provision of L1VPN services into three service models (not to be confused with YANG models): the management-based service model, the signaling-based service model (Basic Mode), and the 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 the L1CSM YANG model that is used for the instantiation of point-to-point L1 connectivity services, which 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 L1CSM specified in this document is generic, and provides support for the three different service models defined in [RFC4847].

The YANG data model defined in Section 3 is consistent with the Service Attributes defined in [MEF63], with the exception of the Service Level Specification Service Attributes which are outside the scope of this document.

This YANG model is NMDA-compliant.

1.1. Deployment Scenarios

Figure 1 depicts a deployment scenario of the L1CSM 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 |..............| PE |---:---| CE |
           +----+    :   +----+              +----+   :   +----+
                     :     |                    |     :
                     :     |                    |     :
                     :     +--------------------+     :
                     :     |                    |     :
                     :     |<-Provider network->|     :

                 Customer                          Customer
                 Interface                         Interface
```

Figure 1: L1CSM SDN Controller/EMS/NMS-Based Service Model:
External Customer

With this scenario, the customer service orchestrator interfaces with the network software-defined networking (SDN) controller of the provider using a Customer Service Model as defined in [RFC8309]. It is worth noting that in some scenarios, there can be a Network Management System (NMS) or Element Management System (EMS) performing the role of the SDN Controller.

Figure 2 depicts another deployment scenario for internal customer (e.g., higher-layer service management departments) 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 L1CSM service provides a different kind of higher-layer service. The customer receiving the L1CSM service (i.e., each service department) can offer its own services, whose payloads can be any layer (e.g., IP, OTN). The Layer 1 transport network and each service network belong to the same organization, but may be managed separately. The Service SDN Controller is the control/management entity owned by higher-layer service department (e.g., L2/3 VPN) whereas the Network SDN Controller is the control/management entity responsible for Layer 1 connectivity service. The CEs in Figure 2 are L2/3 devices that interface with L1 PE devices.

```
                                   +----------+
                                   | Service  |
                                   |   SDN    |
                                   |Controller|
                                   |/EMS/NMS  |
                                   | for L2/3 |
                                   +----------+
                                        |
                                        |
                                        |
                           +--------------------+
                           |                    |
                           |    +----------+    |
                           |    | Network  |    |
                           |    |   SDN    |    |
                           |    |Controller|    |
                           |    | /EMS/NMS |    |
                           |    | for L1CSM|    |
                           |    +----------+    |
                           |                    |
                           |                    |
           +----+        +----+              +----+      +----+
           | CE |--------| PE |..............| PE |------| CE |
           +----+        +----+              +----+      +----+
              |            |                    |          |
              |            |                    |          |
              |            +--------------------+          |
              |            |                    |          |
              |            |<------------------>|          |
              |               Provider Network             |
              |                  For Layer 1               |
              |<------------------------------------------>|
                             Provider Network for L2/3
```

Figure 2: L1CSM 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], [RFC5253] and [MEF63]for the key terms used in this document.

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

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

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

* configuration data
* state data

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

1.3. Tree Diagram

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

1.4. Prefixes in Data Node Names

In this document, names of data nodes and other data model objects are prefixed using the standard prefix associated with the corresponding YANG imported modules. The module ietf-layer1-types specified in [I-D.ietf-ccamp-layer1-types] is imported in this module.

Prefix	YANG module	Reference
l1csm	ietf-l1csm	[RFCXXXX]
l1-types	ietf-layer1-types	[RFCYYYY]

Table 1: Prefixes and Corresponding YANG Modules

Note: The RFC Editor will replace XXXX with the number assigned to the RFC once this document becomes an RFC. The RFC Editor will replace YYYY with the number assigned to the RFC once [I-D.ietf-ccamp-layer1-types] becomes an RFC.

1.5. Abbreviations

L1VC Layer 1 Virtual Connection

UNI User Network Interface

PE Provider Edge

CE Customer Edge

2. L1CSM YANG Model Overview

The L1CSM describes the Layer 1 connectivity services following the convention defined in [MEF63] which includes the description of User Network Interface (UNI) access characteristics and L1 virtual connection (L1VC) service characteristics:

```
       +--rw l1-connectivity
         +--rw access
         |  +--rw unis
         |     +--rw uni* [uni-id]
         |        +--rw uni-id    string
         |        .....................................
         +--rw services
            +--rw service* [service-id]
               +--rw service-id    string
               .........................................
```

The UNI access characteristics can be specified using either the definitions in [MEF63], which are based on the 3-tuple protocol, coding and optical-interface, or the definitions in [I-D.ietf-ccamp-layer1-types], which are based on the client signals in [ITU-T_G.709]:

```
       +--rw (uni-access-type)?
          +--:(mef)
          |  +--rw protocol              identityref
          |  +--rw coding                identityref
          |  +--rw optical-interface    identityref
          +--:(itu)
             +--rw client-signal        identityref
```

The L1VC service characteristics are described by references to a list of L1VC end points. For point-to-point connections, only two end points are allowed.

```
       +--rw endpoint* [endpoint-id]
          +--rw endpoint-id    string
          +--rw uni -> /l1-connectivity/access/unis/uni/uni-id
```

3. L1CSM YANG Model (Tree Structure)

```
module: ietf-l1csm
  +--rw l1-connectivity
     +--rw access
     |  +--rw unis
     |     +--rw uni* [uni-id]
     |        +--rw uni-id                     string
     |        +--rw (uni-access-type)?
     |           +--:(mef)
     |           |  +--rw protocol             identityref
     |           |  +--rw coding               identityref
     |           |  +--rw optical-interface    identityref
     |           +--:(itu)
     |              +--rw client-signal        identityref
     +--rw services
        +--rw service* [service-id]
           +--rw service-id    string
           +--rw endpoints
              +--rw endpoint* [endpoint-id]
                 +--rw endpoint-id    string
                 +--rw uni
                         -> /l1-connectivity/access/unis/uni/uni-id
```

4. L1CSM YANG Code

```
<CODE BEGINS>
file "ietf-l1csm@2023-02-01.yang"
module ietf-l1csm {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-l1csm";
  prefix "l1csm";

  import ietf-layer1-types {
    prefix "l1-types";
    reference
      "RFCYYYY: A YANG Data Model for Layer 1 Types";
  }
  // Note: The RFC Editor will replace XXXX/YYYY with the number
  // assigned to the RFCs once this draft becomes an RFC.

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

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

```
        Editor:  Young Lee
                 <mailto:younglee.tx@gmail.com>

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                 <mailto:kwangkoog.lee@kt.com>

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

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

        Editor:  Daniele Ceccarelli
                 <mailto:daniele.ietf@gmail.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.

        Copyright (c) 2023 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 Revised BSD License
        set forth in Section 4.c of the IETF Trust's Legal Provisions
        Relating to IETF Documents
        (https://trustee.ietf.org/license-info).

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

     revision "2023-02-01" {
       description
         "Initial revision.";
       reference
         "RFC XXXX: A Yang Data Model for L1 Connectivity Service Model
          (L1CSM)";
     }

     /*
      * Groupings
      */

     grouping protocol-coding-optical-interface {
       description
```

```
         "The 3-tuple <p,c,o> where p:protocol type;
          c:coding function; o:optical interface function.

          Valid combinations are defined in Tables 4, 5, 6 and 7
          of MEF 63.";
       reference
         "MEF63: Subscriber Layer 1 Service Attributes";

       leaf protocol {
         type identityref {
           base l1-types:protocol;
         }
         mandatory true;
         description
           "The protocol being used at the UNI.";
       }
       leaf coding {
         type identityref {
           base l1-types:coding-func;
         }
         mandatory true;
         description
           "The coding function being used at the UNI.";
       }
       leaf optical-interface {
         type identityref {
           base l1-types:optical-interface-func;
         }
         mandatory true;
         description
           "The optical interface function being used at the UNI.";
       }
     }

     grouping subscriber-l1vc-endpoint-attributes {
       description
         "Subscriber Layer 1 connection endpoint attributes";
       reference
         "MEF63: Subscriber Layer 1 Service Attributes";

       container endpoints {
         description
           "The container for the list of the subscriber L1VC end
           points";
         list endpoint {
           key "endpoint-id";
           min-elements 2;
           max-elements 2;
```

```
          description
            "The list of the two of the subscriber L1VC end points";
          leaf endpoint-id {
            type string;
            mandatory true;
            description
              "The subscriber L1VC end point ID";
          }
          leaf uni {
            type leafref {
              path "/l1-connectivity/access/unis/uni/uni-id";
            }
            mandatory true;
            description
              "The UNI supporting the subscriber L1VC end point";
          }
        }
      }
    }

    /*
     * Data nodes
     */

    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 UNIs to be configured";
          list uni {
            key "uni-id";
            description
              "UNI identifier";
            leaf uni-id {
              type string;
              description "The UNI ID of UNI Service Attributes";
            }
            choice uni-access-type {
              description
                "The UNI access type can be specified either by the
                 protocol, coding function and optical interface
                 function, defined in MEF, or by the client-signal,
                 defined in ITU-T.";
```

```
              case mef {
                uses protocol-coding-optical-interface;
              }
              case itu {
                leaf client-signal {
                  type identityref {
                    base l1-types:client-signal;
                  }
                  mandatory true;
                  description
                    "The client signal being used at the UNI";
                  reference
                    "ITU-T G.709 v6.0 (06/2020): Interfaces for the
                     Optical Transport Network (OTN)";
                }
              }
            }
          }
        }
      }
      container services {
        description
          "L1VC services";
        list service {
          key "service-id";
          description
            "A unique identifier of a subscriber L1VC service";
          leaf service-id {
            type string;
            description
              "A unique service identifier for subscriber L1VC.";
          }
          uses subscriber-l1vc-endpoint-attributes;
        } //end of service list
      } //end of service container
    } //service top container
  }
  <CODE ENDS>
```

5. Security Considerations

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

The Network Configuration Access Control Model (NACM) [RFC8341] provides the means to restrict access for particular NETCONF or RESTCONF users to a preconfigured subset of all available NETCONF or RESTCONF protocol operations and content.

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 negatively affect network operations and services. Nodes in this YANG module are susceptible to intentional (malicious) and unintentional (misconfiguration) configuration, adversely affecting the connection. The following data nodes and their entire subtrees are considered sensitive:

UNI:

- uni-id

Service:

- service-id

- endpoint-id

The IDs above identify a connection between the subscriber and service provider; they will be unique and may contain sensitive information such as customer information, service type, port information, and location. They must also be correctly configured to ensure the Subscriber and Service Provider connection is established. The security considerations spelled out in the YANG 1.1 specification [RFC7950] apply for this document as well.

6. IANA Considerations

This document registers the following URIs in the "ns" subregistry within the "IETF XML Registry" [RFC3688] as follows:

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

This document registers following YANG modules in the YANG Module Names registry [RFC6020].

```
name:         ietf-l1csm
namespace:    urn:ietf:params:xml:ns:yang:ietf-l1csm
prefix:       l1csm
reference:    RFC XXXX
```

7. Acknowledgements

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Appendix A. JSON Example

This section provides a JSON example of the YANG module described in Section 4. This example configures one L1VC service with two UNIs that describe the connection endpoints.

```
{
  "ietf-l1csm:l1-connectivity": {
    "access": {
      "unis": {
        "uni": [
          {
            "uni-id": "MTL-HQ-Node3-Slot2-Port1",
            "protocol": "ietf-layer1-types:Ethernet",
            "coding": "ietf-layer1-types:ETH-10GR",
            "optical-interface": "ietf-layer1-types:LR-PMD-10G"
          },
          {
            "uni-id": "MTL-STL-Node5-Slot4-Port3",
            "protocol": "ietf-layer1-types:Ethernet",
            "coding": "ietf-layer1-types:ETH-10GR",
            "optical-interface": "ietf-layer1-types:ER-PMD-10G"
          }
        ]
      }
    },
    "services": {
      "service": [
        {
          "service-id": "Sub-L1VC-1867-LT-MEGAMART",
          "endpoints": {
            "endpoint": [
              {
                "endpoint-id": "MTL-HQ_1867-MEGAMART",
                "uni": "MTL-HQ-Node3-Slot2-Port1"
              },
              {
                "endpoint-id": "MTL-STL_1867-MEGAMART",
                "uni": "MTL-STL-Node5-Slot4-Port3"
              }
            ]
          }
        }
      ]
    }
  }
}
```


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Common YANG Data Types for Layer 1 Networks
draft-ietf-ccamp-layer1-types-18

Abstract

This document defines a collection of common common data types, identities, and groupings in the YANG data modeling language. These derived common common data types, identities, and groupings are intended to be imported by modules that model Layer 1 configuration and state capabilities. The Layer 1 types are representative of Layer 1 client signals applicable to transport networks, such as Optical Transport Networks (OTN). The Optical Transport Network (OTN) data structures are included in this document as Layer 1 types.

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.

Status of This Memo

Table of Contents

1. Introduction

This document specifies common data types, groupings, and identities for use in YANG [RFC7950] data models of Layer 1 networks. The derived types and groupings apply to Traffic Engineered (TE) Layer 1 networks.

The Layer 1 (L1) Optical Transport Network (OTN) is specified in [RFC7062]. The corresponding routing and signaling protocols are specified in [RFC7138] and [RFC7139]. The types and groupings defined in this document are consistent with those documents, and can be imported into other Layer 1 data models, including but not limited to, [I-D.ietf-ccamp-otn-topo-yang], [I-D.ietf-ccamp-otn-tunnel-model], [I-D.ietf-ccamp-client-signal-yang] and [I-D.ietf-ccamp-l1csm-yang].

The document is consistent with other specifications, including [MEF63] for Layer 1 service attributes, [ITU-T_G.709] and [ITU-T_G.Sup43] for OTN data plane definitions.

The YANG data model in this document only defines groupings, typedef, and identities. It does not define any configuration or state data, as specified in the Network Management Datastore Architecture defined in [RFC8342].

2. Terminology and Notations

Specific terms used within this document are as follows:

OTN: Optical Transport Network.

ODU: Optical Data Unit. An ODU has the frame structure and overhead, as defined in Figure 12-1 of [ITU-T_G709]. ODUs can be formed in two ways: a) by encapsulating a single non-OTN client, such as SONET/SDH (Synchronous Optical Network / Synchronous Digital Hierarchy) or Ethernet, or b) by multiplexing lower-rate ODUs. In general, the ODU layer represents the path layer in OTN. The only exception is the ODUCn signal (defined below), which is defined to be a section-layer signal. In the classification based on bitrates of the ODU signals, ODUs are of two types: fixed rate and flexible rate. Flexible-rate ODUs, called "ODUflex", have a rate that is 239/238 times the bitrate of the client signal they encapsulate.

ODUCn: Optical Data Unit-C. This signal has a bandwidth of approximately 100 Gbit/s and is of a slightly higher bitrate than the fixed rate ODU4 signal. This signal has the format defined in Figure 12-1 of [ITU-T_G.709]. This signal represents the building block for constructing a higher-rate signal called "ODUCn".

ODUk: Optical Data Unit-k, where k is one of {0, 1, 2, 2e, 3, 4}. The term "ODUk" refers to an ODU whose bitrate is fully specified by the index k. The bitrates of the ODUk signal for k = {0, 1, 2, 2e, 3, 4} are approximately 1.25 Gbit/s, 2.5 Gbit/s, 10 Gbit/s, 10.3 Gbit/s, 40 Gbit/s, and 100 Gbit/s, respectively.

LO ODU: Lower Order ODU. The LO ODUj (j can be 0, 1, 2, 2e, 3, 4, or flex) represents the container transporting a client of the OTN that is either directly mapped into an OTUk (k = j) or multiplexed into a server HO ODUk (k > j) container.

HO ODU: Higher Order ODU. The HO ODUk (k can be 1, 2, 2e, 3, or 4) represents the entity transporting a multiplex of LO ODUj tributary signals in its OPUk area.

The reader may also refer to [RFC7062] and [RFC9376] for other key terms used in this document. The terminology for describing YANG data models can be found in [RFC7950].

3. Prefix in Data Node Names

In this document, the 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
rt-types	ietf-routing-types	[RFC8294]
l1-types	ietf-layer1-types	RFC XXXX

Table 1: Prefixes and Corresponding YANG Modules

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

4. Layer 1 Types Overview

4.1. Relationship with other Modules

This document defines one YANG module for common Layer 1 types. The aim is to specify common Layer 1 TE types (i.e., typedef, identity, grouping) that can be imported by layer 1 specific technology, for example, layer 1 OTN, in its technology-specific modules, such as topology and tunnels. It is worth noting that the generic traffic-engineering (TE) types module is specified as ietf-te-types in [I-D.ietf-teas-rfc8776-update], and both YANG modules, ietf-te-types and ietf-layer1-types, will need importing when the OTN is configured. Generic attributes such as te-bandwidth and te-label, which are specified as ietf-te-types in [I-D.ietf-teas-rfc8776-update], need to be augmented with the OTN-specific attributes, such as odu-type, which are specified as ietf-layer1-types in this document, when OTN is configured.

4.2. Content in Layer 1 Type Module

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

tributary-slot-granularity:

This specifies the granularity levels for tributary slots utilized by the server layer Optical Data Unit (ODU). Specifically, it addresses how ODU links, including both Higher Order Optical Data Unit-k (HO ODUk) and Optical Data Unit-Cn (ODUCn), accommodate client layer ODUs within Label Switched Paths (LSPs). These client layer ODUs could be Lower Order Optical Data Unit-j (LO ODUj) or ODUk, respectively. The specified granularity levels for these configurations are 1.25G, 2.5G, and 5G.

odu-type:

This specifies the type of ODUk LSP, including the types specified in [ITU-T_G.709] and [RFC7139].

Since, as described in [RFC7963], [ITU-T_G.Sup43] does not guarantee interoperability in the data plane for these containers, the type of ODUk LSPs defined in [ITU-T_G.Sup43] and [RFC7963] can be defined in vendor-specific YANG modules using the odu-type identity, defined in this document, as the base.

client-signal:

This specifies the common Layer 1 client signal types, including ETH [IEEE_802.3], STM-n [ITU-T_G.707], OC [ANSI_T1.105] and Fiber Channel [ANSI_INCITS_230]. The input was based on the G-PID types specified in [RFC7139].

otn-label-range-type:

The label range type of OTN is represented in one of two ways, tributary slots (TS) and tributary port number (TPN), as specified in [RFC7139]. Two representations are enumerated in the otn-label-range-type.

otn-link-bandwidth:

This grouping defines the link bandwidth information, usually as the number of ODUs that can be supported by the link for each ODU type: for example an OTN link with 100G bandwidth can support either 1xODU4, 10xODU2 or 80xODU0.

It is also used to represent the ODUflex resources available on a link, as described in Section 4.4.

This grouping could be used in the OTN topology model for link bandwidth representation. In general, all the bandwidth-related sections, which are defined in a generic module, e.g., using the groupings defined in [I-D.ietf-teas-rfc8776-update], need to be augmented with this grouping when used to represent the bandwidth of an OTN link.

otn-path-bandwidth:

This grouping defines the path bandwidth information, usually as the type of ODU (e.g., ODU0, ODU2, ODU4) being set up along the path.

In the case of ODUflex paths, more information about the bandwidth of the ODUflex needs to be provided, as described in Section 4.4.

This grouping could be used in the OTN topology model for path bandwidth representation as well as when setting up the OTN tunnel. In general, all the bandwidth-related sections, which are defined in a generic module, e.g., using the groupings defined in [I-D.ietf-teas-rfc8776-update], need to be augmented with this grouping when used to represent the bandwidth of an OTN tunnel or path.

otn-label-range-info:

This grouping is used to augment the label-restriction list, defined in [I-D.ietf-teas-rfc8776-update], with OTN technology-specific attributes, as defined in Section 4.3.

otn-label-start-end:

This grouping is used to augment the label-start and label-end containers within the label-restriction list, defined in [I-D.ietf-teas-rfc8776-update], with OTN technology-specific attributes, as defined in Section 4.3.

otn-label-step:

This grouping is used to augment the label-step container within the label-restriction list, defined in [I-D.ietf-teas-rfc8776-update], with OTN technology-specific attributes, as defined in Section 4.3.

otn-label-hop:

This grouping is used to augment the label-hop container, defined in [I-D.ietf-teas-rfc8776-update], with OTN technology-specific attributes, as defined in Section 4.3.

optical-interface-func:

The optical interface function is specified in [MEF63]. Identities that describe the functionality are specified to encode bits for transmission and to decode bits upon reception.

4.3. OTN Label and Label Range

As described in [RFC7139], the OTN label usually represents the Tributary Port Number (TPN) and the related set of Tributary Slots (TS) assigned to a client layer ODU LSP (LO ODUj or ODUk) on a given server layer ODU (HO-ODU or ODUCn, respectively) Link (e.g., ODU2 LSP over ODU3 Link). Some special OTN label values are also defined for an ODUk LSP being set up over an OTUk Link.

The same OTN label MUST be assigned to the same ODUk LSP at the two ends of an OTN Link.

As described in [RFC7139], TPN can be a number from 1 to 4095 and TS are numbered from 1 to 4095, although the actual maximum values depend on the type of server layer ODU. For example, a server layer ODU4 provides 80 tributary slots (numbered from 1 to 80), and the TPN values can be any number from 1 to 80.

The OTN Label Range specifies the available values for the Tributary Port Number (TPN) and Tributary Slots (TS) for setting up ODUk Label Switched Paths (LSPs) over an OTN Link, with priorities as defined in [RFC4203]. This range is established according to the guidelines in [RFC7139].

The OTN Label Range is defined by the label-restriction list, defined in [I-D.ietf-teas-rfc8776-update], which, for OTN, SHOULD be augmented using the otn-label-range-info grouping.

Each entry in the label-restriction list represents either the range of the available TPN values or the range of the available TS values: the range-type attribute in the otn-label-range-info grouping defines the type of range for each list entry.

Each entry of the label-restriction list, as defined in [I-D.ietf-teas-rfc8776-update], defines a label-start, a label-end, a label-step, and a range-bitmap. The label-start and label-end definitions for OTN SHOULD be augmented using the otn-label-start-end grouping. The label-step definition for OTN SHOULD be augmented using the otn-label-step grouping. It is expected that the otn-label-step will always be equal to its default value (i.e., 1), which is defined in [I-D.ietf-teas-rfc8776-update].

As described in [RFC7139], in some cases, the TPN assignment rules are flexible (e.g., ODU4 Link) while in other cases the TPN assignment rules are fixed (e.g., ODU1 Link). In the former case, both TPN and TS ranges are reported, while in the latter case, the TPN range is not reported which indicates that the TPN SHALL be set equal to the TS number assigned to the ODUk LSP.

As described in [RFC7139], in some cases, the TPN assignment rules depend on the TS Granularity (e.g., ODU2 or ODU3 Links). Different entries in the label-restriction list will report different TPN ranges for each TS granularity supported by the link, as indicated by the tsg attribute in the otn-label-range-info grouping.

As described in [RFC7139], in some cases the TPN ranges are different for different types of ODUk LSPs. For example, on an ODU2 Link with 1.25G TS granularity, the TPN range is 1-4 for ODU1 but 1-8 for ODU0 and ODUflex. Therefore, different entries in the label-restriction list will report different TPN ranges for a different set of ODUk types, as indicated by the odu-type-list in the otn-label-range-info grouping.

Appendix A provides some examples of how the TPN and TS label ranges described in Table 3 and Table 4 of [RFC7139] can be represented in YANG using the groupings defined in this document.

4.4. ODUflex

ODUflex is a type of ODU with a flexible bit rate which is configured when setting up an ODUflex LSP.

[ITU-T_G.709] defines six types of ODUflex: ODUflex(CBR), ODUflex(GFP), ODUflex(GFP,n,k), ODUflex(IMP), ODUflex(IMP,s), and ODUflex(FlexE-aware).

The main difference between these types of ODUflex is the formula used to calculate the nominal bit rate of the ODUflex, as described in Table 7-2 of [ITU-T_G.709]. A YANG choice has been defined to describe these cases:

```
+--rw (oduflex-type)?
   +--:(generic)
   |  +--rw nominal-bit-rate        union
   +--:(cbr)
   |  +--rw client-type             identityref
   +--:(gfp-n-k)
   |  +--rw gfp-n                   uint8
   |  +--rw gfp-k?                  l1-types:gfp-k
   +--:(flexe-client)
   |  +--rw flexe-client
   |          l1-types:flexe-client-rate
   +--:(flexe-aware)
   |  +--rw flexe-aware-n           uint16
   +--:(packet)
      +--rw opuflex-payload-rate    union
```

The OPUflex payload rate can be expressed either in a floating point notation or a scientific notation, as defined in [IEEE_754] and [ISO_IEC_9899_1999].

The 'generic' case has been added to allow the ODUflex nominal bit rate to be defined independently of the type of ODUflex. This could be useful for forward compatibility in the transit domain/nodes where the set up of ODUflex LSPs does not depend on the ODUflex type.

In order to simplify interoperability the 'generic' case SHOULD be used only when needed; the ODUflex type-specific case SHOULD be used whenever possible.

The 'cbr' case is used for Constant Bit Rate (CBR) client signals. The client-type indicates which CBR client signal is carried by the ODUflex and, implicitly, the client signal bit rate, which is then used to calculate the ODUflex(CBR) nominal bit rate as described in Table 7-2 of [ITU-T_G.709].

The 'gfp-n-k' case is used for GFP-F mapped client signals based on ODUk.ts and 'n' 1.25G tributary slots. 'gfp-k' defines the nominal bit-rate of the ODUk.ts which, together with the value of 'gfp-n', is used to calculate the ODUflex(GFP,n,k) nominal bit rate as described in Table 7-8 and Table L-7 of [ITU-T_G.709] . With a few exceptions, shown in Table L-7 of [ITU-T_G.709], the nominal bit-rate of the ODUk.ts could be inferred from the value of 'n', as shown in Table 7-8 of [ITU-T_G.709] and therefore the 'gfp-k' is optional.

The 'flexe-client' case is used for Idle Mapping Procedure (IMP) mapped FlexE client signals, The 'flexe-client' represents the type of FlexE client carried by the ODUflex which implicitly defines the value of 's' used to calculate the ODUflex(s) nominal bit rate as described in Table 7-2 of [ITU-T_G.709]. The '10G' and '40G' enumeration values are used for 10G and 40G FlexE clients to implicitly define the values of s=2 and s=8. For the 'n x 25G' FlexE Clients the value of 'n' is used to define the value of s=5 x n.

The 'flexe-aware' case is used for FlexE-aware client signals. The flexe-aware-n represents the value n (n = n1 + n2 + ... + np) which is used to calculate the ODUflex(FlexE-aware) nominal bit rate as described in Table 7-2 of [ITU-T_G.709].

The 'packet' case is used for both the GFP-F mapped client signals and the IMP mapped client signals. The opuflex-payload-rate is either the GFP-F encapsulated-packet client nominal bit rate or the 64b/66b encoded-packet client nominal bit rate. The calculation of ODUflex(GFP) nominal bit rate is defined in Section 12.2.5 of [ITU-T_G.709], and the calculation of ODUflex(IMP) nominal bit rate is defined in Section 12.2.6 of [ITU-T_G.709]. The same formula is used in both cases.

Sections 5.1 and 5.2 of [RFC7139] defines two rules to compute the number of tributary slots to be allocated to ODUflex(CBR) and ODUflex(GFP) LSPs when carried over a HO-ODUk link. According to Section 19.6 of [ITU-T_G.709], the rules in Section 5.2 apply only to ODUflex(GFP,n,k) while the rules defined in Section 5.1 apply to any other ODUflex type, including, but not limited, to ODUflex(CBR). Section 20.5 of [ITU-T_G.709] defines the rules for computing the number of tributary slots to be allocated to ODUflex LSPs when carried over an ODUCn link.

In order to compute the number of tributary slots required to set up an ODUflex LSP, or ODUflex LSPs, the type of Optical channel Data Tributary Unit (ODTU) is reported for the OTN Links or the OTN LTPs (Link Termination Points).

Following the [ITU-T_G.709] definitions, the rules defined for ODUflex(GFP,n,k) are used only when the 'gfp-n-k' case is used. In all the other cases, including the (generic) case, the rules defined for any other ODUflex type are used.

The number of available ODUs, defined for each ODUk type, including ODUflex, does not provide sufficient information to infer the OTN link bandwidth availability for ODUflex LSPs.

The OTN link bandwidth definitions for ODUflex LSPs also depend on the number of tributary slots (TS) and on the type of ODTU used to compute the number of TS required to set up an ODUflex LSP, according to the rules defined in Section 19.6 and Section 20.5 of [ITU-T_G.709], as described above.

Similarly, bandwidth constraints for ODUflex LSPs of the OTN connectivity matrix and of the OTN local link connectivity entries depend also on the number of tributary slots (TS) and on the type of ODTU used to compute the number of TS required to set up an ODUflex LSP along the underlay path, according to the rules defined in Section 19.6 and Section 20.5 of [ITU-T_G.709], as described above. For example, with reference to Figure 1 of [RFC7139], the connectivity matrix entry or the local link connectivity entry corresponding to the A-C underlay path, would report 2 Tributary Slots (TS) with ODTU4.ts ODTU type.

4.4.1. Resizable ODUflex

Resizable ODUflex is a special type of ODUflex that supports the procedures defined in [ITU-T_G.7044] for hitless resizing of the ODUflex nominal bit rate.

Two odu-type identities have been defined for ODUflex:

* The ODUflex identity, which is used with any type of non-resizable ODUflex, as defined in Table 7-2 of [ITU-T_G.709].

* The ODUflex-resizable identity, which is used only with resizable ODUflex(GFP,n,k).

These two identities are used to identify whether an ODUflex(GFP,n,k) LSP does or does not support the [ITU-T_G.7044] hitless resizing procedures. They also identify whether an OTN link only supports the set up of non-resizable ODUflex LSPs or also supports the set up of resizable ODUflex(GFP,n,k) LSP but with different capabilities (e.g., a lower number of LSPs).

5. YANG Tree for Layer1 Types

```
   module: ietf-layer1-types

     grouping otn-link-bandwidth:
       +-- otn-bandwidth
          +-- odulist* [odu-type]
             +-- odu-type?    identityref
             +-- number?      uint16
             +-- ts-number?   uint16
     grouping otn-path-bandwidth:
       +-- otn-bandwidth
          +-- odu-type?                        identityref
          +-- (oduflex-type)?
             +--:(generic)
             |  +-- nominal-bit-rate           union
             +--:(cbr)
             |  +-- client-type                identityref
             +--:(gfp-n-k)
             |  +-- gfp-n                      uint8
             |  +-- gfp-k?                     gfp-k
             +--:(flexe-client)
             |  +-- flexe-client               flexe-client-rate
             +--:(flexe-aware)
             |  +-- flexe-aware-n              uint16
             +--:(packet)
                +-- opuflex-payload-rate       union
     grouping otn-max-path-bandwidth:
       +-- otn-bandwidth
          +-- odu-type?        identityref
          +-- max-ts-number?   uint16
     grouping otn-label-range-info:
       +-- otn-label-range
          +-- range-type?      otn-label-range-type
          +-- tsg?             identityref
          +-- odu-type-list*   identityref
          +-- priority?        uint8
     grouping otn-label-start-end:
       +-- otn-label
          +-- tpn?   otn-tpn
          +-- ts?    otn-ts
     grouping otn-label-hop:
       +-- otn-label
          +-- tpn?       otn-tpn
          +-- tsg?       identityref
          +-- ts-list?   string
     grouping otn-label-step:
       +-- otn-label-step
```

```
          +-- tpn?   otn-tpn
          +-- ts?    otn-ts
```

6. YANG Code for Layer1 Types

```
   <CODE BEGINS>
   file "ietf-layer1-types@2024-02-22.yang"
   module ietf-layer1-types {
     yang-version 1.1;
     namespace "urn:ietf:params:xml:ns:yang:ietf-layer1-types";
     prefix "l1-types";

     import ietf-routing-types {
       prefix rt-types;
       reference
         "RFC 8294: Common YANG Data Types for the Routing Area";
     }

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

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

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

     description
       "This module defines Layer 1 YANG types. The model fully conforms
        to the Network Management Datastore Architecture (NMDA).

        Copyright (c) 2024 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 Revised BSD License
        set forth in Section 4.c of the IETF Trust's Legal Provisions
        Relating to IETF Documents
        (https://trustee.ietf.org/license-info).

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

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

     revision "2024-02-22" {
       description
         "Initial Version";
       reference
         "RFC XXXX: A YANG Data Model for Layer 1 Types";
       // RFC Editor: replace RFC XXXX with actual RFC number,
       // update date information and remove this note.
     }

     /*
      * Identities
      */

     identity tributary-slot-granularity {
       description
         "Tributary Slot Granularity (TSG).";
       reference
         "ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
          Transport Network (OTN)";
     }

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

       identity tsg-2.5G {
         base tributary-slot-granularity;
         description
           "2.5G tributary slot granularity.";
       }

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

     identity odu-type {
       description
         "Base identity from which specific Optical Data Unit (ODU)
```

```
         type is derived.";
       reference
         "RFC7139: GMPLS Signaling Extensions for Control of Evolving
          G.709 Optical Transport Networks

          ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
          Transport Network (OTN)";
     }

       identity ODU0 {
         base odu-type;
         description
           "ODU0 type (1.24Gb/s).";
         reference
           "RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)";
       }

       identity ODU1 {
         base odu-type;
         description
           "ODU1 type (2.49Gb/s).";
         reference
           "RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)";
       }

       identity ODU2 {
         base odu-type;
         description
           "ODU2 type (10.03Gb/s).";
         reference
           "RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)";
       }

       identity ODU2e {
         base odu-type;
         description
```

```
      "ODU2e type (10.39Gb/s).";
    reference
      "RFC7139: GMPLS Signaling Extensions for Control of Evolving
      G.709 Optical Transport Networks

      ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
      Transport Network (OTN)";
  }

  identity ODU3 {
    base odu-type;
    description
      "ODU3 type (40.31Gb/s).";
    reference
      "RFC7139: GMPLS Signaling Extensions for Control of Evolving
      G.709 Optical Transport Networks

      ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
      Transport Network (OTN)";
  }

  identity ODU4 {
    base odu-type;
    description
      "ODU4 type (104.79Gb/s).";
    reference
      "RFC7139: GMPLS Signaling Extensions for Control of Evolving
      G.709 Optical Transport Networks

      ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
      Transport Network (OTN)";
  }

  identity ODUflex {
    base odu-type;
    description
      "ODUflex type (flexible bit rate, not resizable).

      It could be used for any type of ODUflex, including
      ODUflex(CBR), ODUflex(GFP), ODUflex(GFP,n,k), ODUflex(IMP,s),
      ODUflex(IMP) and ODUflex(FlexE-aware).";
    reference
      "RFC7139: GMPLS Signaling Extensions for Control of Evolving
      G.709 Optical Transport Networks

      ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
      Transport Network (OTN)";
  }
```

```
       identity ODUflex-resizable {
         base odu-type;
         description
           "ODUflex protocol (flexible bit rate, resizable).

           It could be used only for ODUflex(GFP,n,k).";
         reference
           "RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)";
       }

     identity protocol {
       description
         "Base identity from which specific protocol is derived.";
       reference
         "MEF63: Subscriber Layer 1 Service Attributes";
     }

       identity Ethernet {
         base protocol;
         description
           "Ethernet protocol.";
         reference
           "MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity Fibre-Channel {
         base protocol;
         description
           "Fibre-Channel (FC) protocol.";
         reference
           "MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity SDH {
         base protocol;
         description
           "SDH protocol.";
         reference
           "MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity SONET {
         base protocol;
         description
```

```
           "SONET protocol.";
         reference
           "MEF63: Subscriber Layer 1 Service Attributes";
       }

     identity client-signal {
       description
         "Base identity from which specific Constant Bit Rate (CBR)
         client signal is derived";
     }

     identity coding-func {
       description
         "Base identity from which specific coding function
          is derived.";
       reference
         "MEF63: Subscriber Layer 1 Service Attributes";
     }

       identity ETH-1Gb {
         base client-signal;
         description
           "Client signal type of 1GbE.";
         reference
           "IEEE 802.3-2018, Clause 36: IEEE Standard for Ethernet

           RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)";
       }

       identity ETH-10Gb-LAN {
         base client-signal;
         description
           "Client signal type of ETH-10Gb-LAN (10.3 Gb/s).";
         reference
           "IEEE 802.3-2018, Clause 49: IEEE Standard for Ethernet

           RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)";
       }

       identity ETH-10Gb-WAN {
```

```
         base client-signal;
         description
           "Client signal type of ETH-10Gb-WAN (9.95 Gb/s).";
         reference
           "IEEE 802.3-2018, Clause 50: IEEE Standard for Ethernet

           RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)";
       }

       identity ETH-40Gb {
         base client-signal;
         description
           "Client signal type of 40GbE.";
         reference
           "IEEE 802.3-2018, Clause 82: IEEE Standard for Ethernet

           RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)";
       }

       identity ETH-100Gb {
         base client-signal;
         description
           "Client signal type of 100GbE.";
         reference
           "IEEE 802.3-2018, Clause 82: IEEE Standard for Ethernet

           RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)";
       }

       identity STM-1 {
         base client-signal;
         base coding-func;
         description
           "Client signal type of STM-1;
           STM-1 G.707 (N=1) coding function.";
         reference
```

```
           "ITU-T G.707 v7.0 (01/2007): Network node interface for the
           synchronous digital hierarchy (SDH)

           RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity STM-4 {
         base client-signal;
         base coding-func;
         description
           "Client signal type of STM-4;
           STM-4 G.707 (N=4) coding function.";
         reference
           "ITU-T G.707 v7.0 (01/2007): Network node interface for the
           synchronous digital hierarchy (SDH)

           RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity STM-16 {
         base client-signal;
         base coding-func;
         description
           "Client signal type of STM-16;
           STM-16 G.707 (N=16) coding function.";
         reference
           "ITU-T G.707 v7.0 (01/2007): Network node interface for the
           synchronous digital hierarchy (SDH)

           RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)

           MEF63: Subscriber Layer 1 Service Attributes";
```

```
       }

       identity STM-64 {
         base client-signal;
         base coding-func;
         description
           "Client signal type of STM-64;
           STM-64 G.707 (N=64) coding function.";
         reference
           "ITU-T G.707 v7.0 (01/2007): Network node interface for the
           synchronous digital hierarchy (SDH)

           RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity STM-256 {
         base client-signal;
         base coding-func;
         description
           "Client signal type of STM-256;
           STM-256 G.707 (N=256) coding function.";
         reference
           "ITU-T G.707 v7.0 (01/2007): Network node interface for the
           synchronous digital hierarchy (SDH)

           RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity OC-3 {
         base client-signal;
         base coding-func;
         description
           "Client signal type of OC3;
           OC-3 GR-253-CORE (N=3) coding function.";
         reference
           "ANSI T1.105-2001: Synchronous Optical Network (SONET)
```

```
            Basic Description including Multiplex Structure, Rates,
            and Formats

            MEF63: Subscriber Layer 1 Service Attributes";
        }

        identity OC-12 {
          base client-signal;
          base coding-func;
          description
            "Client signal type of OC12;
            OC-12 GR-253-CORE (N=12) coding function.";
          reference
            "ANSI T1.105-2001: Synchronous Optical Network (SONET)
            Basic Description including Multiplex Structure, Rates,
            and Formats

            MEF63: Subscriber Layer 1 Service Attributes";
        }

        identity OC-48 {
          base client-signal;
          base coding-func;
          description
            "Client signal type of OC48;
            OC-48 GR-253-CORE (N=48) coding function.";
          reference
            "ANSI T1.105-2001: Synchronous Optical Network (SONET)
            Basic Description including Multiplex Structure, Rates,
            and Formats

            MEF63: Subscriber Layer 1 Service Attributes";
        }

        identity OC-192 {
          base client-signal;
          base coding-func;
          description
            "Client signal type of OC192;
            OC-192 GR-253-CORE (N=192) coding function.";
          reference
            "ANSI T1.105-2001: Synchronous Optical Network (SONET)
            Basic Description including Multiplex Structure, Rates,
            and Formats

            MEF63: Subscriber Layer 1 Service Attributes";
        }
```

```
       identity OC-768 {
         base client-signal;
         base coding-func;
         description
           "Client signal type of OC768;
           OC-768 GR-253-CORE (N=768) coding function.";
         reference
           "ANSI T1.105-2001: Synchronous Optical Network (SONET)
           Basic Description including Multiplex Structure, Rates,
           and Formats

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity FC-100 {
         base client-signal;
         base coding-func;
         description
           "Client signal type of Fibre Channel FC-100;
           FC-100 FC-FS-2 (1.0625 Gb/s) coding function.";
         reference
           "ANSI INCITS 230-1994 R1999): Information Technology -
           Fibre Channel - Physical and Signaling Interface (FC-PH)

           RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity FC-200 {
         base client-signal;
         base coding-func;
         description
           "Client signal type of Fibre Channel FC-200;
           FC-200 FC-FS-2 (2.125 Gb/s) coding function.";
         reference
           "ANSI INCITS 230-1994 R1999): Information Technology -
           Fibre Channel - Physical and Signaling Interface (FC-PH)

           RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)
```

```
           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity FC-400 {
         base client-signal;
         base coding-func;
         description
           "Client signal type of Fibre Channel FC-400;
           FC-400 FC-FS-2 (4.250 Gb/s) coding function.";
         reference
           "ANSI INCITS 230-1994 R1999): Information Technology -
           Fibre Channel - Physical and Signaling Interface (FC-PH)

           RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity FC-800 {
         base client-signal;
         base coding-func;
         description
           "Client signal type of Fibre Channel FC-800;
           FC-800 FC-FS-2 (8.500 Gb/s) coding function.";
         reference
           "ANSI INCITS 230-1994 R1999): Information Technology -
           Fibre Channel - Physical and Signaling Interface (FC-PH)

           RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity FC-1200 {
         base client-signal;
         base coding-func;
         description
           "Client signal type of Fibre Channel FC-1200;
           FC-1200 FC-10GFC (10.51875 Gb/s) coding function.";
         reference
```

```
           "ANSI INCITS 230-1994 R1999): Information Technology -
           Fibre Channel - Physical and Signaling Interface (FC-PH)

           RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity FC-1600 {
         base client-signal;
         base coding-func;
         description
           "Client signal type of Fibre Channel FC-1600;
           FC-1600 FC-FS-3 (14.025 Gb/s) coding function.";
         reference
           "ANSI INCITS 230-1994 R1999): Information Technology -
           Fibre Channel - Physical and Signaling Interface (FC-PH)

           RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity FC-3200 {
         base client-signal;
         base coding-func;
         description
           "Client signal type of Fibre Channel FC-3200;
           FC-3200 FC-FS-4 (28.05 Gb/s) coding function.";
         reference
           "ANSI INCITS 230-1994 R1999): Information Technology -
           Fibre Channel - Physical and Signaling Interface (FC-PH)

           RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)

           MEF63: Subscriber Layer 1 Service Attributes";
```

```
       }

       identity ETH-1000X {
         base coding-func;
         description
           "1000BASE-X PCS clause 36 coding function.";
         reference
           "IEEE 802.3-2018, Clause 36: IEEE Standard for Ethernet

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity ETH-10GW {
         base coding-func;
         description
           "IEEE 802.3-2018, Clause 50: IEEE Standard for Ethernet

           10GBASE-W (WAN PHY) PCS clause 49 and WIS clause 50
           coding function.";
         reference
           "MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity ETH-10GR {
         base coding-func;
         description
           "10GBASE-R (LAN PHY) PCS clause 49 coding function.";
         reference
           "IEEE 802.3-2018, Clause 49: IEEE Standard for Ethernet

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity ETH-40GR {
         base coding-func;
         description
           "40GBASE-R PCS clause 82 coding function.";
         reference
           "IEEE 802.3-2018, Clause 82: IEEE Standard for Ethernet

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity ETH-100GR {
         base coding-func;
         description
           "100GBASE-R PCS clause 82 coding function.";
         reference
```

```
           "IEEE 802.3-2018, Clause 82: IEEE Standard for Ethernet

           MEF63: Subscriber Layer 1 Service Attributes";
       }

     identity optical-interface-func {
       description
         "Base identity from which optical-interface-function
          is derived.";
       reference
         "MEF63: Subscriber Layer 1 Service Attributes";
     }

       identity SX-PMD-1000 {
         base optical-interface-func;
         description
           "SX-PMD-clause-38 Optical Interface function for
           1000BASE-X PCS-36.";
         reference
           "IEEE 802.3-2018, Clause 38: IEEE Standard for Ethernet

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity LX-PMD-1000 {
         base optical-interface-func;
         description
           "LX-PMD-clause-38 Optical Interface function for
           1000BASE-X PCS-36.";
         reference
           "IEEE 802.3-2018, Clause 38: IEEE Standard for Ethernet

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity LX10-PMD-1000 {
         base optical-interface-func;
         description
           "LX10-PMD-clause-59 Optical Interface function for
           1000BASE-X PCS-36.";
         reference
           "IEEE 802.3-2018, Clause 59: IEEE Standard for Ethernet

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity BX10-PMD-1000 {
         base optical-interface-func;
```

```
         description
           "BX10-PMD-clause-59 Optical Interface function for
           1000BASE-X PCS-36.";
         reference
           "IEEE 802.3-2018, Clause 59: IEEE Standard for Ethernet

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity LW-PMD-10G {
         base optical-interface-func;
         description
           "LW-PMD-clause-52 Optical Interface function for
           10GBASE-W PCS-49-WIS-50.";
         reference
           "IEEE 802.3-2018, Clause 52: IEEE Standard for Ethernet

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity EW-PMD-10G {
         base optical-interface-func;
         description
           "EW-PMD-clause-52 Optical Interface function for
           10GBASE-W PCS-49-WIS-50.";
         reference
           "IEEE 802.3-2018, Clause 52: IEEE Standard for Ethernet

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity LR-PMD-10G {
         base optical-interface-func;
         description
           "LR-PMD-clause-52 Optical Interface function for
           10GBASE-R PCS-49.";
         reference
           "IEEE 802.3-2018, Clause 52: IEEE Standard for Ethernet

           MEF63: Subscriber Layer 1 Service Attributes";
       }

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

```
           "IEEE 802.3-2018, Clause 52: IEEE Standard for Ethernet

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity LR4-PMD-40G {
         base optical-interface-func;
         description
           "LR4-PMD-clause-87 Optical Interface function for
           40GBASE-R PCS-82.";
         reference
           "IEEE 802.3-2018, Clause 87: IEEE Standard for Ethernet

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity ER4-PMD-40G {
         base optical-interface-func;
         description
           "ER4-PMD-clause-87 Optical Interface function for
           40GBASE-R PCS-82.";
         reference
           "IEEE 802.3-2018, Clause 87: IEEE Standard for Ethernet

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity FR-PMD-40G {
         base optical-interface-func;
         description
           "FR-PMD-clause-89 Optical Interface function for
           40GBASE-R PCS-82.";
         reference
           "IEEE 802.3-2018, Clause 89: IEEE Standard for Ethernet

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity LR4-PMD-100G {
         base optical-interface-func;
         description
           "LR4-PMD-clause-88 Optical Interface function for
           100GBASE-R PCS-82.";
         reference
           "IEEE 802.3-2018, Clause 88: IEEE Standard for Ethernet

           MEF63: Subscriber Layer 1 Service Attributes";
       }
```

```
     identity ER4-PMD-100G {
       base optical-interface-func;
       description
         "ER4-PMD-clause-88 Optical Interface function for
         100GBASE-R PCS-82.";
       reference
         "IEEE 802.3-2018, Clause 88: IEEE Standard for Ethernet

         MEF63: Subscriber Layer 1 Service Attributes";
     }

   /*
    * Typedefs
    */

   typedef otn-tpn {
     type uint16 {
       range "1..4095";
     }
     description
       "Tributary Port Number (TPN) for OTN.";
     reference
       "RFC7139: GMPLS Signaling Extensions for Control of Evolving
        G.709 Optical Transport Networks.";
   }

   typedef otn-ts {
     type uint16 {
       range "1..4095";
     }
     description
       "Tributary Slot (TS) for OTN.";
     reference
       "RFC7139: GMPLS Signaling Extensions for Control of Evolving
        G.709 Optical Transport Networks.";
   }

   typedef otn-label-range-type {
     type enumeration {
       enum trib-slot {
         description
           "Defines a range of OTN tributary slots (TS).";
       }
       enum trib-port {
         description
           "Defines a range of OTN tributary ports (TPN).";
       }
     }
```

```
       description
         "Defines the type of OTN label range: TS or TPN.";
     }

     typedef gfp-k {
       type enumeration {
         enum 2 {
           description
             "The ODU2.ts rate (1,249,177.230 kbit/s) is used
              to compute the rate of an ODUflex(GFP,n,2).";
         }
         enum 3 {
           description
             "The ODU3.ts rate (1,254,470.354 kbit/s) is used
              to compute the rate of an ODUflex(GFP,n,3).";
         }
         enum 4 {
           description
             "The ODU4.ts rate (1,301,467.133 kbit/s) is used
              to compute the rate of an ODUflex(GFP,n,4).";
         }
       }
       description
         "The ODUk.ts used to compute the rate of an ODUflex(GFP,n,k).";
       reference
         "ITU-T G.709 v6.0 (06/2020), Table 7-8 and L.7: Interfaces for
          the Optical Transport Network (OTN)";
     }

     typedef flexe-client-rate {
       type union {
         type uint16;
         type enumeration {
           enum "10G" {
             description
               "Represents a 10G FlexE Client signal (s=2).";
           }
           enum "40G" {
             description
               "Represents a 40G FlexE Client signal (s=8).";
           }
         }
       }
       description
         "The FlexE Client signal rate (s x 5,156,250.000 kbit/s)
          used to compute the rate of an ODUflex(IMP, s).

          Valid values for s are s=2 (10G), s=4 (40G) and
```

```
          s=5 x n (n x 25G).

          In the first two cases an enumeration value
          (either 10G or 40G) is used, while in the latter case
          the value of n is used.";
       reference
         "ITU-T G.709 v6.0 (06/2020), Table 7-2: Interfaces for the
          Optical Transport Network (OTN)";
     }

     typedef odtu-flex-type {
       type enumeration {
         enum "2" {
           description
             "The ODTU2.ts ODTU type.";
         }
         enum "3" {
           description
             "The ODTU3.ts ODTU type.";
         }
         enum "4" {
           description
             "The ODTU4.ts ODTU type.";
         }
         enum "Cn" {
           description
             "The ODTUCn.ts ODTU type.";
         }
       }
       description
         "The type of Optical Data Tributary Unit (ODTU),
         whose nominal bitrate is used to compute the number of
         Tributary Slots (TS) required by an ODUflex LSP, according to
         the (19-1a) and (20-1a) formulas defined in G.709.";
       reference
         "ITU-T G.709 v6.0 (06/2020), Table 7-7, clause 19.6 and
         clause 20.5: Interfaces for the Optical Transport
         Network (OTN)";
     }

     typedef bandwidth-scientific-notation {
       type string {
         pattern
           '0(\.0?)?([eE](\+)?0?)?|'
         + '[1-9](\.[0-9]{0,6})?[eE](\+)?(9[0-6]|[1-8][0-9]|0?[0-9])?';
       }
       units "bps";
       description
```

```
         "Bandwidth values, expressed using the scientific notation
         in bits per second.

         The encoding format is the external decimal-significant
         character sequences specified in IEEE 754 and ISO/IEC 9899:1999
         for 32-bit decimal floating-point numbers:
         (-1)**(S) * 10**(Exponent) * (Significant),
         where Significant uses 7 digits.

         An implementation for this representation MAY use decimal32
         or binary32. The range of the Exponent is from -95 to +96
         for decimal32, and from -38 to +38 for binary32.
         As a bandwidth value, the format is restricted to be
         normalized, non-negative, and non-fraction:
         n.dddddde{+}dd, N.DDDDDDE{+}DD, 0e0 or 0E0,
         where 'd' and 'D' are decimal digits; 'n' and 'N' are
         non-zero decimal digits; 'e' and 'E' indicate a power of ten.
         Some examples are 0e0, 1e10, and 9.953e9.";
       reference
         "IEEE Std 754-2001: IEEE Standard for Floating-Point
         Arithmetic

         ISO/IEC 9899:1999: Information technology - Programming
         Languages - C";
     }

     /*
      * Groupings
      */

     grouping otn-link-bandwidth {
       description
         "Bandwidth attributes for OTN links.";
       container otn-bandwidth {
         description
           "Bandwidth attributes for OTN links.";
         list odulist {
           key "odu-type";
           description
             "OTN bandwidth definition";
           leaf odu-type {
             type identityref {
               base odu-type;
             }
             description "ODU type";
           }
           leaf number {
             type uint16;
```

```
             description "Number of ODUs.";
           }
           leaf ts-number {
             when 'derived-from-or-self(../odu-type,"ODUflex") or
                   derived-from-or-self(../odu-type,
                   "ODUflex-resizable")' {
               description
                 "Applicable when odu-type is ODUflex or
                 ODUflex-resizable.";
             }
             type uint16 {
               range "1..4095";
             }
             description
               "The number of Tributary Slots (TS) that
               could be used by all the ODUflex LSPs.";
           }
         }
       }
     }

     grouping otn-path-bandwidth {
       description
         "Bandwidth attributes for OTN paths.";
       container otn-bandwidth {
         description
           "Bandwidth attributes for OTN paths.";
         leaf odu-type {
           type identityref {
             base odu-type;
           }
           description "ODU type";
         }
         choice oduflex-type {
           when 'derived-from-or-self(./odu-type,"ODUflex") or
                 derived-from-or-self(./odu-type,
                 "ODUflex-resizable")' {
             description
               "Applicable when odu-type is ODUflex or
                ODUflex-resizable.";
           }
           description
             "Types of ODUflex used to compute the ODUflex
              nominal bit rate.";
           reference
             "ITU-T G.709 v6.0 (06/2020), Table 7-2: Interfaces for the
              Optical Transport Network (OTN)";
           case generic {
```

```
          leaf nominal-bit-rate {
            type union {
              type l1-types:bandwidth-scientific-notation;
              type rt-types:bandwidth-ieee-float32;
            }
            mandatory true;
            description
              "Nominal ODUflex bit rate.";
          }
        }
        case cbr {
          leaf client-type {
            type identityref {
              base client-signal;
            }
            mandatory true;
            description
              "The type of Constant Bit Rate (CBR) client signal
              of an ODUflex(CBR).";
          }
        }
        case gfp-n-k {
          leaf gfp-n {
            type uint8 {
              range "1..80";
            }
            mandatory true;
            description
              "The value of n for an ODUflex(GFP,n,k).";
            reference
              "ITU-T G.709 v6.0 (06/2020), Tables 7-8 and L.7:
               Interfaces for the Optical Transport Network (OTN)";
          }
          leaf gfp-k {
            type gfp-k;
            description
              "The value of k for an ODUflex(GFP,n,k).

               If omitted, it is calculated from the value of gfp-n
               as described in Table 7-8 of G.709.";
            reference
              "ITU-T G.709 v6.0 (06/2020), Tables 7-8 and L.7:
               Interfaces for the Optical Transport Network (OTN)";
          }
        }
        case flexe-client {
          leaf flexe-client {
            type flexe-client-rate;
```

```
              mandatory true;
              description
                "The rate of the FlexE-client for an ODUflex(IMP,s).";
            }
          }
          case flexe-aware {
            leaf flexe-aware-n {
              type uint16;
              mandatory true;
              description
                "The rate of FlexE-aware client signal
                 for ODUflex(FlexE-aware)";
            }
          }
          case packet {
            leaf opuflex-payload-rate {
              type union {
                type l1-types:bandwidth-scientific-notation;
                type rt-types:bandwidth-ieee-float32;
              }
              mandatory true;
              description
                "Either the GFP-F encapsulated packet client nominal
                 bit rate for an ODUflex(GFP) or the 64b/66b encoded
                 packet client nominal bit rate for an ODUflex(IMP).";
            }
          }
        }
      }
    }

    grouping otn-max-path-bandwidth {
      description
        "Maximum bandwidth attributes for OTN paths.";
      container otn-bandwidth {
        description
          "Maximum bandwidth attributes for OTN paths.";
        leaf odu-type {
          type identityref {
            base odu-type;
          }
          description "ODU type.";
        }
        leaf max-ts-number {
          when 'derived-from-or-self(../odu-type,"ODUflex") or
                derived-from-or-self(../odu-type,
                "ODUflex-resizable")' {
            description
```

```
              "Applicable when odu-type is ODUflex or
               ODUflex-resizable.";
          }
          type uint16 {
            range "1..4095";
          }
          description
            "The maximum number of Tributary Slots (TS) that could be
            used by an ODUflex LSP.";
        }
      }
    }

    grouping otn-label-range-info {
      description
        "Label range information for OTN.

         This grouping SHOULD be used together with the
         otn-label-start-end and otn-label-step groupings to provide
         OTN technology-specific label information to the models which
         use the label-restriction-info grouping defined in the module
         ietf-te-types.";
      container otn-label-range {
        description
          "Label range information for OTN.";
        leaf range-type {
          type otn-label-range-type;
          description "The type of range (e.g., TPN or TS)
            to which the label range applies";
        }
        leaf tsg {
          type identityref {
            base tributary-slot-granularity;
          }
          description
            "Tributary slot granularity (TSG) to which the label range
            applies.

            This leaf MUST be present when the range-type is TS.

            This leaf MAY be omitted when mapping an ODUk over an OTUk
            Link. In this case the range-type is tpn, with only one
            entry (ODUk), and the tpn range has only one value (1).";
          reference
            "ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
            Transport Network (OTN)";
        }
        leaf-list odu-type-list {
```

```
          type identityref {
            base odu-type;
          }
          description
            "List of ODU types to which the label range applies.

            An Empty odu-type-list means that the label range
            applies to all the supported ODU types.";
        }
        leaf priority {
          type uint8 {
            range 0..7;
          }
          description
            "Priority in Interface Switching Capability
            Descriptor (ISCD).";
          reference
            "RFC4203: OSPF Extensions in Support of Generalized
            Multi-Protocol Label Switching (GMPLS)";
        }
      }
    }

    grouping otn-label-start-end {
      description
        "The OTN label-start or label-end used to specify an OTN label
         range.

         This grouping is dependent on the range-type defined in the
         otn-label-range-info grouping.

         This grouping SHOULD be used together with the
         otn-label-range-info and otn-label-step groupings to provide
         OTN technology-specific label information to the models which
         use the label-restriction-info grouping defined in the module
         ietf-te-types.";
      container otn-label {
        description
          "Label start or label end for OTN.

          It is either a TPN or a TS depending on the OTN label range
          type specified in the 'range-type' leaf defined in the
          otn-label-range-info grouping.";
        leaf tpn {
          when "../../../../otn-label-range/range-type =
                'trib-port'" {
            description
              "Valid only when range-type represented by
```

```
               trib-port.";
           }
           type otn-tpn;
           description
             "Tributary Port Number (TPN).";
           reference
             "RFC7139: GMPLS Signaling Extensions for Control of
             Evolving G.709 Optical Transport Networks";
         }
         leaf ts {
           when "../../../../otn-label-range/range-type =
                 'trib-slot'" {
             description
               "Valid only when range-type represented by
               trib-slot.";
           }
           type otn-ts;
           description
             "Tributary Slot (TS) number.";
           reference
             "RFC7139: GMPLS Signaling Extensions for Control of
             Evolving G.709 Optical Transport Networks";
         }
       }
     }

     grouping otn-label-hop {
       description "OTN Label";
       reference
         "RFC7139, section 6: GMPLS Signaling Extensions for Control of
          Evolving G.709 Optical Transport Networks";
       container otn-label {
         description
           "Label hop for OTN.";
         leaf tpn {
           type otn-tpn;
           description
             "Tributary Port Number (TPN).";
           reference
             "RFC7139: GMPLS Signaling Extensions for Control of
             Evolving G.709 Optical Transport Networks";
         }
         leaf tsg {
           type identityref {
             base tributary-slot-granularity;
           }
           description "Tributary Slot Granularity (TSG).";
           reference
```

```
            "ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
            Transport Network (OTN)";
        }
        leaf ts-list {
          type string {
              pattern "([1-9][0-9]{0,3}(-[1-9][0-9]{0,3})?"
                    + "(,[1-9][0-9]{0,3}(-[1-9][0-9]{0,3})?)*)";
            }
          description
            "A list of available Tributary Slots (TS) ranging
            between 1 and 4095. If multiple values or
            ranges are given, they all MUST be disjoint
            and MUST be in ascending order.
            For example 1-20,25,50-1000.";
          reference
            "RFC 7139: GMPLS Signaling Extensions for Control
            of Evolving G.709 Optical Transport Networks";
        }
      }
    }

    grouping otn-label-step {
      description
        "Label step for OTN.

         This grouping is dependent on the range-type defined in the
         otn-label-range-info grouping.

         This grouping SHOULD be used together with the
         otn-label-range-info and otn-label-start-end groupings to
         provide OTN technology-specific label information to the
         models which use the label-restriction-info grouping defined
         in the module ietf-te-types.";
      container otn-label-step {
        description
          "Label step for OTN.

          It is either a TPN or a TS depending on the OTN label range
          type specified in the 'range-type' leaf defined in the
          otn-label-range-info grouping.";
        leaf tpn {
          when "../../../otn-label-range/range-type =
                'trib-port'" {
            description
              "Valid only when range-type represented by
              trib-port.";
          }
          type otn-tpn;
```

```
          description
            "Label step which represents possible increments for
            Tributary Port Number (TPN).";
          reference
            "RFC7139: GMPLS Signaling Extensions for Control of
            Evolving G.709 Optical Transport Networks";
        }
        leaf ts {
          when "../../../otn-label-range/range-type =
                'trib-slot'" {
            description
              "Valid only when range-type represented by
              trib-slot";
          }
          type otn-ts;
          description
            "Label step which represents possible increments for
            Tributary Slot (TS) number.";
          reference
            "RFC7139: GMPLS Signaling Extensions for Control of
            Evolving G.709 Optical Transport Networks";
        }
      }
    }
  }
  <CODE ENDS>
```

7. Security Considerations

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

If using secure channels, such as SSH for NETCONF or TLS for RESTCONF, an array of secure validation methods are availible. These methods range from public key and password authentication to host identity verification. It is strongly advised to not use options that require no authentication. However, it is important to acknowledge that not all authentication methods offer the same level of security. For instance, password-based authentication is notably susceptible to security threats such as phishing attacks and password reuse.

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

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

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

8. IANA Considerations

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

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

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

```
name:         ietf-layer1-types
namespace:    urn:ietf:params:xml:ns:yang:ietf-layer1-types
prefix:       l1-types
reference:    RFC XXXX
```

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

9. Acknowledgements

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Appendix A. Examples of OTN Label Ranges

This appendix provides some examples of how the TPN and TS label ranges described in Table 3 and Table 4 of [RFC7139] can be represented in YANG using the groupings defined in this document.

It also considers the OTUk links in addition to HO-ODUk links.

The JSON code examples provided in this appendix provides some embedded comments following the conventions in Section 3.2 of [I-D.ietf-ccamp-transport-nbi-app-statement] and have been folded using the tool in [RFC8792].

```
=============== NOTE: '\\' line wrapping per RFC 8792 ===============

{
  "// examples of label-restrictions for different OTN Links": [
    {
      "// example": "HO-ODU1 or OTU1 Link",
      "label-restrictions": {
        "label-restriction": [
          {
            "index ": 1,
            "// default restriction": "inclusive",
            "otn-label-range": {
              "range-type": "label-range-trib-port",
              "// not-present tsg": "",
              "odu-type-list": "[ ODU1 ]",
              "// default priority": 7
            },
            "// tpn-range": 1,
            "// comment": "Since no TS range and no TSG are reported\
\ for ODU1, the link is an OTU1 Link. TS allocation is not needed an\
\d TPN shall be set to '1' for mapping ODU1 over OTU1. This entry is\
\ not present if the OTN Link is an HO-ODU1 Link."
          },
          {
            "index ": 2,
            "// default restriction": "inclusive",
            "otn-label-range": {
              "range-type": "label-range-trib-slot",
              "tsg": "tsg-1.25G",
```

```
                "odu-type-list": "[ ODU0 ]",
                "// default priority": 7
              },
              "// ts-range": "1-2",
              "// comment": "Since no TPN range is reported for ODU0 w\
   \ith 1.25G TSG, the TPN allocation rule is fixed (TPN = TS#) for map\
   \ping LO-ODU0 over HO-ODU1 with 1.25G TSG. See Table 4 of [RFC7139]."
            }
          ]
        }
      },
      {
        "// example": "HO-ODU2 or OTU2 Link",
        "label-restrictions": {
          "label-restriction": [
            {
              "index ": 1,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-port",
                "// not-present tsg": "",
                "odu-type-list": "[ ODU2 ]",
                "// default priority": 7
              },
              "// tpn-range": 1,
              "// comment": "Since no TS range and no TSG are reported\
   \ for ODU2, the link is an OTU2 Link. TS allocation is not needed an\
   \d TPN shall be set to '1' for mapping ODU2 over OTU2. This entry is\
   \ not present if the OTN Link is an HO-ODU2 Link."
            },
            {
              "index ": 2,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-slot",
                "tsg": "tsg-1.25G",
                "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, OD\
   \U1 ]",
                "// default priority": 7
              },
              "// ts-range": "1-8"
            },
            {
              "index ": 3,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-port",
                "tsg": "tsg-1.25G ",
```

```
                  "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0 ]",
                  "// default priority": 7
                },
                "// tpn-range": "1-8",
                "// comment": "Since this TPN range is reported for ODUf\
   \lex and ODU0 with 1.25G TSG, the TPN assignment rule is flexible wi\
   \thin a common range for mapping LO-ODUflex and LO-ODU0 over HO-ODU2\
   \ with 1.25G TSG. See Table 4 of [RFC7139]."
              },
              {
                "index ": 4,
                "// default restriction": "inclusive",
                "otn-label-range": {
                  "range-type": "label-range-trib-port",
                  "tsg": "tsg-1.25G",
                  "odu-type-list": "[ ODU1 ]",
                  "// default priority": 7
                },
                "// tpn-range": "1-4",
                "// comment": "Since this TPN range is reported for ODU1\
   \ with 1.25G TSG, the TPN assignment rule is flexible within a commo\
   \n range for mapping LO-ODU1 over HO-ODU2 with 1.25G TSG. See Table \
   \4 of [RFC7139]."
              },
              {
                "index ": 5,
                "// default restriction": "inclusive",
                "otn-label-range": {
                  "range-type": "label-range-trib-slot",
                  "tsg": "tsg-2.5G",
                  "odu-type-list": "[ ODU1 ]",
                  "// default priority": 7
                },
                "// ts-range": "1-4",
                "// comment": "Since no TPN range is reported for ODU1 w\
   \ith 2.5G TSG, the TPN allocation rule is fixed (TPN = TS#) for mapp\
   \ing LO-ODU1 over HO-ODU2 with 2.5G TSG. See Table 3 of [RFC7139]."
              }
            ]
          }
        },
        {
          "// example": "HO-ODU3 or OTU3 Link",
          "label-restrictions": {
            "label-restriction": [
              {
                "index ": 1,
                "// default restriction": "inclusive",
```

```
              "otn-label-range": {
                "range-type": "label-range-trib-port",
                "// not-present tsg": "",
                "odu-type-list": "[ ODU3 ]",
                "// default priority": 7
              },
              "// tpn-range": 1,
              "// comment": "Since no TS range and no TSG are reported\
   \ for ODU3, the link is an OTU3 Link. TS allocation is not needed an\
   \d TPN shall be set to '1' for mapping ODU3 over OTU3. This entry is\
   \ not present if the OTN Link is an HO-ODU3 Link."
            },
            {
              "index ": 2,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-slot",
                "tsg": "tsg-1.25G",
                "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, OD\
   \U1, ODU2, ODU2e ]",
                "// default priority": 7
              },
              "// ts-range": "1-32"
            },
            {
              "index ": 3,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-port",
                "tsg": "tsg-1.25G",
                "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, OD\
   \U2e ]",
                "// default priority": 7
              },
              "// tpn-range": "1-32",
              "// comment": "Since this TPN range is reported for ODUf\
   \lex, ODU0 and ODU2e with 1.25G TSG, the TPN assignment rule is flex\
   \ible within a common range for mapping LO-ODUflex, LO-ODU0 and LO-O\
   \DU2e over HO-ODU3 with 1.25G TSG. See Table 4 of [RFC7139]."
            },
            {
              "index ": 4,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-port",
                "tsg": "tsg-1.25G",
                "odu-type-list": "[ ODU1 ]",
                "// default priority": 7
```

```
              },
              "// tpn-range": "1-16",
              "// comment": "Since this TPN range is reported for ODU1\
   \ with 1.25G TSG, the TPN assignment rule is flexible within a commo\
   \n range for mapping LO-ODU1 over HO-ODU3 with 1.25G TSG. See Table \
   \4 of [RFC7139]."
            },
            {
              "index ": 5,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-port",
                "tsg": "tsg-1.25G",
                "odu-type-list": "[ ODU2 ]",
                "// default priority": 7
              },
              "// tpn-range": "1-4",
              "// comment": "Since this TPN range is reported for ODU2\
   \ with 1.25G TSG, the TPN assignment rule is flexible within a commo\
   \n range for mapping LO-ODU2 over HO-ODU3 with 1.25G TSG. See Table \
   \4 of [RFC7139]."
            },
            {
              "index ": 6,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-slot",
                "tsg": "tsg-2.5G",
                "odu-type-list": "[ ODU1, ODU2 ]",
                "// default priority": 7
              },
              "// ts-range": "1-16"
            },
            {
              "index ": 7,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-port",
                "tsg": "tsg-2.5G ",
                "odu-type-list": "[ ODU2 ]",
                "// default priority": 7
              },
              "// tpn-range": "1-4",
              "// comment": "Since this TPN range is reported for ODU2\
   \ with 2.5G TSG, the TPN assignment rule is flexible within a common\
   \ range for mapping LO-ODU2 over HO-ODU3. Since no TPN range is repo\
   \rted for ODU1 with 2.5G TSG, the TPN allocation rule is fixed (TPN \
   \= TS#) for mapping LO-ODU1 over HO-ODU3 with 2.5G TSG. See Table 3 \
```

```
   \of [RFC7139]."
             }
           ]
         }
       },
       {
         "// example": "HO-ODU4 or OTU4 Link",
         "label-restrictions": {
           "label-restriction": [
             {
               "index ": 1,
               "// default restriction": "inclusive",
               "otn-label-range": {
                 "range-type": "label-range-trib-port",
                 "// not-present tsg": "",
                 "odu-type-list": "[ ODU4 ]",
                 "// default priority": 7
               },
               "// tpn-range": 1,
               "// comment": "Since no TS range and no TSG are reported\
   \ for ODU4, the link is an OTU4 Link. TS allocation is not needed an\
   \d TPN shall be set to '1' for mapping ODU4 over OTU4. This entry is\
   \ not present if the OTN Link is an HO-ODU4 Link."
             },
             {
               "index ": 2,
               "// default restriction": "inclusive",
               "otn-label-range": {
                 "range-type": "label-range-trib-slot",
                 "tsg": "tsg-1.25G",
                 "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, OD\
   \U1, ODU2, ODU2e, ODU3 ]",
                 "// default priority": 7
               },
               "// ts-range": "1-80"
             },
             {
               "index ": 3,
               "// default restriction": "inclusive",
               "otn-label-range": {
                 "range-type": "label-range-trib-port",
                 "tsg": "tsg-1.25G",
                 "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, OD\
   \U1, ODU2, ODU2e, ODU3 ]",
                 "// default priority": 7
               },
               "// tpn-range": "1-80",
               "// comment": "Since this TPN range is reported for any \
```

```
   \LO-ODUj with 1.25G TSG, the TPN assignment rule is flexible within \
   \a common range for mapping any LO-ODUj over HO-ODU4 with 1.25G TSG.\
   \ See Table 4 of [RFC7139]."
             }
           ]
         }
       },
       {
         "// example": "ODUC1 Link",
         "label-restrictions": {
           "label-restriction": [
             {
               "index ": 1,
               "// default restriction": "inclusive",
               "otn-label-range": {
                 "range-type": "label-range-trib-slot",
                 "tsg": "tsg-5G",
                 "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, OD\
   \U1, ODU2, ODU2e, ODU3, ODU4 ]",
                 "// default priority": 7
               },
               "// ts-range": "1-20",
               "// comment": "Since the TS range is specified for any O\
   \DUk, the OTN Link is an ODUCn Link."
             },
             {
               "index ": 2,
               "// default restriction": "inclusive",
               "otn-label-range": {
                 "range-type": "label-range-trib-port",
                 "tsg": "tsg-5G",
                 "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, OD\
   \U1, ODU2, ODU2e, ODU3, ODU4 ]",
                 "// default priority": 7
               },
               "// tpn-range": "1-10",
               "// comment": "Since this TPN range is reported for any \
   \ODUk with 5G TSG, the TPN assignment rule is flexible within a comm\
   \on range for mapping any ODUk over ODUCn with 5G TSG."
             }
           ]
         }
       }
     ]
   }
```


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                                                           13 February 2026

A YANG Data Model for Optical Impairment-aware Topology
draft-ietf-ccamp-optical-impairment-topology-yang-21

Abstract

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

This document provides a YANG data model for the impairment-aware Traffic Engineering topology (TE topology) in optical networks. It augments the technology agnostic YANG Data Model for TE topologies. The topology YANG model provides read-only topology data including optical impairments that can be used for example by a Path Computation Engine (PCE) for calculating an optically feasible path for a new connection before it is established through an optical network.

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This Internet-Draft will expire on 17 August 2026.

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Table of Contents

1. Introduction

In order to provision an optical connection (an optical path) through wavelength switched optical networks (WSONs) as defined in [RFC9094] 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.

An introduction to optical impairments and their impact on optical signals (degradation) is provided in [RFC6566].

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, that can be utilized by a Multi-Domain Service Coordinator (MDSC) to collect WSON or SSON impairment data from the Provisioning Network Controllers (PNCs) to enable impairment-aware optical path computation according to the ACTN Architecture [RFC8453]. The communication between controllers is done via a NETCONF [RFC6241] or a RESTCONF interface [RFC8040].

Optical data plane interoperability, particularly for optical transponders across multiple vendors, is a complex challenge that typically necessitates joint engineering regardless of control and management plane capabilities. However, the YANG data model defined in this document provides the essential optical impairment data required for impairment-aware path computation including optical transponder interoperability if it exists.

Optical data plane interoperability is outside the scope of this document.

This document augments the generic TE topology YANG model defined in [RFC8795].

The impairment-aware topology for a WSON/SSON network based on the YANG data model defined in this document is intended to be used for exposing the network topology including optical impairments. Therefore, the topology information that is typically provided by a PNC is assumed to be read-only data. This may change when the same impairment-aware topology model is used for other optical network use cases than exposing the network topology. For example, for a path computation engine, where topological elements could be added in the context of a what-if scenario analysis. This is outside of the scope of this document.

This document defines one YANG module: ietf-optical-impairment-topology (Section 3).

1.1. Terminology

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

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

* client

* server

* augment

* data model

* data node

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

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

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

The term WDM-TE-node refers to those parts of a WDM-node (physical device) that are modeled as a TE-node as defined in [RFC8795], which may include a ROADM and/or multiple local optical transponders (OTs). Hence, a WDM-TE-node might only contain OTs.

The term "WDM-TE-network" refers to a set of WDM-TE-nodes as defined above that are interconnected via TE-links carrying WDM signals. These TE-links may include optical amplifiers.

The term "add/drop TE-link" refers to a TE-link representing the media channel between a transceiver’s media port of a remote optical transponder (OT) and an add/drop port of the ROADM in the adjacent WDM-node. The add/drop TE-link typically carries a single optical tributary signal (OTSi, i.e., a modulated optical carrier, see Section 2.3.1).

The term "bundled add/drop TE-link" refers to the TE-link bundling concept as defined in [RFC8795]. Multiple component links, add/drop TE-links in this case, are bundled into a single bundled add/drop TE-Link.

In the context of this document, the term "layer 0" refers to the photonic layer or WDM layer network in the architecture of the optical transport network (OTN) as defined in ITU-T Recommendation

G.709 [G.709], ITU-T Recommendation G.872 [G.872], and ITU-T Recommendation G.807 [G.807] as opposed to the electrical switching layers of the OTN, which are typically referred to as layer 1 (L1). The term "layer 0" may also be used for other transport network technologies (e.g. copper-based, radio-based, or free space optics-based, etc.), which are outside the scope of this document.

The term "muxponder" is a short for "multiplexer-transponder" and refers to a device used in optical networking, especially in DWDM (Dense Wavelength Division Multiplexing) systems, to combine multiple client signals onto a single high-speed optical wavelength.

1.2. Tree Diagram

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

1.3. Prefixes in Data Node Names

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

Prefix	YANG module	Reference
oit	ietf-optical-impairment-topology	[RFCXXXX]
l0-types	ietf-layer0-types	[I-D.ietf-ccamp-rfc9093-bis]
nw	ietf-network	[RFC8345]
nt	ietf-network-topology	[RFC8345]
te-types	ietf-te-types	[I-D.ietf-teas-rfc8776-update]
tet	ietf-te-topology	[RFC8795]

Table 1: Prefixes and corresponding YANG modules

[Note to RFC editor: Please replace XXXX with the number assigned to the RFC once this draft becomes an RFC.]

1.4. Requirements Language

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

2. Scope of this document and Data Plane Reference Architecture

2.1. Scope of this document

The impairment-aware topology YANG model for optical networks defined in this document is a network model as defined in [RFC8969]. The topology model provides read-only network topology status information that is typically used for path computation during service provisioning when a new service is established on the network.

The model in this document does not provide device configuration capabilities. Where those capabilities are needed, a device model as defined in [RFC8969] can be used: [I-D.ietf-ccamp-dwdm-if-param-yang] defines a device model for Dense Wavelength Division Multiplexing (DWDM) interfaces.

2.2. Optical Transport Network Data Plane

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

Figure 1 shows the reference architecture.

```
     +-------------------+                      +-------------------+
     |     WDM-node 1    |                      |     WDM-node 2    |
     |                   |                      |                   |
     | PA  +-------+ BA  |         ILA          | PA  +-------+ BA  |
     | +-+ |       | +-+ |  _____  +--+  _____  | +-+ |       | +-+ |
   --|-| |-| ROADM |-| |-|-()____)-|  |-()____)-|-| |-| ROADM |-| |-|--
     | +-+ |       | +-+ |         +--+         | +-+ |       | +-+ |
     |     +-------+     | optical              |     +-------+     |
     |       | | |       |  fiber               |       | | |       |
     |       o o o       |                      |       o o o       |
     |    local          |                      |    local          |
     |    transponders   |                      |    transponders   |
     +-------------------+                      +-------------------+

                          OTS MCG        OTS MCG
                        <--------->    <--------->
                            OMS MCG = TE-link
                    <-------------------------------->
```

BA: Booster Amplifier (or egress amplifier)
PA: Pre-Amplifier (or ingress amplifier)
ILA: In-Line Amplifier
MCG: Media Channel Group [G.807]
OTS MCG: Optical Transmission Section MCG [G.807]
OMS MCG: Optical Multiplex Section MCG [G.807]

Figure 1: Reference Architecture for Optical Transport Network

BA (WDM-node 1) is the egress Amplifier and PA (WDM-node 2) is the ingress amplifier for the Optical Multiplex Section Media Channel Group (OMS MCG) [G.807] in the direction from left to right in Figure 1.

According to [G.807], clause 3.2.4, a Media Channel Group (MCG) represents "a unidirectional point-to-point management/control abstraction that represents a set of one or more media channels that are co-routed. A media channel group (MCG) is bounded by a pair of media ports."

2.3. OTS and OMS Media Channel Group

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

(i) between a WDM-TE-node's BA and the adjacent ILA,
(ii) between a pair of ILAs,
(iii) between an ILA and the adjacent WDM-TE-node's PA.

[G.807] defines an OMS MCG as "The topological relationship between the media port on a filter or coupler where a set of media channels are aggregated and the media port on a filter or coupler where one or more media channel is added to or removed from that aggregate. All of the media channels that are represented by the OMS MCG must be carried over the same serial concatenation of OTS MCGs and amplifiers."

An OMS MCG originates at the ROADM in the source WDM-node and terminates at the ROADM in the destination WDM-node traversing the Booster Amplifier (BA) and the Pre-Amplifier (PA) in the WDM-nodes as well as the In-Line Amplifiers (ILAs) between the two WDM-nodes.

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

An OMS MCG traverses a sequence of optical elements between the ROADM function of two adjacent WDM-nodes as depicted in Figure 1 where the OMS MCG is terminated. These elements can be in the transmit direction: a Booster Amplifier (BA), one or more fiber sections with in-line amplifiers (ILAs), and a Pre-Amplifier (PA). A concentrated loss element can be used to describe an insertion loss caused, for example, by a fiber connector along the sequence of optical elements.

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

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

A WDM TE-link is terminated on both ends by a link termination point (LTP) as defined in [RFC8795]. Links between WDM nodes in optical transport networks are typically bidirectional. Generally, they have different impairments in the two directions and hence they MUST be modeled as a pair of two unidirectional TE-links following the [RFC8795] modeling approach. Unlike TE-links, which are unidirectional, the LTPs on either end of the TE-link pair forming the bidirectional link, are bidirectional as described in [I-D.ietf-teas-te-topo-and-tunnel-modeling] and the pair of unidirectional links are connected to the same bidirectional LTP on either end of the link pair.

2.3.1. Optical Tributary Signal (OTSi)

The OTSi is defined in ITU-T Recommendation G.959.1, section 3.2.4 [G.959.1] as "Optical signal that is placed within a network media channel for transport across the optical network. This may consist of a single modulated optical carrier or a group of modulated optical carriers or subcarriers." The YANG model defined in Section 3 assumes that a single OTSi consists of a single modulated optical carrier. This single modulated optical carrier conveys digital information. Characteristics of the OTSi signal are modulation scheme (e.g. QPSK, 8-QAM, 16-QAM, etc.), baud rate (measure of the symbol rate), pulse shaping (e.g. raised cosine - complying with the Nyquist inter symbol interference criterion), etc.

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

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

The impairment-aware topology YANG model for optical networks in Section 3 defines the optical OTSi properties needed for impairment-aware path computation including the spectrum occupied by each OTSi signal. The model also defines a pointer (leafref) from the OTSi to the transceiver module terminating the OTSi signal.

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

2.3.2. Optical Tributary Signal Group (OTSiG)

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

All OTSiGs are described in the YANG model by augmenting the network and each OTSiG is uniquely identified by its otsi-group-id, which is unique within the network. Each OTSiG also contains a list of the OTSi signals belonging to the OTSiG.

```
                          OTSiG
       _________________________/\__________________________
      /                                                     \
                            m=7
- - - +--------------------------X--------------------------+ - - -
/ / / |                                                     | / / /
 / / /|      OTSi          OTSi          OTSi          OTSi |/ / /
/ / / |        ^             ^             ^             ^  | / / /
 / / /|        |             |             |             |  |/ / /
/ / / |        |             |             |             |  | / / /
 / / /|        |             |             |             |  |/ / /
 -4  -3  -2  -1   0   1   2   3   4   5   6   7   8   9  10  11  12
--+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---
                           n = 4

  X: indicates the center of the frequency slot
```

Figure 2: MC Example containing all 4 OTSi signals of an OTSiG

2.3.3. Media Channel (MC)

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

In this document, an end-to-end MC is defined as a type of MC, which is formed by the serial concatenation of all the MCs from source transceiver media ports to destination transceiver media ports. This end-to-end MC is defined across all the ROADM nodes along the end-to-end optical path with the same nominal central frequency n and frequency slot of width m, which represents the effective frequency slot of the end-to-end MC. An end-to-end MC can carry a single OTSi, or multiple OTSi signals belonging to the same OTSiG.

[G.807_Amd1] defines a "network media channel (NMC)" as "a type of media channel that is formed by the serial concatenation of all media channels between the media port of a modulator and the media port of a demodulator". The modulator and demodulator are integral functions of a transceiver and their media ports do not necessarily coincide with the media port of the transceiver, which is associated with the transceiver's physical optical port. Due to this difference, the end-to-end MC is used in this document based on the definition in the previous paragraph.

In Section 2.11, the term "end-to-end MC path" is used to describe the topological aspect of the end-to-end MC, i.e., the path through the media (see: [G.807_Amd1], section 7.1.2). This is in line with the TE path defined in [RFC8795], section 3.9, where the TE path is defined as "an ordered list of TE links and/or TE nodes on the TE topology graph" interconnecting a pair of tunnel termination points (TTPs).

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

     <----------------------- Media Channel ----------------------->

     X: indicates the center of the frequency slot
```

Figure 3: MC Example containing both OTSi signals of an OTSiG

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

2.3.4. Media Channel Group (MCG)

ITU-T [G.807] defines the Media Channel Group MCG as "A unidirectional point to point management/control abstraction that represents a set of one or more media channels that are co-routed." The YANG model in Section 3 assumes that the MCG is a logical grouping of one or more MCs that are used to carry all OTSi's belonging to the same OTSiG.

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

```
                                    MCG1 = {M1.1, M1.2}
           __________________________/\_________________________
          /                                                     \
                      M1.1                  M2          M1.2
           ____________/\____________  _____/\_____  ____/\_____
          /                          \/            \/           \
    - - - +---------------------------+-------------+-----------+ - - -
    / / / |                           | / / / / / / |           | / / /
     / / /|    OTSi    OTSi    OTSi   |/ / / / / / /|    OTSi   |/ / /
    / / / |     ^       ^       ^     | / / / / / / |     ^     | / / /
     / / /|     |       |       |     |/ / / / / / /|     |     |/ / /
    / / / |     |       |       |     | / / / / / / |     |     | / / /
     / / /|     |       |       |     |/ / / / / / /|     |     |/ / /
         -7    -4    -1 0 1 2 3 4 5 6 7 8    ...    14    17    20
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                        n=0                               n=17
                K1      K2      K3                        K4
```

Figure 4: MCG Example with 2 MCs

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

2.4. Optical Amplifiers

Optical amplifiers are used in WDM networks for amplifying the optical signal in the optical domain without any optical to electrical and electrical to optical conversion. Three major optical amplifier technologies are existing at the time of writing:

* Erbium Doped Fiber Amplifiers (EDFAs)
* Raman Amplifiers
* Semiconductor Optical Amplifiers (SOAs)

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

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

1. a passive fiber element accounting for the fiber loss only and not the resulting loss including the Raman gain

2. an amplifier element providing all optical amplifier properties (gain, tilt, etc.). On the OMS-link, the amplifier element is placed where the pump is located and the geolocation information also indicates the location of the pump.

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

ILAs may have a variable optical attenuator on the ingress side (in-voa attribute) allowing control of the input power of the WDM signal (OMS MCG) entering the gain stage of the ILA. It may also have a variable optical attenuator on the egress side, which allows control of the optical power of the WDM output signal (OMS MCG) of the ILA. The actual-gain attribute reflects the gain of the ILA gain stage and does not include the attenuation of the in-voa and/or out-voa.

To support the modeling of multi-band (e.g., C + L band) and multi-stage (cascaded) amplifiers as depicted in Figure 5, the OMS element that describes an optical amplifier may contain an unordered list of amplifier-elements. The position of the element is based on the following attributes:

* lower-frequency and upper-frequency describing the frequency band the set of amplifier-elements are operating in.

* stage-order describing the sequential order of the cascaded amplifier-elements for the frequency band.

The detailed representation of the amplifier stages is not always mandatory. Abstraction is allowed as long as the optical impairments of the multi-stage amplifier are modeled properly. For example, the detailed representation of the cascaded elements is needed in case the amplifier supports both amplification of the signal as well as the DGE function described in Section 2.5.

Multi-band amplifiers like the dual-band amplifier depicted in Figure 5 have a band-separating filter at the input and a band-combining multiplexer combining all the bands at the output. These filter and multiplexer functions are not modeled explicitly and their optical impairments are subsumed in the optical impairments of the amplifier components.

```
                 Dual-band, Multi-stage Amplifier with DGE
             +-----------------------------------------------+
             |                                               |
             |                         C BAND                |
             |                  lower/upper-frequency        |
             |                            |                  |
             |                +-----------+----------+       |
             |                |                      |       |
             |                  OA1      DGE      OA2        |
             |                  |\      +---+     |\         |
             |                  | \     |   |     | \        |
         --->o---+-------------->|  +----+   +-----+  +-->+---o--->
             |   |              | /     |   |     | /    |   |
             |   |              |/      +---+     |/     |   |
             |   | stage-order = 1        2        3     |   |
             |   |                                       |   |
             |   |                                       |   |
             |   | stage-order = 1        2        3     |   |
             |   |              |\      +---+     |\     |   |
             |   |              | \     |   |     | \    |   |
             |   +-------------->|  +----+   +-----+  +-->+   |
             |                  | /     |   |     | /        |
             |                  |/      +---+     |/         |
             |                  OA1      DGE      OA2        |
             |                |                       |      |
             |                +-----------+-----------+      |
             |                            |                  |
             |                  lower/upper-frequency        |
             |                         L BAND                |
             |                                               |
             +-----------------------------------------------+
```

Figure 5: Example of a Dual-band, Multi-stage Amplifier with DGE Functionality

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

2.5. Dynamic Gain Equalizers

A Dynamic Gain Equalizer (DGE) is optical equipment that is capable of adjusting the optical power on a per-channel basis in order to compensate the channel power variation as a result of variable gain or loss the DWDM signals experienced while propagating through the network. The channel power can be configured explicitly or in the form of power-spectral-density.

2.6. Transponders

A transponder is optical equipment that sends and receives the optical signal from a DWDM network. A transponder can have one or more transceiver modules. A transceiver represents a transmitter and its corresponding receiver (Tx/Rx pair) as defined in ITU-T Recommendation G.698.2 [G.698.2]. In addition to the transceiver, which is terminating an OTSi signal, a transponder typically provides additional layer 1 functionality such as, for example, aggregation (multiplexing) of client traffic from multiple input ports into a single OTSi signal, which is outside the scope of this document addressing optical layer 0 aspects of transponders.

The termination of an OTSi signal by a transceiver is modeled as a function of the tunnel termination point (TTP) as defined in [RFC8795]. Because optical transport services (TE tunnels) are typically bidirectional, a TTP is also modeled as a bidirectional entity like the LTP described in Section 2.3. Moreover, a TTP can terminate one or several OTSiG signals (tunnels) as described in [I-D.ietf-teas-te-topo-and-tunnel-modeling] and each OTSiG consists of one or multiple OTSi signals as described in Section 2.3.2. Therefore, a TTP can be associated with multiple transceivers.

A transponder is typically characterized by its data/symbol rate and the maximum distance the signal can travel. Other transponder properties are for example but are not limited to: carrier frequency range for the optical channel, output power per channel, measured input power, modulation scheme, Forward Error Correction (FEC), etc.

From a path computation perspective, the selection of the compatible configuration of the source and the destination transceivers is an important factor for optical signals to traverse through the DWDM network.

The YANG model defines three different approaches to describe the transceiver capabilities (called "modes") that are needed to determine optical signal compatibility:

* Standard Modes

* Organizational Modes

* Explicit Modes

2.6.1. Standard Modes

A standard mode is related to an optical specification developed by a Standards Development Organization (SDO). Currently, the "Standard Modes" can only be referred to ITU-T Recommendation G.698.2 [G.698.2] since ITU-T Recommendation G.698.2 is the only standard defining "Standard Modes" today. Nothing is precluding, however, consideration of other specifications provided by any other SDO in the Standard Mode context as soon as such specifications might be available. An application code as defined in ITU-T G.698.2 [G.698.2] represents a standard ITU-T G.698.2 optical interface specification towards the realization of transversely compatible DWDM systems that it is a standard that ensures transceivers from different vendors can work together in a DWDM network. Two transceivers supporting the same application code and a line system matching the constraints, defined in ITU-T G.698.2, for that application code will interoperate. As the characteristics are encoded in the application code, the YANG model in this document only defines a string, which represents that application code.

For the standard modes, some additional attributes are defined. The most important one is the line-coding-bitrate attribute, which was added because [G.698.2] lists 100gpbs application codes supporting two data formats, an OTU4 related data format and a Flex-O related data format. The supported data formats for an application code can be described by listing the supported data formats via the line-coding-bitrate attribute as a transceiver capability.

Moreover, the transceiver properties like optical carrier frequency range, optical carrier tunability, and transmitter/receiver optical power ranges can be described as optional attributes in case they differ from the specification for the standard mode, i.e., as defined in [G.698.2]. A transceiver may support extended optical frequency ranges or optical power ranges or a finer optical carrier tunability. These capabilities can be described explicitly if needed.

2.6.2. Organizational Modes

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

An organizational mode is identified by the organization-identifier attribute defining the scope and an operational-mode that is meaningful within the scope of the organization. Hence, the two attributes MUST always be considered together. It is the responsibility of the organization to assign operational modes and to ensure that operational modes are unique and unambiguous within the scope of the organization.

Two transceivers can be interconnected, if they have at least one (organization-identifier, operational-mode) pair in common and if the supported carrier frequency and power attributes have a matching range. This is a necessary condition for path computation in the context of organizational modes.

An operational mode is a transceiver preset (a configuration with well-defined parameter values) subsuming several transceiver properties defined by the optical interface specification - these properties are not provided for an operational mode and are therefore not defined in the YANG model. Examples of these properties are:

* FEC type

* Modulation scheme

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

* Baud rate (symbol rate)

* Carrier bandwidth (typically measured in GHz)

The major reason for these transceiver presets is the fact that the attribute values typically cannot be configured independently and are therefore advertised as supported operational mode capabilities. It is the responsibility of the organization to assign operational modes and to ensure that operational modes are unique and not ambiguous within the scope of the organization.

In addition to the transceiver properties subsumed by the operational mode, optical power and carrier frequency related properties are modeled separately, i.e., outside of the operational mode. This modeling approach allows transponders using different transceiver variants (e.g. optical modules) with slightly different power and/or frequency range properties to interoperate without defining separate operational modes. Different optical modules (pluggables) from different suppliers typically have slightly different input and output power ranges or may have slightly different carrier frequency tuning ranges.

The received channel power and the received total power are two parameters that can be measured by the receiver and can be provided by the transceiver in order to allow a controller to determine the expected performance of the end-to-end service taking into account the optical impairments along the path.

An organization MAY define the operational modes to include the optical power and carrier frequency related properties following the application code approach as defined in ITU-T Recommendation G.698.2 [G.698.2]. In such a case, the explicit optical power and carrier frequency related optional attributes should be omitted in order to avoid redundant information in the description of the transceiver capabilities. If these attributes are provided in addition to the operational modes including these attribute values implicitly, the parameter values provided explicitly replace the implicit values and take precedence. This should, however, only be done in exceptional cases and should be avoided whenever possible. In case an implicitly given range is extended utilizing the explicit optional attributes, a path computation policy rule may be applied to select a value preferably from the range defined implicitly and to only select a value from the extended range if no path can be found for values in the implicitly defined range. Path computation policy is outside the scope of this topology YANG model.

In summary, the optical power and carrier frequency related attributes shall either be described implicitly by the operational mode following the definition provided by that organization or shall be described explicitly when the optical power and carrier frequency related properties are not included in the operational mode definition.

2.6.3. Explicit Modes

The explicit mode allows the encoding, explicitly, of any subset of parameters e.g., FEC type, Modulation type, etc., to enable a controller entity to check for interoperability by means outside of this document. It shall be noted that using the explicit encoding does not guarantee interoperability between two transceivers even in case of identical parameter definitions. The explicit mode shall therefore be used with care, but it could be useful when no common Application Codes or Organizational Modes exist or the constraints of common Application Codes or Organizational Modes cannot be met by the line system.

2.6.4. Transponder Capabilities and Current Configuration

The YANG model described in Section 3 defines the optical transceiver properties. They are divided between:

a. Optical transceiver capabilities, describing how it can be configured

b. Current transceiver setting, indicating how it is currently configured

The transceiver capabilities are described by the set of modes the transceiver is supporting. Each mode must follow only one of the three mode options defined in Section 2.6.1, Section 2.6.2, and Section 2.6.3 (choice in the YANG model). The YANG model allows the description of the transceiver capabilities by mixing different modes. A transceiver may support some ITU-T application codes and in addition some organizational or explicit modes.

A transceiver mode description comprises the following properties:

* Supported transmitter tuning range with min/max nominal carrier frequency [f_tx_min, f_tx_max]

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

* Supported transmitter power range [p_tx-min, p_tx_max]

* Supported receiver channel power range [p_rx-min, p_rx_max]

* Supported maximum total power, rx power for all channels fed into the receiver

These optical transceiver properties are explicitly defined in the model for explicit and organizational modes, while they are implicitly defined for the application codes (see ITU-T G698.2 [G.698.2]).

The set of optical impairment limits, e.g., min optical signal to noise ratio (OSNR), max polarization mode dispersion (PMD),max chromatic dispersion (CD), max polarization dependent loss (PDL), quality factor (Q-factor) limit, are explicitly defined for the explicit modes while they are defined implicitly for the application codes and organizational modes.

The model provides information about the maximum accumulated impairments supported by the transceiver modes (i.e., max-chromatic-dispersion, max-polarization-dependent-loss, max-polarization-mode-dispersion, max-diff-group-delay). For CD, PMD and PDL impairments, the model also supports the option to provide more detailed OSNR penalties as a function of the accumulated impairments (i.e., cd-penalty, pmd-penalty and pdl-penalty). In this case the attributes providing the maximum accumulated impairments MAY be omitted and the maximum accumulated impairment MUST be listed in the penalty list. In case both are present, there MUST NOT be any value in the penalty list above the maximum accumulated impairment.

It is possible that the set of parameter values defined for an explicit mode may also be represented in form of an organizational mode or one or more application codes. The "compatible-modes" container may provide two different lists with pointers to application codes and organizational modes, respectively.

The current transponder configuration describes the properties of the OTSi transmitted or received by the transceiver attached to a specific transponder port.

Each OTSi has the following three pointer attributes modeled as leafrefs:

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

* Pointer to the transceiver instance terminating the OTSi

* Pointer to the currently configured transceiver mode

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

* current carrier-frequency

* currently transmitted channel power

* currently received channel power

* currently received total power

2.7. 3R Regenerators

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

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

3R regenerators are usually realized by a pair of optical transponders, which are described in Section 2.6. If a pair of optical transponders is used to perform a 3R regeneratator function, two different configurations are possible involving the pair of optical transceivers of the two optical transponders:

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

```
               Optical Transponder 1         Optical Transponder 2
             +------------------------+    +------------------------+
             | Transceiver            |    |            Transceiver |
             |-------------+   +------|    |------+   +-------------|
         --->| Receiver    |---|Sig.  |--->|Sig.  |---| Transmitter |--->
             |-------------+   |      |    |      |   +-------------|
         <---| Transmitter |---|Proc. |<---|Proc. |---|    Receiver |<---
             |-------------+   +------|    |------+   +-------------|
             |                        |    |                        |
             +------------------------+    +------------------------+

             Sig. Proc. = Signal Processing
```

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

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

  Implementations MAY support the change of the carrier frequency where the receiver may operate at a different optical frequency than the transmitter. The transceiver mode is a property of the transceiver and is applied to the transmitter and the receiver. Therefore, the transceiver mode is the same for the two segments on the two sides of the 3R regeneratator realized by two transceivers operated in the uni-directional mode.

```
            Optical Transponder 1
            3R in forward direction
        +-----------------------------+
        | Transceiver                 |
        |-------------+   +---------+ |
------->| Receiver    |---|Sig. --+ | |
        |-------------+   |       | | |
    +---| Transmitter |---|Proc.<-+ | |
    |   |-------------+   +---------+ |
    |   |                             |
    |   +-----------------------------+
    |
    +----------------------------------------->

<-----------------------------------------+
                                          |
        +-----------------------------+   |
        |                 Transceiver |   |
        | +---------+   +-------------|   |
        | | +->Sig. |---| Transmitter |---+
        | | |       |   +-------------|
        | | +--Proc.|---| Receiver    |<-------
        | +---------+   +-------------|
        |                             |
        +-----------------------------+
            Optical Transponder 2
            3R in backward direction

        Sig. Proc. = Signal Processing
```

Figure 7: Cross-3R Regenerator Example

Since 3R regenerators are composed of an optical transponder pair, the capability that an optical transponder can be used as a 3R regenerator is added to the transponder capabilities. Hence, no additional entity is required for describing 3R regenerators in the TE-topology YANG model. The optical transponder capabilities regarding the 3R regenerator function are described by the following two YANG model attributes:

* supported-termination-type

* supported-3r-mode

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

2.8. Wavelength Selective Switch (WSS)/Filter

A WSS is a device that dynamically routes individual wavelengths from a common input fiber to any of several output ports without converting them into electrical signals. The WSS/Filter is internal to a ROADM device. This document does not model the internals of a ROADM's WSS.

2.9. Optical Fiber

There are various optical fiber types defined by ITU-T. For optical feasibility calculation, several fiber-level parameters need to be taken into account, such as, fiber-type, length, loss coefficient, PMD, connectors (in/out).

The loss of a fiber span can be described in two ways:

i. As calculated loss using the provided loss coefficient (loss-coef) and length of the fiber.

ii. As measured loss provided by the total-loss attribute.

The total-loss SHOULD be provided when it can be measured with a power measurement facility at the output of the upstream node (input of the fiber span) and a power measurement facility at the input of the downstream node (output of the fiber span). This measured loss typically differs from the calculated loss because it includes all loss contributions including possible accumulated loss due to imperfect fiber splices and connector losses. It can also change over time due to changing fiber conditions, e.g., in case of a fiber cut. In case the total-loss cannot be measured (no power measurement facilities in place), the total-loss defined as optional leaf in the YANG model SHALL be omitted.

N.B.: In case of Raman amplifiers, the Raman gain SHALL NOT be included in the measured loss to properly reflect only the loss of the fiber span in the total-loss attribute.

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

2.10. WDM-node Architectures

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

* Integrated WDM-node architecture with local optical transponders

* Integrated WDM-node architecture with local optical transponders and single channel add/drop ports for remote optical transponders

* Disaggregated WDM-node architecture where the WDM-TE-node is composed of degree, add/drop, and optical transponder subsystems handled as separate WDM-nodes

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

The different WDM-node architectures are briefly described and illustrated in the following subsections.

2.10.1. Integrated WDM-node Architecture with Local Optical Transponders

Figure 1 and Figure 8 below show the typical architecture of an integrated WDM-node, which contains the optical transponders as an integral part of the WDM-node. Such an integrated WDM-node provides DWDM interfaces as external interfaces for interconnecting the device with its neighboring WDM-node (see OMS MCG in Figure 1). The number of these interfaces denote also the degree of the WDM-node. A degree 3 WDM-node for example has 3 DWDM links that interconnect the WDM-node with 3 neighboring WDM-nodes. Additionally, the WDM-node provides client interfaces for interconnecting the WDM-node with client devices such as IP routers or Ethernet switches. These client interfaces are the client interfaces of the integrated optical transponders.

```
                    . . . . . . . . . . . . . . . . . .
                    .           WDM-TE-node           .
              +-----.-------------------------------- .-----+
              |     .             WDM-node            .     |
              |     .   /|  +-----------------+  |\   .     |
         Line |     .  / |--|                 |--| \  .     | Line
         WEST |  /| . |  |--|                 |--|  | . |\  | EAST
        ------+-/ |-.-|  |--|  photonic       |--|  |-.-| \-+-----
        ------+-\ |-.-|  |--|  cross-connect  |--|  |-.-| /-+-----
              |  \| . |  |--|                 |--|  | . |/  |
              |     .  \ |--|                 |--| /  .     |
              |     .   \|  +-----------------+  |/   .     |
              |     .                                 .     |
              |     .     +---+ +---+ +---+ +---+     .     |
              |     .     | O | | O | | O | | O |     .     |
              |     .     | T | | T | | T | | T |     .     |
              |     .     +---+ +---+ +---+ +---+     .     |
              |     .      | |   | |   | |   | |      .     |
              +-----.------+-+---+-+---+-+---+-+------.-----+
                    . . . .|.| . |.| . |.| . |.|. . . .
                           | |   | |   | |   | |
                             Client Interfaces
```

Figure 8: Integrated WDM-node Architecture with Local Transponders

2.10.2. Integrated WDM-node with Integrated Optical Transponders and Single Channel Add/Drop Interfaces for Remote Optical Transponders

Figure 9 below shows the extreme case where all optical transponders are not integral parts of the WDM-node but are separate devices that are connected to the add/drop ports of the WDM-node. If the optical transponders and the WDM-node are co-located and if short single channel fiber links are used to interconnect the optical transponders with an add/drop port of the WDM-node, the optical domain controller MAY present these optical transponders in the same way as local optical transponders. If, however, the optical impairments of the single channel fiber link between the optical transponder and the add/drop port of the WDM-node cannot be neglected, it is necessary to represent the fiber link with its optical impairments in the topology model. This also implies that the optical transponders belong to a separate TE-node.

Appendix C provides a modeling example for a configuration where the optical transponders and the ROADM are different WDM-TE-nodes (remote OT configuration).

```
                    . . . . . . . . . . . . . . . . . .
                    .           WDM-TE-node           .
              +-----.-------------------------------- .-----+
              |     .            WDM-node             .     |
              |     .   /|  +-----------------+  |\   .     |
         Line |     .  / |--|                 |--| \  .     | Line
         WEST |  /| . |  |--|                 |--|  | . |\  | EAST
        ------+-/ |-.-|  |--|  photonic       |--|  |-.-| \-+-----
        ------+-\ |-.-|  |--|  cross-connect  |--|  |-.-| /-+-----
              |  \| . |  |--|                 |--|  | . |/  |
              |     .  \ |--|                 |--| /  .     |
              |     .   \|  +-----------------+  |/   .     |
              +-----.---------|----|---|----|---------.-----+
           OT       .       +-+   ++   ++   +-+       .
           line I/F .       |     |     |     |       .
                    .     +---+ +---+ +---+ +---+     .
                    .     | O | | O | | O | | O |     .
                    .     | T | | T | | T | | T |     .
                    .     +---+ +---+ +---+ +---+     .
                    . . . .|.| . |.| . |.| . |.|. . . .
                           | |   | |   | |   | |
                             Client Interfaces
```

Figure 9: Integrated WDM-node Architecture with Remote Transponders

2.10.3. Disaggregated WDM-TE-node Subdivided into Degree, Add/Drop, and Optical Transponder Subsystems

Some DWDM network operators are demanding WDM subsystems from their vendors. An example is the OpenROADM project [OpenROADM] where multiple operators and vendors are developing related YANG models. The subsystems of a disaggregated WDM-TE-node are:

* Single degree subsystems

* Add/drop subsystems

* Optical transponder subsystems

These subsystems are separate network elements and each network element provides a separate management and control interface. The subsystems are typically interconnected using short fiber patch cables and form together a disaggregated WDM-TE-node. This disaggregated WDM-TE-node architecture is depicted in Figure 10 below.

As this document defines TE topology YANG model augmentations for the TE topology YANG model [RFC8795] provided at the north-bound interface of the optical domain controller, it is a valid assumption that the optical domain controller abstracts the subsystems of a disaggregated WDM-TE-node and presents the disaggregated WDM-TE-node in the same way as an integrated WDM-node hiding all the interconnects that are not relevant from an external TE topology view.

```
           . . . . . . . . . . . . . . . . .  .
           .            WDM-TE-node           .
     +-----.----------+            +----------.-----+
     | Degree 1       |            |       Degree 2 |
Line |     .  +-----+ |            + +-----+  .     | Line
 1   |  /| .  |  W  |-|------------|-|  W  |  . |\  |  2
-----+-/ |-.--|  S  ********  ********  S  |--.-| \-+-----
-----+-\ |-.--|  S  | |    *  *    | |  S  |--.-| /-+-----
     |  \| .  |     |-|-+  *  *  +-|-|     |  . |/  |
     |     .  +-+-+-+ | |  *  *  | | +-+-+-+  .     |
     +-----.----|-----+ |  *  *  | +-----|----.-----+
           .    |       |  *  *  |       |    .
     +-----.----|-----+ |  *  *  | +-----|----.-----+
     | Degree 4 |     | |  *  *  | |     | Degree 3 |
Line |     .  +-----+ | |  *  *  | | +-----+  .     | Line
 4   |  /| .  |  W  |-|-|--*--*--+ | |  W  |  . |\  |  3
-----+-/ |-.--|  S  | | +--*--*----|-|  S  |--.-| \-+-----
-----+-\ |-.--|  S  |-|----*--*----|-|  S  |--.-| /-+-----
     |  \| .  |     | |    *  *    | |     |  . |/  |
     |     .  +--*--+ |    *  *    | +--*--+  .     |
     +-----.-----*----+    *  *    +----*-----.-----+
           .     *         *  *         *     .
           .  +--*---------*--*---------*--+  .
           .  |          ADD               |  .
           .  |          DROP              |  .
           .  +----------------------------+  .
 Colored OT  .     |     |     |     |     .
  Line I/F   .   +---+ +---+ +---+ +---+   .
             .   | O | | O | | O | | O |   .
             .   | T | | T | | T | | T |   .
             .   +---+ +---+ +---+ +---+   .
             . . .|.| . |.| . |.| . |.|. . .
                  | |   | |   | |   | |
                    Client Interfaces
```

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

2.10.4. Optical Impairments Imposed by WDM-TE-nodes

When an optical OTSi signal traverses a ROADM node, optical impairments are imposed on the signal by various passive or active optical components inside the ROADM node. Examples of optical impairments are:

* Chromatic dispersion (CD)

* Polarization mode dispersion (PMD)

* Polarization dependent loss (PDL)

* Optical amplifier noise due to amplified spontaneous emission (ASE)

* In-band cross-talk

* Filtering effects (out of scope of this document)

A ROADM node contains a wavelength selective photonic switching function (WSS)that can switch media channels (MCs) described in Section 2.3.4. These MCs can be established between two line ports of the ROADM or between a line port and an Add/Drop port of the ROADM. The Add/Drop ports of a ROADM are those ports to which optical transponders are connected. Typically, add/drop ports are used for a single optical channel signal (single OTSi), but principally this could also be a group of OTSi signals (OTSiG). The optical impairments associated with these MCs are different and the paths of the MCs inside the ROADM node can be categorized as follows:

* Express path: MC path between two line ports of the ROADM (unidirectional)

* Add Path: MC path from an Add port to a line port of the ROADM

* Drop path: MC path from a line port to a Drop port of the ROADM

Due to the symmetrical architecture of the ROADM node, the optical impairments associated with the express path are typically the same between any two line ports of the ROADM whereas the optical impairments for the add and drop paths are different and therefore MUST be modeled separately.

The optical impairments associated with each of the three types of ROADM-node-internal paths listed above are modeled as optical impairment parameter sets. These parameter sets are modeled as an augmentation of the te-node-attributes defined in [RFC8795]. The te-node-attributes are augmented with a list of roadm-path-impairments for the three ROADM path types distinguished by the impairment-type. Each roadm-path-impairments list entry contains the set of optical impairment parameters for one of the three path types indicated by the impairment-type. For the optical feasibility calculation based on the optical impairments, it is necessary to know whether the optical power of the OTSi stays within a certain power window. This is reflected by some optical power related parameters such as loss parameters or power parameters (see also [G.680]), which are included in the optical impairment parameter sets (see tree view in Appendix A).

[RFC8795] defines a connectivity matrix and a local link connectivity list for the TE node. The connectivity matrix describes the connectivity for the express paths between the different lines of the ROADM and the local link connectivity list describes the connectivity for the Add and Drop paths of the ROADM. These matrices are augmented with a new roadm-path-impairment matrix element, an add-path-impairment, and drop-path-impairment matrix element, respectively, which are defined as a pointer to the corresponding entry in the roadm-path-impairments list (leaf-ref).

2.11. Optical Protection Architectures

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

* Individual OTSi protection

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

2.11.1. Individual OTSi Protection

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

To achieve short protection switching times, it is necessary that the OTSi signals of the two legs are identical in terms of wavelength, modulation format, FEC, etc., which means no receiver configuration changes when a protection switch at the selector occurs selecting the other leg. This is important when 3R regenerators are needed between the two end-points terminating the protected segment, which typically is end-to-end.

In case of individual OTSi protection without 3R regenerators, two end-to-end MC paths are associated with the OTSi signal. In the YANG model, this is modeled as leaf list of the OTSi providing the e2e-mc-path-id for the two end-to-end MC paths associated with the individually 1+1 protected OTSi. This scenario is depicted in Figure 11 (forward direction) and Figure 12 (reverse direction) below.

```
                           end-to-end MC path1
        |------------------------------------------------------->|

   +-----------+                                          +-----------+
   | WDM Node1 |           +-----+      +-----+           | WDM Node2 |
   |      +----|           | WDM |      | WDM |           |----+      |
   |      |   -o---------->o-----o----->o-----o---------->o-   |      |
   |  OT  |  / |           |Node3|      |Node4|           | \  |  OT  |
   | +--+ | /  |           +-----+      +-----+           |  \ | +--+ |
  -o-o  o-o-   |                                          |   -o-o  o-o-
   | +--+ | \  |     +-----+     +------+     +-----+     |  / | +--+ |
   |      |  \ |     | WDM |     | WDM  |     | WDM |     | /  |      |
   |      |   -o---->o-----o---->o------o---->o-----o---->o-   |      |
   |      +----|     |Node5|     | Node6|     |Node7|     |----+      |
   |   Splitter|     +-----+     +------+     +-----+     |Selector    |
   +-----------+                                          +-----------+

        |------------------------------------------------------->|
                           end-to-end MC path2
```

Figure 11: Individual OTSi Protection without 3R regenerators (forward direction)

```
                           end-to-end MC path1'
        |<-------------------------------------------------------|

   +-----------+                                          +-----------+
   | WDM Node1 |           +-----+      +-----+           | WDM Node2 |
   |      +----|           | WDM |      | WDM |           |----+      |
   |      |   -o<----------o-----o<-----o-----o<----------o-   |      |
   |  OT  |  / |           |Node3|      |Node4|           | \  |  OT  |
   | +--+ | /  |           +-----+      +-----+           |  \ | +--+ |
  -o-o  o-o-   |                                          |   -o-o  o-o-
   | +--+ | \  |     +-----+     +------+     +-----+     |  / | +--+ |
   |      |  \ |     | WDM |     | WDM  |     | WDM |     | /  |      |
   |      |   -o<----o-----o<----o------o<----o-----o<----o-   |      |
   |      +----|     |Node5|     | Node6|     |Node7|     |----+      |
   |   Selector|     +-----+     +------+     +-----+     |Splitter   |
   +-----------+                                          +-----------+

        |<-------------------------------------------------------|
                           end-to-end MC path2'
```

Figure 12: Individual OTSi Protection without 3R regenerators (reverse direction)

For each OMS MCG (TE-link) along the two end-to-end MC paths in the forward direction (end-to-end MC path1 and end-to-end MC path2) as well as the two end-to-end MC paths in the reverse direction (end-to-end MC path1' and end-to-end MC path2'), the e2e-mc-path-id is provided for the individually protected OTSi signal. Based on this information, it is possible to construct the end-to-end MC paths between the optical transponders terminating the individually 1+1 protected OTSi.

In the scenario depicted in Figure 11 and Figure 12, the e2e-mc-path-id of end-to-end MC path1 and end-to-end MC path1' is provided for the TE-links between WDM Node1 and WDM Node3, WDM Node3 and WDM Node4 as well as WDM Node4 and WDM Node2 while the e2e-mc-path-id of end-to-end MC path2 and end-to-end MC path2' is provided for the TE-links between WDM Node1 and WDM Node5, WDM Node5 and WDM Node6, WDM Node6 and WDM Node7 as well as WDM Node7 and WDM Node2.

If a 3R regenerator is crossed on one of the two legs or even on both legs, the end-to-end MCs are terminated on both sides of the 3R regenerator. The configured-termination-type attribute set to "3r-regeneration" SHALL be used to indicate that the transceivers are forming a 3R regenerator instead of terminating the layer 0 tunnel (layer 0 service). At WDM-nodes containing a 3R regenerator, the end-2-end MCs are stitched together forming the end-to-end path for the layer 0 tunnel (layer 0 service). This is reflected in the leaf list of the OTSi, which now lists all e2e-mc-path-ids of the end-to-end MC paths on the two legs of the individually 1+1 protected OTSi signal.

In the scenario depicted in Figure 13 and Figure 14 below where a 3R regenerator is crossed in WDM Node6 on the lower leg, the e2e-mc-path-id leaf list has 3 entries (assumption: the same e2e-mc-path-id can be used for the path in the forward and reverse directions):

1. The e2e-mc-path-id identifying end-to-end MC path1 from WDM Node1 via WDM Node3 and WDM Node4 to WDM Node2 as well as end-to-end MC path1’ in the reverse direction (upper leg)

2. The e2e-mc-path-id identifying end-to-end MC path2 from WDM Node1 via WDM Node5 to WDM Node6 containing the 3R regenerator as well as end-to-end MC path2’ in the reverse direction (left hand segment of the lower leg)

3. The e2e-mc-path-id identifying end-to-end MC path3 from WDM Node6 containing the 3R regenerator via WDM Node7 to WDM Node2 as well as end-to-end MC path3’ in the reverse direction (right hand segment of the lower leg)

Based on this modeling approach it is possible to identify the end-2-end MCs stitched together at 3R regenerators on each of the two legs of the individually protected 1+1 OTSi signal. Similarly, for the case without 3R regenerators it is also possible to associate two end-to-end paths in the forward and reverse directions for the two legs between the optical transponders terminating the individually 1+1 protected OTSi in WDM Node1 and WDM Node2, respectively:

1. end-to-end MC path1 and end-to-end MC path1’ (upper leg)
2. end-to-end MC path2 and end-to-end MC path2’ stitched together with end-to-end MC path3 and end-to-end MC path3’ (lower leg)

```
                           end-to-end MC path1
        |------------------------------------------------------->|

   +-----------+                                          +-----------+
   | WDM Node1 |           +-----+      +-----+           | WDM Node2 |
   |      +----|           | WDM |      | WDM |           |----+      |
   |      |   -o---------->o-----o----->o-----o---------->o-   |      |
   |  OT  |  / |           |Node3|      |Node4|           | \  |  OT  |
   | +--+ | /  |           +-----+      +-----+           |  \ | +--+ |
  -o-o  o-o-   |                                          |   -o-o  o-o-
   | +--+ | \  |     +-----+     +------+     +-----+     |  / | +--+ |
   |      |  \ |     |     |     | +--+ |     |     |     | /  |      |
   |      |   -o---->o-----o---->o-o  o-o---->o-----o---->o-   |      |
   |      +----|     | WDM |     | +--+ |     | WDM |     |----+      |
   |   Splitter|     |Node5|     |  3R  |     |Node7|     |Selector   |
   +-----------+     +-----+     +------+     +-----+     +-----------+
                                 WDM Node6
                                 with 3R
                                 Regenerator

        |------------------------->|  |------------------------->|
            end-to-end MC path2           end-to-end MC path3
```

Figure 13: Individual OTSi Protection with a 3R regenerator
(forward direction)

```
                           end-to-end MC path1'
        |<-------------------------------------------------------|

   +-----------+                                          +-----------+
   | WDM Node1 |           +-----+      +-----+           | WDM Node2 |
   |      +----|           | WDM |      | WDM |           |----+      |
   |      |   -o<----------o-----o<-----o-----o<----------o-   |      |
   |  OT  |  / |           |Node3|      |Node4|           | \  |  OT  |
   | +--+ | /  |           +-----+      +-----+           |  \ | +--+ |
  -o-o  o-o-   |                                          |   -o-o  o-o-
   | +--+ | \  |     +-----+     +------+     +-----+     |  / | +--+ |
   |      |  \ |     |     |     | +--+ |     |     |     | /  |      |
   |      |   -o<----o-----o<----o-o  o-o<----o-----o<----o-   |      |
   |      +----|     | WDM |     | +--+ |     | WDM |     |----+      |
   |   Selector|     |Node5|     |  3R  |     |Node7|     |Splitter   |
   +-----------+     +-----+     +------+     +-----+     +-----------+
                                 WDM Node6
                                 with 3R
                                 Regenerator

        |<-------------------------|  |<-------------------------|
            end-to-end MC path2'          end-to-end MC path3'
```

Figure 14: Individual OTSi Protection with a 3R regenerator (reverse direction)

Individual OTSi protection use cases:

(i) OT and OTSi protection function are an integral part of the WDM-TE-node

(ii) OT and OTSi protection/ROADM functions are in two adjacent WDM-TE-nodes (remote OT)

(iii) OT and OTSi protection function are both in the adjacent WDM-TE-node (protected remote OT)

The different use cases are described in the following sub-sections and examples are provided as to how these uses cases can be modeled properly using the impairment-aware TE-topology YANG data model for optical networks.

2.11.1.1. OT and OTSi protection function are an integral part of the WDM-TE-node

This use case is based on the architecture illustrated in Figure 8 and the following entities are all integral parts of the WDM-TE-node:

* Local optical transponder
* Splitter/selector protection function
* ROADM function

Figure 15 illustrates such a WDM-TE-node configuration in the transmit/forward direction where the protection function is an optical splitter and Figure 16 illustrates the same WDM-TE-node configuration in the receive/reverse direction where the protection function is an optical selector selecting one of the two incoming OTSi signals and switching to the other incoming OTSi signal when the optical power of the selected OTSi signal drops below a pre-defined threshold.

The TE-topology YANG model has been augmented to describe this protection architecture. The already existing optional protection-type leaf of the TTP associated with the optical transceiver is used to indicate whether the TTP is protected, i.e., whether it is connected to a protection function or whether it is unprotected, i.e., whether it is directly connected to an add-drop port of the ROADM function in the WDM-TE-node.

For unprotected TTPs associated with an optical transceiver, the local-link-connectivity list (LLCL) as defined in [RFC8795] describes the potential connectivity between the TTP and the LTPs of the WDM-TE-node that are the local end-points of the TE-links (OMS MCGs) interconnecting the WDM-TE-node with its neighbors, also often called degrees of the WDM-TE-node as opposed to its add-drop ports.

For protected TTPs, the local-link-connectivity list has been augmented such that the potential connectivity can now be described between the TTP and multiple LTPs including the related optical impairments. Without this new capability, it was only possible to describe the potential connectivity between a TTP and a single LTP (unprotected case). If the optical impairments are the same for all local-link-connectivity list entries for a particular TTP, which is usually the case, the optical impairments should be omitted for the additional LTPs leading to a more compact topology description. If the optical impairments are different, however, they can be described for each additional LTP entry separately.

A local-link-connectivity list example for a protected TTP in JSON format is provided in Appendix B.

```
                                 WDM-TE-node
        +---------------------------------------------------------+
        |                                                         |
        |                                       ROADM             |
        |      Local OT        Splitter    +--------------+       |
        |   +------------+    +--------+   |              | Line  |
        |   |         TTP|    |     ---o-->o------\       | LTP 1 |
        |   |       +----|    |    /   |   |      \------o-------o->
      --o-->|       | Tx o--->o---o    |   |              |       |
        |   |       +----|    |    \   |   |              |       |
      <-o---|       | Rx o    |     ---o-->o---\          | Line  |
        |   |       +----|    +--------+   |    \         | LTP 2 |
        |   |            |                 |     \        o-------o->
        |   +------------+        internal |      \       |       |
        |                         AD ports o       \      |       |
        |                                  |        \     | Line  |
        |                                  |         \    | LTP 3 |
        |                                  |          \---o-------o->
        |                                  o              |       |
        |                                  |              |       |
        |                                  +--------------+       |
        +---------------------------------------------------------+
```

Figure 15: OT and OTSi protection function are an integral part of the WDM-TE- node (transmit direction)

```
                                 WDM-TE-node
        +---------------------------------------------------------+
        |      Local OT                                           |
        |   +------------+                      ROADM             |
        |   |            |     Selector    +--------------+       |
        |   |       +----|    +--------+   |              | Line  |
      --o-->|       | Tx o    |     ---o<--o------\       | LPT 1 |
        |   |       +----|    |    /   |   |       \------o-------o<-
      <-o---|       | Rx o<---o---o    |   |              |       |
        |   |       +----|    |    \   |   |              |       |
        |   |         TTP|    |     ---o<--o---\          | Line  |
        |   +------------+    +--------+   |    \         | LTP 2 |
        |                                  |     \        o-------o<-
        |                         internal |      \       |       |
        |                         AD ports o       \      |       |
        |                                  |        \     | Line  |
        |                                  |         \    | LTP 3 |
        |                                  |          \---o-------o<-
        |                                  o              |       |
        |                                  |              |       |
        |                                  +--------------+       |
        +---------------------------------------------------------+
```

Figure 16: OT and OTSI protection function are an integral part of the WDM-TE- node (receive direction)

2.11.1.2. OT and OTSi protection/ROADM functions are in two adjacent WDM-TE-node (remote OT)

This use case is based on the architecture illustrated in Figure 9 where the optical transponder is not part of the WDM-TE-node containing the ROADM function (WDM-TE-node-2) but is part of a separate WDM-TE-node (WDM-TE-node-1) containing one or more optical transponders (remote OTs). WDM-TE-node-2 contains:

* Splitter/selector protection function
* ROADM function

Figure 17 illustrates such a network configuration in the transmit/ forward direction showing the two WDM-TE-nodes where the protection function is the optical splitter in WDM-TE-node-2 and Figure 18 illustrates the same network configuration in the receive/reverse direction where the protection function is the optical selector in WDM-TE-node-2 selecting one of the two incoming OTSi signals and switching to the other incoming OTSi signal when the optical power of the selected OTSi signal drops below a pre-defined threshold.

In the network configuration shown in Figure 17 and Figure 18, respectively, the two WDM-TE-nodes are interconnected via a TE-link carrying a single OTSi signal. This TE-link interconnects the remote OT with an add-drop port of WDM-TE-node-2 and in the following the qualifier "add-drop" is used to refer to that LTP as opposed to the line LTPs representing degrees of WDM-TE-node-2. Like for the protected TTP in Section 2.11.1.1, the optional protection-type leaf is used to indicate whether the add-drop LTP is connected to a protection function and then to two line LTPs via the ROADM function inside WDM-TE-node-2 or whether it is connected to a single line LTP via the ROADM function inside WDM-TE-node-2 (unprotected add-drop LTP). While the protection-type attribute was already defined for the TTP, the YANG model has been augmented to also support this optional attribute for the LTP.

For protected LTPs, the connectivity-matrix has been augmented such that the potential connectivity can now be described between an add-drop LTP and multiple line LTPs including the related optical impairments. Without this new capability, it was only possible to describe the potential connectivity between an add-drop LTP and a single line LTP (unprotected case). If the optical impairments are the same from the protected add-drop LTP to all line LTPs, which is usually the case, the optical impairments should be omitted for the additional LTPs leading to a more compact connectivity matrix description. If the optical impairments are different, however, they can be described for each additional LTP separately.

```
        WDM-TE-node-1                      WDM-TE-node-2
     +----------------+      +---------------------------------------+
     |                |      |                     ROADM             |
     |      Remote OT |      |    Splitter    +--------------+       |
     |   +------------+      |   +--------+   |              | Line  |
     |   |         TTP|      |AD |     ---o-->o------\       | LTP 1 |
     |   |       +----|      |LTP|    /   |   |       \------o-------o->
   --o-->|       | Tx o----->o-->o---o        |              |       |
     |   |       +----|      |   |    \   |   |              |       |
   <-o---|       | Rx o      |   |     ---o-->o---\          | Line  |
     |   |       +----|      |   +--------+   |    \         | LTP 2 |
     |   |            |      |                |     \        o-------o->
     |   +------------+      |AD LTP          |      \       |       |
     |                |      o----------------o       \      |       |
     |                |      |                |        \     | Line  |
     |                |      |unprot. AD LTPs |         \    | LTP 3 |
     |                |      |                |          \---o-------o->
     |                |      o----------------o              |       |
     |                |      |AD LTP          |              |       |
     |                |      |                +--------------+       |
     +----------------+      +---------------------------------------+
```

Figure 17: OT and OTSi protection/ROADM functions are in two adjacent WDM-TE- node (remote OT, transmit direction)

```
        WDM-TE-node-1                      WDM-TE-node-2
     +----------------+      +---------------------------------------+
     |      Remote OT |      |                                       |
     |   +------------+      |                     ROADM             |
     |   |            |      |    Selector    +--------------+       |
     |   |       +----|      |   +--------+   |              | Line  |
   --o-->|       | Tx o      |   |     ---o<--o------\       | LTP 1 |
     |   |       +----|      |   |    /   |   |       \------o-------o<-
   <-o---|       | Rx o<-----o<--o---o    |   |              |       |
     |   |       +----|      |AD |    \   |   |              |       |
     |   |          TTP|      |LTP|     ---o<--o---\          | Line  |
     |   +------------+      |   +--------+   |    \         | LTP 2 |
     |                |      |                |     \        o-------o<-
     |                |      |AD LTP          |      \       |       |
     |                |      o----------------o       \      |       |
     |                |      |                |        \     | Line  |
     |                |      |unprot. AD LTPs |         \    | LTP 3 |
     |                |      |                |          \---o-------o<-
     |                |      o----------------o              |       |
     |                |      |AD LTP          |              |       |
     |                |      |                +--------------+       |
     +----------------+      +---------------------------------------+
```

Figure 18: OT and OTSi protection/ROADM functions are in two adjacent WDM-TE- node (remote OT, receive direction)

2.11.1.3. OT and protection function are both in an adjacent WDM-TE-node (protected remote OT)

The use case illustrated in Figure 19 is similar to the use case in Section 2.11.1.1. The difference is that WDM-TE-node-1 does not contain the ROADM function but contains:

* Optical transponder function including the transceiver
* Splitter/selector protection function

WDM-TE-node-1 can be a data center device or a router device that is supporting 1+1 OTSi protection for its OTs while WDM-TE-node-2 is a WDM-TE-node providing add-drop ports for remote OTs as depicted in Figure 9. WDM-TE-node-1 and WDM-TE-node-2 are interconnected via two separate TE-links, each carrying a single OTSi signal. The protection configuration for the protected TTP in WDM-TE-node-1 can be described in the same way as for the use in Section 2.11.1.1 using the local-link-connectivity list.

```
            WDM-TE-node-1                        WDM-TE-node-2
    +-----------------------------+      +---------------------------+
    |      protected              |      |         ROADM             |
    |      remote OT     Splitter|      |    +--------------+       |
    |   +------------+   +--------+      |AD  |              | Line  |
    |   |         TTP|   |     ---o----->o----o------\       | LTP 1 |
    |   |       +----|   |    /LTP|      |LTP |       \------o-------o->
  --o-->|       | Tx o-->o---o    |      |    |              |       |
    |   |       +----|   |    \   |      |AD  |              |       |
  <-o---|       | Rx o   |     ---o----->o----o---\          | Line  |
    |   |       +----|   |     LTP|      |LTP |    \         | LTP 2 |
    |   |            |   +--------+      |    |     \        o-------o->
    |   +------------+            |      |    |      \       |       |
    |                             |      o----o       \      |       |
    |                             |      |AD  |        \     | Line  |
    |                             |      |LTPs|         \    | LTP 3 |
    |                             |      |    |          \---o-------o->
    |                             |      o----o              |       |
    |                             |      |    |              |       |
    |                             |      |    +--------------+       |
    +-----------------------------+      +---------------------------+
```

Figure 19: OT and OTSI protection function are both in an adjacent WDM-TE-node (protected remote OT, transmit direction)

2.11.2. OMS MCG protection

OMS MCG protection is a 1+1 protection architecture where a TE-link representing an OMS MCG between two adjacent WDM-TE-nodes is 1+1 protected. This media layer protection type is also described in Appendix III of [G.873.1_Amd1]. Figure 20 illustrates this 1+1 OMS MCG protection type and shows a 1+1 protected TE-link together with an unprotected TE-link between the same two adjacent WDM-TE-nodes. The protected TE-link in Figure 20 is composed of an underlying primary and secondary TE-link. This modeling approach is described below.

1+1 OMS MCG protection is a local protection scheme, which can be modeled based on TE-link properties already defined in [RFC8795]. The 1+1 protected TE-link is associated with the two underlying TE-links representing the physical links, which are forming the 1+1 protection group together with the splitter and selector functions in the adjacent WDM-TE-nodes as depicted in Figure 20. This modeling approach is described in more detail in Section 2.11.2.1.

Alternatively, it is possible to model the 1+1 OMS MCG protection as single protected TE-link abstracting the two underlying physical links as well as the splitter and selector functions in the two adjacent WDM-TE-nodes. This modeling approach is described in more detail in Section 2.11.2.2.

For both modeling approaches, the splitter and selector functions are not represented as separate entities in the model. Their optical impairments can be included in the optical impairments of the ROADM paths in the two adjacent WDM-TE-nodes (connectivity matrix and LLCL, respectively) or in the optical impairments of the 1+1 protected TE-link abstracting the two underlying physical OMS links.

```
               WDM-TE-node-1                     WDM-TE-node-2
         +-----------------------+         +-----------------------+
         |     ROADM     Splitter|         |Selector     ROADM     |
         |   +-------+   +-------+  prot.  +-------+   +-------+   |
         |   |       |   |    -->o-------->o-->    |   |       |   |
         |   |       |   |   /   |  prim.  |   \   |   |       |   |
         |   |       o-->o--o    |         |    o--o-->o       |   |
         |   |       |   |   \   |  second.|   /   |   |       |   |
         |   |       |   |    -->o-------->o-->    |   |       |   |
         |   |       |   +-------+         +-------+   |       |   |
         |   |       |   Selector| Line 1  |Splitter   |       |   |
         |   |       |   +-------+         +-------+   |       |   |
         |   |       |   |    <--o<--------o<--    |   |       |   |
         |   |       |   |   /   |  prim.  |   \   |   |       |   |
         |   |       o<--o--o    |         |    o--o<--o       |   |
         |   |       |   |   \   |  second.|   /   |   |       |   |
         |   |       |   |    <--o<--------o<--    |   |       |   |
         |   |       |   +-------+ TE-link +-------+   |       |   |
         |   |       |           |         |           |       |   |
         |   |       |           | unprot. |           |       |   |
         |   |       o---------->o-------->o---------->o       |   |
         |   |       |           | Line 2  |           |       |   |
         |   |       o<----------o<--------o<----------o       |   |
         |   |       |           | TE-link |           |       |   |
         |   |       |           |         |           |       |   |
         |   +-------+           |         |           +-------+   |
         |                       |         |                       |
         +-----------------------+         +-----------------------+
```

Figure 20: Two WDM-TE-nodes with a protected and an unprotected OMS MCG (TE- link)

2.11.2.1. OMS MCG Protection Modeled as Protected TE-link with underlying TE-links

This modeling approach models the 1+1 protected TE-link as an additional TE-link entity on top of the primary and secondary TE-link between the two adjacent WDM-TE-nodes terminating the 1+1 OMS MCG protection group formed by these two TE-links and the splitter and selector functions in the two nodes. This 1+1 protected TE-link is associated with underlying primary and secondary TE-links forming the 1+1 protection group. The following "te-link-attributes" already defined in [RFC8795] and [I-D.ietf-teas-rfc8776-update] can be used for modeling the 1+1 protected TE-link ("te-link-attributes") augmentation copied from [RFC8795]:

```
augment /nw:networks/nw:network/nt:link:
+--rw te!
   +--rw te-link-attributes
   |  ....................
   |  +--rw underlay {te-topology-hierarchy}?
   |  |  +--rw enabled?                    boolean
   |  |  +--rw primary-path
   |  |  |  +--rw network-ref?    leafref
   |  |  |     ....................
   |  |  +--rw backup-path* [index]
   |  |  |  +--rw index           uint32
   |  |  |  +--rw network-ref?    leafref
   |  |  |     ....................
   |  ....................
   |  +--rw link-protection-type?          identityref
   |  ....................
```

These attributes are used as follows:

* "underlay": the presence of this container indicates that an underlying protection scheme exists
* "enabled": (boolean) is set to 'true'
* "primary-path": is referencing the primary OMS MCG (TE-link)
* "backup-path": is referencing the secondary OMS MCG (TE-link)
* "link-protection-type" (identityref) set to 'link-protection-1-plus-1' as defined in [I-D.ietf-teas-rfc8776-update]

The optical impairments for the underlying primary and secondary TE-link can be described as for unprotected TE-links. It MAY also be possible to only describe the optical impairments for the 1+1 protected TE-link. In this case the optical impairments of the worst of the two underlying TE-links shall be used. This should be sufficient as input for path computation (worst case optical feasibility consideration).

```
            WDM-TE-node-1                        WDM-TE-node-2
       +-----------------------+           +-----------------------+
       |     ROADM     Splitter|           |Selector     ROADM     |
       |   +-------+   +-------+LTP2   LTP4+-------+   +-------+   |
       |   |       |   |    -->o---------->o-->    |   |       |   |
   LTP1|   |    RP1|   |   /   |  prim.    |   \   |   |RP2    |   |LTP6
   --->o-->o.......o-->o--o    |           |    o--o-->o.......o-->o--->
       |   |       |   |   \   |  second.  |   /   |   |       |   |
       |   |       |   |    -->o---------->o-->    |   |       |   |
       |   +-------+   +-------+LTP3   LTP5+-------+   +-------+   |
       |                       |           |                       |
       +-----------------------+           +-----------------------+

                 --+                                   +--
        ROADM port |                                   | ROADM port
               RP1 o---------------------------------->o RP2
                   |                                   |
                 --+                                   +--
                      1+1 protected OMS MCG (TE-link)
                      between ROADM ports RP1 and RP2

                underlying primary and secondary TE-links:

                             --+           +--
                               |  prim.    |
                          LTP2 o---------->o LTP4
                          LTP3 o---------->o LTP5
                               |  second.  |
                             --+           +--

           connectivity matrix provides optical impairments in
           forward direction between LTPs in the two WDM-TE-nodes:
           * LTP1 and LTP2,                     * LTP4 and LTP6,
           * LTP1 and LTP3                      * LTP5 and LTP6
```

Figure 21: Modeling view of 1+1 protected TE-link with underlying primary and secondary TE-link (forward direction)

```
            WDM-TE-node-1                         WDM-TE-node-2
       +-----------------------+           +-----------------------+
       |     ROADM             |           |             ROADM     |
       |   +-------+   +-------+LTP2' LTP4'+-------+   +-------+   |
       |   |       |   |    <--o<----------o<--    |   |       |   |
   LTP1'   |   RP1'|   |   /   |  prim.    |   \   |   |RP2'   |   LTP6'
   <---o<--o.......o<--o--o    |           |    o--o<--o.......o<--o<---
       |   |       |   |   \   |  second.  |   /   |   |       |   |
       |   |       |   |    <--o<----------o<--    |   |       |   |
       |   +-------+   +-------+LTP3' LTP5'+-------+   +-------+   |
       |               Selector|           |Splitter               |
       +-----------------------+           +-----------------------+

                 --+                                   +--
        ROADM port |                                   | ROADM port
               RP1'o<----------------------------------o RP2'
                   |                                   |
                 --+                                   +--
                     1+1 protected OMS MCG (TE-link)
                     between ROADM ports RP1' and RP2'

                underlying primary and secondary TE-links:

                             --+           +--
                               |  prim.    |
                          LTP2'o<----------o LTP4'
                          LTP3'o<----------o LTP5'
                               |  second.  |
                             --+           +--

           connectivity matrix provides optical impairments in
           reverse direction between LTPs in the two WDM-TE-nodes:
           * LTP2' and LTP1',                   * LTP6' and LTP4',
           * LTP3' and LTP1'                    * LTP6' and LTP5'
```

Figure 22: Modeling view of 1+1 protected TE-link with underlying primary and secondary TE-link (reverse direction)

Figure 21 and Figure 22 illustrate this modeling approach including the LTPs in WDM-TE-node-1 and WDM-TE-node-2, respectively. In addition to the physical view, the following TE-links are shown in the two directions:

* The 1+1 protected TE-link

* The underlying primary TE-link
* The underlying secondary TE-link

The optical impairments of the splitter (outgoing direction) and the selector (incoming direction) are included in the optical impairments described by the connectivity matrix and the local link connectivity list for the TE node. For the example shown in Figure 21 in the forward direction, the connectivity matrix describes the optical impairments between LPT1 and LTP2 as well as LTP1 and LTP3 for WDM-TE-node-1. Likewise, the connectivity matrix describes the optical impairments between LPT4 and LTP6 as well as LTP5 and LTP6 in WDM-TE-node-2. The same applies to the corresponding LTPs in the reverse direction.

2.11.2.2. OMS MCG Protection Modeled as Single Protected TE-link

This modeling approach abstracts the two physical OMS links carrying the same OMS MCG together with the splitter and selector functions in the two WDM-TE-nodes forming the OMS protection group into a single TE-link. When this modeling approach is used the "te-link-attributes" already defined in [RFC8795] and [I-D.ietf-teas-rfc8776-update] are used as follows:

```
 augment /nw:networks/nw:network/nt:link:
   +--rw te!
      +--rw te-link-attributes
      |  ....................
      |  +--rw link-protection-type?          identityref
      |  ....................
```

* "underlay": this container MUST NOT be present
* "link-protection-type" (identityref) set to 'link-protection-1-plus-1' as defined in [I-D.ietf-teas-rfc8776-update]

The optical impairments exposed for this 1+1 protected TE-link are typically based on the optical impairments of the worse of the two underlying physical OMS links including the optical impairments imposed by the splitter (outgoing direction) and selector (incoming direction).

Figure 23 and Figure 24 illustrate this modeling approach where the splitter/selector in the adjacent WDM-TE-nodes, WDM-TE-node-1 and WDM-TE-node-2, as well as the two physical OMS MCG links are abstracted into a single 1+1 protected TE-link. This is illustrated by the dotted line surrounding these four physical entities in Figure 23 and Figure 24, respectively. Based on this modeling approach, the ROADM port connected to the splitter/selector function is modeled as LTP for the 1+1 protected TE-link (LTP2 in WDM-TE-node-1 and LTP3 in WDM-TE-node-2). In this example, the connectivity matrix describes the optical impairments between LPT1 and LTP2 in WDM-TE-node-1. Likewise, the connectivity matrix describes the optical impairments between LPT3 and LTP4 in WDM-TE-node-2.

```
         WDM-TE-node-1                         WDM-TE-node-2
    +-----------------------+           +-----------------------+
    |     ROADM     Splitter|           |Selector     ROADM     |
    |   +-------+   +.......+...........+.......+   +-------+   |
    |   |       |   .    -->o---------->o-->    .   |       |   |
LTP1|   |   LTP2|   .   /   |           |   \   .   |LTP3   |   |LTP4
--->o-->o.......o-->o--o    |           |    o--o-->o.......o-->o--->
    |   |       |   .   \   |           |   /   .   |       |   |
    |   |       |   .    -->o---------->o-->    .   |       |   |
    |   +-------+   +...................+.......+   +-------+   |
    |                       |           |                       |
    +-----------------------+           +-----------------------+

              --+                                   +--
     ROADM port |                                   | ROADM port
           LTP2 o---------------------------------->o LTP3
                |                                   |
              --+                                   +---
                  Splitter/Selector abstracted into
                  1+1 protected OMS MCG (TE-link)

        connectivity matrix provides optical impairments in
        forward direction between LTPs in the two WDM-TE-nodes:
        * LTP1 and LTP2                      * LTP3 and LTP4
```

Figure 23: Modeling view of abstracted 1+1 protected TE-link (forward direction) - ROADM ports modeled as LTPs

```
            WDM-TE-node-1                         WDM-TE-node-2
       +-----------------------+           +-----------------------+
       |     ROADM             |           |             ROADM     |
       |   +-------+   +.......+...........+.......+   +-------+   |
       |   |       |   .    <--o<----------o<--    .   |       |   |
   LTP1'   |  LTP2'|   .   /   |           |   \   .   |LTP3'  |   LTP4'
   <---o<--o.......o<--o--o    |           |    o--o<--o.......o<--o<---
       |   |       |   .   \   |           |   /   .   |       |   |
       |   |       |   .    <--o<----------o<--    .   |       |   |
       |   +-------+   +...................+.......+   +-------+   |
       |               Selector|           |Splitter               |
       +-----------------------+           +-----------------------+

                 --+                                 +--
        ROADM port |                                 | ROADM port
              LTP2 o<----------------------------------o LTP3
                   |                                   |
                 --+                                 +---
                     Splitter/Selector abstracted into
                     1+1 protected OMS MCG (TE-link)

           connectivity matrix provides optical impairments in
           reverse direction between LTPs in the two WDM-TE-nodes:
           * LTP2' and LTP1'                    * LTP4' and LTP3'
```

Figure 24: Modeling view of abstracted 1+1 protected TE-link (reverse direction) - ROADM ports modeled as LTPs

Alternatively, the optical impairments imposed by the splitter and selector in each of the two adjacent WDM-TE-nodes can also be included in the optical impairments described by the connectivity matrix of the two nodes instead of taking them into account as optical impairments of the 1+1 protected TE-link. This is illustrated in Figure 25 in forward direction and Figure 26 in reverse direction below. In this case, the two physical ports on both ends of the 1+1 protected TE-link are abstracted into a single LTP, LTP2 and LTP3, in forward direction and LTP3' and LTP2' in reverse direction.

```
            WDM-TE-node-1                         WDM-TE-node-2
       +-----------------------+           +-----------------------+
       |  ROADM     Splitter|           |Selector     ROADM      |
       |   +-------+   +-------+...........+-------+   +-------+   |
       |   |       |   |    -->o---------->o-->    |   |       |   |
   LTP1|   |       |   |   /   |LTP2   LTP3|   \   |   |       |   |LTP4
   --->o-->o.......o-->o--o    |           |    o--o-->o.......o-->o--->
       |   |       |   |   \   |LTP2   LTP3|   /   |   |       |   |
       |   |       |   |    -->o---------->o-->    |   |       |   |
       |   +-------+   +-------+...........+-------+   +-------+   |
       |                       |           |                       |
       +-----------------------+           +-----------------------+

                             --+           +--
                               |           |
                          LTP2 o---------->o LTP3
                               |           |
                             --+           +--
                               1+1 protected
                               OMS MCG (TE-link)

           connectivity matrix provides optical impairments in
           forward direction between LTPs in the two WDM-TE-nodes:
           * LTP1 and LTP2                      * LTP3 and LTP4
```

Figure 25: Modeling view of abstracted 1+1 protected TE-link
(forward direction) - physical ports abstracted into single LTP
on both link ends

```
            WDM-TE-node-1                         WDM-TE-node-2
       +-----------------------+           +-----------------------+
       |     ROADM             |           |             ROADM     |
       |   +-------+   +-------+...........+-------+   +-------+   |
       |   |       |   |    <--o<----------o<--    |   |       |   |
   LTP1'   |       |   |   /   |LTP2' LTP3'|   \   |   |       |   LTP4'
   <---o<--o.......o<--o--o    |           |    o--o<--o.......o<--o<---
       |   |       |   |   \   |LTP2' LTP3'|   /   |   |       |   |
       |   |       |   |    <--o<----------o<--    |   |       |   |
       |   +-------+   +-------+...........+-------+   +-------+   |
       |               Selector|           |Splitter               |
       +-----------------------+           +-----------------------+

                             --+           +--
                               |           |
                          LTP2'o<----------o LTP3'
                               |           |
                             --+           +--
                               1+1 protected
                               OMS MCG (TE-link)

           connectivity matrix provides optical impairments in
           reverse direction between LTPs in the two WDM-TE-nodes:
           * LTP2' and LTP1'                    * LTP4' and LTP3'
```

Figure 26: Modeling view of abstracted 1+1 protected TE-link (reverse direction) - physical ports abstracted into single LTP on both link ends

3. Optical Impairment Topology YANG Model

```
<CODE BEGINS> file "ietf-optical-impairment-topology@2026-02-06.yang"
module ietf-optical-impairment-topology {
  yang-version 1.1;
  namespace "urn:ietf:params:xml"
          + ":ns:yang:ietf-optical-impairment-topology";
  prefix oit;

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

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

     /* Note: The RFC Editor will replace YYYY with the number assigned
        to the RFC once draft-ietf-teas-rfc8776-update becomes an RFC.*/

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

     /* Note: The RFC Editor will replace ZZZZ with the number assigned
        to the RFC once draft-ietf-ccamp-rfc9093-bis becomes an RFC.*/

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

        Editor:   Young Lee <younglee.tx@gmail.com>
        Editor:   Haomian Zheng <zhenghaomian@huawei.com>
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        Editor:   Jean-Luc Auge <jeanluc.auge@orange.com>
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        Editor:   Julien Meuric <julien.meuric@orange.com>
        Editor:   Italo Busi <Italo.Busi@huawei.com>
        Editor:   Dieter Beller <dieter.beller@nokia.com>
        Editor:   Sergio Belotti <Sergio.belotti@nokia.com>
        Editor:   Griseri Enrico <enrico.griseri@nokia.com>
        Editor:   Gert Grammel <ggrammel@juniper.net>";
     description
       "This module contains a collection of YANG definitions for
```

```
         impairment-aware optical networks.

         Copyright (c) 2026 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 Revised BSD
         License set forth in Section 4.c of the IETF Trust's Legal
         Provisions Relating to IETF Documents
         (https://trustee.ietf.org/license-info).

         All revisions of IETF and IANA published modules can be found
         at the YANG Parameters registry group
         (https://www.iana.org/assignments/yang-parameters).

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

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

      // RFC Ed.: replace XXXX with actual RFC number and remove
      // this note
      // replace the revision date with the module publication date
      // the format is (year-month-day)

      revision 2026-02-06 {
        description
          "Initial version.";
        reference
          "RFC XXXX: A YANG Data Model for Impairment-aware
                     Optical Networks";
      }

      /*
       * Identities
       */

      identity otsi-protection {
        base te-types:lsp-protection-type;
        description
          "Individual OTSi(G) protection LSP protection type.";
        reference
          "ITU-T G.873.1 v5.2 (02/2022): Optical transport network:
```

```
                       Linear protection, Appendix III";
     }

     /*
      * Groupings
      */

     grouping amplifier-params {
       description
         "Describes parameters for an amplifier.";
       reference
         "RFC XXXX: A YANG Data Model for Impairment-aware
                    Optical Networks, Section 2.4";
       container amplifier {
         description
           "The attributes of an amplifier.";
         leaf type-variety {
           type string;
           mandatory true;
           description
             "The type of the amplifier.

              It is usually a vendor-specific string referencing
              specification in a separate equipment catalog.";
         }
         container operational {
           description
             "Amplifier operational parameters.";
           list amplifier-element {
             key "frequency-range-id stage-order";
             description
               "The list of parallel amplifier elements within an
                amplifier used to amplify different frequency ranges.

                Two elements in the list MUST NOT have the same range
                or overlapping ranges.";
             uses l0-types:frequency-range-with-identifier;
             leaf stage-order {
               type uint8;
               description
                 "It allows defining for each spectrum bandwidth the
                  cascade order of each amplifier-element.";
             }
             leaf name {
               type string;
               description
                 "The name of the amplifier element as specified in
                  the vendor’s specification associated with the
```

```
                 type-variety.";
            }
            leaf type-variety {
              type string;
              description
                "The type of the amplifier element.

                 It is usually a vendor-specific string referencing
                 specification in a separate equipment catalog.

                 This attribute applies only when the type-variety of
                 the amplifier is not sufficient to describe the
                 amplifier element type.";
            }
            container power-param {
              description
                "Amplifier elements typically equalize the optical
                 power across the amplified channels using one of the
                 available equalization strategies - either targeting
                 a specific output power, or a specific power spectral
                 density (PSD), after the out-voa.";
              choice power-param {
                mandatory true;
                description
                  "Select the mode: channel power or power spectral
                   density (PSD).";
                case channel-power {
                  leaf nominal-carrier-power {
                    type l0-types:power-dbm-or-unknown;
                    mandatory true;
                    description
                      "Reference channel power.";
                  }
                }
                case power-spectral-density {
                  leaf nominal-psd {
                    type l0-types:psd-or-unknown;
                    mandatory true;
                    description
                      "Reference power spectral density (PSD).";
                  }
                }
              }
            } // container power-param
            leaf pdl {
              type l0-types:power-loss-or-unknown;
              description
                "Polarization Dependent Loss (PDL).";
```

```
              reference
                "ITU-T G.671 v9.0 (11/2025): Transmission
                             characteristics of optical components and
                             subsystems, clause 3.2.2.35
                 ITU-T G.Sup41 v5.0 (07/2024): Design guidelines for
                               optical fibre submarine cable systems,
                               clause 8.1.5.2.2";
            }
            choice amplifier-element-type {
              mandatory true;
              description
                "Identifies whether the amplifier element is an
                 Optical Amplifier (OA) or a Dynamic Gain Equalizer
                 (DGE).";
              container optical-amplifier {
                description
                  "The attributes applicable only to amplifier
                   elements.";
                leaf actual-gain {
                  type l0-types:power-gain-or-unknown;
                  mandatory true;
                  description
                    "The value of the gain provided by the
                     amplification stage of the optical amplifier.";
                }
                leaf in-voa {
                  type l0-types:power-loss-or-unknown;
                  description
                    "Loss introduced by the Variable Optical Attenuator
                     (VOA) at the input of the amplification stage of
                     the amplifier, if present.";
                }
                leaf out-voa {
                  type l0-types:power-loss-or-unknown;
                  description
                    "Loss introduced by the Variable Optical Attenuator
                     (VOA) at the output of the amplification stage of
                     the amplifier, if present.";
                }
                leaf tilt-target {
                  type l0-types:decimal-2-or-unknown;
                  units "dB";
                  mandatory true;
                  description
                    "The tilt target defined between lower and upper
                     frequency of the amplifier frequency range.";
                }
                leaf total-output-power {
```

```
                   type l0-types:power-dbm-or-unknown;
                   mandatory true;
                   description
                     "It represents the total output power measured in
                      the range specified by the frequency-range.

                      Optical power is especially needed to
                      re-compute/check consistency of span
                      (fiber + concentrated loss) loss value, with
                      respect to loss/gain information on elements.";
                 }
                 leaf raman-direction {
                   type enumeration {
                     enum co-propagating {
                       description
                         "Co-propagating indicates that optical pump
                          light is injected in the same direction to the
                          optical signal that is amplified
                          (forward pump).";
                     }
                     enum counter-propagating {
                       description
                         "Counter-propagating indicates that optical
                          pump light is injected in opposite direction
                          to the optical signal that is amplified
                          (backward pump).";
                     }
                   }
                   description
                     "The direction of injection of the raman pump.";
                 }
                 list raman-pump {
                   key "pump-id";
                   description
                     "The list of pumps for the Raman amplifier.";
                   leaf pump-id {
                     type uint16;
                     description
                       "The identifier of a pump within an amplifier
                        element.";
                   }
                   leaf frequency {
                     type l0-types:frequency-thz;
                     description
                       "The raman pump central frequency.";
                   }
                   leaf power {
                     type l0-types:decimal-2-or-unknown;
```

```
                     units "Watts";
                     description
                       "The total pump power considering a depolarized
                        pump at the raman pump central frequency.";
                   }
                 }
               } // container optical-amplifier
               container dynamic-gain-equalizer {
                 presence
                   "When present it indicates that the amplifier element
                    is a Dynamic Gain Equalizer (DGE).";
                 description
                   "The attributes applicable only to DEG amplifier
                    elements.";
                 list media-channel {
                   key "flexi-n";
                   description
                     "List of media channels represented as (n,m).";
                   uses l0-types:flexi-grid-frequency-slot {
                     refine "flexi-m" {
                       mandatory true;
                     }
                   }
                   leaf delta-power {
                     type l0-types:power-ratio-or-unknown;
                     description
                       "Deviation of the carrier power with respect to
                        the reference carrier power, to account for
                        power offset related to the carrier signal
                        spectrum width or baud rate.";
                   }
                 } // media channels list
               } // container dynamic-gain-equalizer
             } // choice amplifier-element-type
           } // list amplifier-element
         } // container operational
       } // container amplifier
     } // grouping amplifier-params

     grouping fiber-params {
       description
         "String identifier of fiber type referencing a
          specification in a separate equipment catalog.";
       container fiber {
         description
           "Fiber characteristics.";
         reference
           "RFC XXXX: A YANG Data Model for Impairment-aware Optical
```

```
                      Networks, Section 2.9";
          leaf type-variety {
            type string;
            mandatory true;
            description
              "The type of the fiber.

               It can be a string referencing a standard document (e.g.,
               ITU-T G.652) or a vendor-specific string referencing
               specification in a separate equipment catalog.";
          }
          leaf length {
            type l0-types:decimal-2-or-unknown;
            units "km";
            mandatory true;
            description
              "Length of fiber.";
          }
          leaf loss-coef {
            type l0-types:decimal-2-or-unknown;
            units "dB/km";
            mandatory true;
            description
              "Loss coefficient of the fiber.";
          }
          leaf total-loss {
            type l0-types:power-loss-or-unknown;
            config false;
            description
              "The measured total loss of the fiber, which includes
               all possible losses: fiber loss and conn-in and conn-out
               losses.

               This attribute is not present when the total loss cannot
               be measured.";
          }
          leaf pmd {
            type l0-types:decimal-2-or-unknown;
            units "ps";
            description
              "Polarization Mode Dispersion (PMD) of the fiber.";
            reference
              "ITU-T G.671 v9.0 (11/2025): Transmission characteristics
                           of optical components and subsystems,
                           clause 3.2.2.37
               ITU-T G.Sup41 v5.0 (07/2024): Design guidelines for
                             optical fibre submarine cable systems,
                             clause 6.2.2.3";
```

```
        }
        leaf conn-in {
          type l0-types:power-loss-or-unknown;
          description
            "The loss of the connector at the input of the fiber.";
        }
        leaf conn-out {
          type l0-types:power-loss-or-unknown;
          description
            "The loss of the connector at the output of the fiber.";
        }
      }
    }

    grouping roadm-common-path {
      description
        "The optical impairments of a ROADM which are common to all
         its paths (express path, add path or drop path).";
      reference
        "RFC XXXX: A YANG Data Model for Impairment-aware Optical
                   Networks, Section 2.10.4";
      leaf roadm-pmd {
        type union {
          type decimal64 {
            fraction-digits 8;
            range "0..max";
          }
          type l0-types:unknown-value;
        }
        units "ps";
        description
          "Polarization Mode Dispersion (PMD).";
        reference
          "ITU-T G.671 v9.0 (11/2025): Transmission characteristics of
                        optical components and subsystems,
                        clause 3.2.2.37
           ITU-T G.Sup41 v5.0 (07/2024): Design guidelines for optical
                          fibre submarine cable systems,
                          clause 6.2.2.3";
      }
      leaf roadm-cd {
        type l0-types:decimal-5-or-unknown;
        units "ps/nm";
        description
          "Chromatic Dispersion (CD).";
        reference
          "ITU-T G.Sup41 v5.0 (07/2024): Design guidelines for optical
                          fibre submarine cable systems,
```

```
                      clause 6.2.2.4";
       }
       leaf roadm-pdl {
         type l0-types:power-loss-or-unknown;
         description
           "Polarization Dependent Loss (PDL).";
         reference
           "ITU-T G.671 v9.0 (11/2025): Transmission characteristics of
                        optical components and subsystems,
                        clause 3.2.2.35
            ITU-T G.Sup41 v5.0 (07/2024): Design guidelines for optical
                          fibre submarine cable systems,
                          clause 8.1.5.2.2";
       }
       leaf roadm-inband-crosstalk {
         type l0-types:decimal-2-or-unknown;
         units "dB";
         description
           "One of the basic properties of the key optical device
            wavelength selective switch (WSS) is the isolation (i.e.,
            the ratio between the optical power of a selected optical
            channel and the leakage power of unselected channels).

            In the presence of imperfect isolation, the originated
            leakage signals, usually known as crosstalk signals, will
            interfere with the primary signal at the receiver end,
            contributing to degrade the signal quality.
            This interference is particularly harmful when both the
            signal and interference have the same nominal wavelength
            leading to the in-band crosstalk.";
         reference
           "ISSN 1068-5200: A framework for analyzing in-band crosstalk
                            accumulation in ROADM-based optical
                            networks";
       }
       leaf roadm-maxloss {
         type l0-types:power-loss-or-unknown;
         description
           "This is the maximum expected path loss from the
            ROADM ingress to the ROADM egress
            assuming no additional path loss is added.";
       }
     } // grouping roadm-common-path

     grouping roadm-add-path {
       description
         "The optical impairments of a ROADM add path.";
       reference
```

```
          "RFC XXXX: A YANG Data Model for Impairment-aware Optical
                     Networks, Section 2.10.4";
        uses roadm-common-path {
          refine "roadm-inband-crosstalk" {
            description
              "In-band crosstalk, or coherent crosstalk,
               can occur in components that can have multiple same
               wavelength inputs,with the inputs either
               routed to different output ports,
               or all but one blocked.

               In the case of add path it is the total
               of the add block + egress WSS crosstalk contributions.";
          }
          refine "roadm-maxloss" {
            description
              "This is the maximum expected add path loss from
               the add/drop port input to the ROADM egress,
               assuming no additional add path loss is added.

               This is used to establish the minimum required
               transponder output power required to hit the ROADM
               egress target power levels and preventing to hit
               the WSS attenuation limits.

               If the add path contains an internal amplifier
               this loss value MUST be based on worst case expected
               amplifier gain due to ripple or gain uncertainty.";
          }
        }
        leaf roadm-pmax {
          type l0-types:power-dbm-or-unknown;
          description
            "This is the maximum (per carrier) power level
             permitted at the add block input ports,
             that can be handled by the ROADM node.

             This can reflect either add amplifier power
             constraints or WSS adjustment limits.

             Higher power transponders would need to have
             their launch power reduced to this value or lower.";
        }
        leaf roadm-osnr {
          type l0-types:snr-or-unknown;
          description
            "Optical Signal-to-Noise Ratio (OSNR).
```

```
            If the add path contains the ability to adjust the
            carrier power levels into an add path amplifier
            (if present) to a target value,
            this reflects the OSNR contribution of the
            add amplifier assuming this target value is obtained.

            The worst case OSNR based on the input power and
            NF calculation method, and this value, MUST be used
            (if both are defined).";
         reference
           "ITU-T G.Sup41 v5.0 (07/2024): Design guidelines for optical
                          fibre submarine cable systems, clause 8.1.3";
       }
       leaf roadm-noise-figure {
         type l0-types:decimal-5-or-unknown;
         units "dB";
         description
           "Noise Figure. If the add path contains an amplifier,
            this is the noise figure of that amplifier inferred
            to the add port.
            This permits add path OSNR calculation based
            on the input power levels to the add block
            without knowing the ROADM path losses to
            the add amplifier.";
         reference
           "ITU-T G.Sup41 v5.0 (07/2024): Design guidelines for optical
                          fibre submarine cable systems, clause 8.1.3";
       }
     } // grouping roadm-add-path

     grouping roadm-drop-path {
       description
         "The optical impairments of a ROADM drop path.";
       uses roadm-common-path {
         refine "roadm-inband-crosstalk" {
           description
             "In-band crosstalk, or coherent crosstalk, can occur in
              components that can have multiple same wavelength
              inputs,with the inputs either routed to different
              output ports,or all but one blocked.

              In the case of drop path it is the total
              of the ingress to drop, e.g. WSS and drop block
              crosstalk contributions.";
         }
         refine "roadm-maxloss" {
           description
             "The net loss from the ROADM input,to the output
```

```
               of the drop block.

               If this ROADM ingress-to-drop path includes an amplifier,
               the amplifier gain reduces the net loss.
               This is before any additional drop path attenuation
               that may be required due to drop amplifier power
               constraints.

               The max value corresponds to the worst case expected
               loss, including amplifier gain ripple or uncertainty.
               It is the maximum output power of the drop amplifier.";
         }
       }
       leaf roadm-minloss {
         type l0-types:power-loss-or-unknown;
         description
           "The net loss from the ROADM input, to the
            output of the drop block.

            If this ROADM ingress-to-drop path includes
            an amplifier,the amplifier gain reduces the net loss.
            This is before any additional drop path attenuation
            that may be required due to drop amplifier power
            constraints.

            The min value correspond to best case expected loss,
            including amplifier gain ripple or uncertainty.";
       }
       leaf roadm-typloss {
         type l0-types:power-loss-or-unknown;
         description
           "The net loss from the ROADM input, to the output
            of the drop block.

            If this ROADM ingress-to-drop path includes an amplifier,
            the amplifier gain reduces the net loss.

            This is before any additional drop path attenuation
            that may be required due to drop amplifier power
            constraints.

            The typ value correspond to typical case expected loss.";
       }
       leaf roadm-pmin {
         type l0-types:power-dbm-or-unknown;
         description
           "If the drop path has additional loss that is added, for
            example, to hit target power levels into a drop path
```

```
             amplifier, or simply, to reduce the power of a strong
             carrier (due to ripple, for example), then the use of the
             ROADM input power levels and the above drop losses is
             not appropriate.

             This parameter corresponds to the minimum value of the Drop
             Channel output power range.";
          reference
            "ITU-T G.680 v1.0 (07/2007): Physical transfer functions of
                         optical network elements, Table 8-6";
        }
        leaf roadm-pmax {
          type l0-types:power-dbm-or-unknown;
          description
            "If the drop path has additional loss that is added, for
             example, to hit target power levels into a drop path
             amplifier, or simply ,to reduce the power of a strong
             carrier (due to ripple, for example), then the use of the
             ROADM input power levels and the above drop losses is
             not appropriate.

             This parameter corresponds to the maximum value of the Drop
             Channel output power range.";
          reference
            "ITU-T G.680 v1.0 (07/2007): Physical transfer functions of
                         optical network elements, table 8-6";
        }
        leaf roadm-ptyp {
          type l0-types:power-dbm-or-unknown;
          description
            "If the drop path has additional loss that is added,
             for example, to hit target power levels into a
             drop path amplifier,or simply,to reduce the
             power of a strong carrier(due to ripple, for example),
             then the use of the ROADM input power levels and
             the above drop losses is not appropriate.

             This parameter corresponds to the typical case
             per carrier power levels expected at the output
             of the drop block.";
        }
        leaf roadm-osnr {
          type l0-types:snr-or-unknown;
          description
            "Optical Signal-to-Noise Ratio (OSNR).

             Expected OSNR contribution of the drop path
             amplifier (if present) for the case of additional drop
```

```
            path loss (before this amplifier) in order to hit
            a target power level (per carrier).

            If both, the OSNR based on the ROADM
            input power level
            (Pcarrier =
            Pref+10Log(carrier-baudrate/ref-baud) + delta-power)
            and the input inferred NF(NF.drop),
            and this OSNR value, are defined,
            the minimum value between these two MUST be used.";
         reference
           "ITU-T G.Sup41 v5.0 (07/2024): Design guidelines for optical
                           fibre submarine cable systems, clause 8.1.3";
       }
       leaf roadm-noise-figure {
         type l0-types:decimal-5-or-unknown;
         units "dB";
         description
           "Drop path Noise Figure.

            If the drop path contains an amplifier, this is the noise
            figure of that amplifier, inferred to the ROADM ingress
            port.

            This permits to determine amplifier OSNR contribution
            without having to specify the ROADM node's losses to
            that amplifier.

            This applies for the case of no additional drop path loss,
            before the amplifier, in order to reduce the power
            of the carriers to a target value.";
         reference
           "ITU-T G.Sup41 v5.0 (07/2024): Design guidelines for optical
                           fibre submarine cable systems, clause 8.1.3";
       }
     } // grouping roadm-drop-path

     grouping concentrated-loss-params {
       description
         "Concentrated loss";
       container concentrated-loss {
         description
           "Concentrated loss";
         reference
           "RFC XXXX: A YANG Data Model for Impairment-aware Optical
                      Networks, section 2.3";
         leaf loss {
           type l0-types:power-loss-or-unknown;
```

```
          mandatory true;
          description
            "Loss introduced by the concentrated loss element (e.g., a
             fiber connector, a fiber splice).";
        }
      }
    }

    grouping oms-general-optical-params {
      description
        "The optical paramaters of an OMS link.";
      reference
        "RFC XXXX: A YANG Data Model for Impairment-aware Optical
                   Networks, Section 2.3";
      leaf generalized-snr {
        type l0-types:snr;
        description
          "Generalized SNR.";
        reference
          "ITU-T G.Sup41 v5.0 (07/2024): Design guidelines for optical
                         fibre submarine cable systems, clause 8.1.4";
      }
      leaf equalization-mode {
        type identityref {
          base l0-types:type-power-mode;
        }
        description
          "The equalization mode.

           ROADMs typically equalize the optical power across the
           channels on the OMS using one of the available equalization
           strategies - either targeting a specific output power, or a
           specific power spectral density (PSD).

           When not present it indicates that the information about
           the equalization mode is not reported.

           Reporting this value is needed to support optical
           impairments applications.";
      }
      container power-param {
        description
          "Optical channel power or power spectral densitity (PSD)
           after the ROADM.";
        leaf nominal-carrier-power {
          when "derived-from-or-self(../../equalization-mode, "
             + "'l0-types:carrier-power')";
          type l0-types:power-dbm-or-unknown;
```

```
          description
            "Reference channel power.";
        }
        leaf nominal-psd {
          when "derived-from-or-self(../../equalization-mode, "
             + "'l0-types:power-spectral-density')";
          type l0-types:psd-or-unknown;
          description
            "Reference power spectral density (PSD).";
        }
      } // container power-param
    } // grouping oms-general-optical-params

    grouping otsi-group {
      description
        "The list of the OTSis contained in one OTSiG.";
      reference
        "RFC XXXX: A YANG Data Model for Impairment-aware Optical
                   Networks, Sections 2.3.1 and 2.3.2";
      list otsi {
        key "carrier-id";
        description
          "The list of the OTSis contained in one OTSiG.
           The list could also be of only one element.";
        leaf carrier-id {
          type uint16;
          description
            "The identifier of the OTSi within the OTSiG.";
        }
        leaf carrier-frequency {
          type union {
            type l0-types:frequency-thz;
            type l0-types:unknown-value;
          }
          description
            "OTSi carrier frequency, equivalent to the
             actual configured transmitter frequency.";
        }
        leaf-list e2e-mc-path-id {
          type uint16;
          description
            "The list of the possible end-to-end Media Channel
             (e2e-MC) paths associated with the OTSi which have
             different optical impairments.

             This list is meaningful in case the OTSi can be associated
             with multiple end-to-end Media Channel (e2e-MC) paths
             (e.g., when OPS protection is configured).
```

```
              The list can be empty when the OTSi has only one
              e2e-MC path.";
           reference
             "RFC XXXX: A YANG Data Model for Impairment-aware Optical
                        Networks, Section 2.11.1";
         }
       } // OTSi list
     } // OTSiG grouping

     grouping media-channel-groups {
       description
         "The list of media channel groups (MCGs) and of their
          constituent media channels (MCs).

          This grouping is not intended to be reused outside of this
          module.";
       reference
         "RFC XXXX: A YANG Data Model for Impairment-aware Optical
                    Networks, Sections 2.3.3 and 2.3.4";
       container media-channel-groups {
         presence
           "When present, it indicates that the list media channel
            groups is reported.";
         description
           "The top level container for the list of media channel
            groups.";
         list media-channel-group {
           key "otsi-group-ref";
           description
             "The list of media channel groups";
           leaf otsi-group-ref {
             type leafref {
               path "../../../../../../../otsis/"
                  + "otsi-group/otsi-group-id";
             }
             description
               "Reference to the OTSiG to which the OTSis carried by
                this media channel group belong to.";
           }
           list media-channel {
             key "media-channel-id";
             unique "flexi-n";
             description
               "The list of media channels within the media channel
                group.";
             leaf media-channel-id {
               type int16;
               description
```

```
                "The identifier of media channel within media channel
                 group.

                 It may be equal to the flexi-n attribute, when the
                 flexi-n attribute is present.";
            }
            uses l0-types:flexi-grid-frequency-slot;
            list otsi-ref {
              key "carrier-ref";
              description
                "The list of references to the OTSis and their
                 end-to-end Media Channel (e2e-MC) paths within the
                 OTSiG carried by this media channel.";
              leaf carrier-ref {
                type leafref {
                  path "../../../../../../../../../../otsis/"
                     + "otsi-group[otsi-group-id=current()"
                     + "/../../../otsi-group-ref]/"
                     + "otsi/carrier-id";
                }
                description
                  "Reference to the OTSi within the OTSiG carried
                   by this media channel.";
              }
              leaf-list e2e-mc-path-ref {
                type leafref {
                  path "../../../../../../../../../../otsis/"
                     + "otsi-group[otsi-group-id=current()"
                     + "/../../../otsi-group-ref]/"
                     + "otsi[carrier-id=current()"
                     + "/../carrier-ref]/e2e-mc-path-id";
                }
                description
                  "References to the end-to-end Media Channel (e2e-MC)
                   paths of this OTSi which are routed through this
                   media channel.";
              }
            }
            leaf delta-power {
              type l0-types:power-ratio-or-unknown;
              description
                "Deviation from the reference carrier power defined
                 for the OMS.";
            }
          } // media channels list
        } // media-channel-groups list
      }
    } // media media-channel-groups grouping
```

```
     grouping oms-element {
       description
         "The list of the OMS elements, i.e., the building blocks
          (e.g., fibers, amplifiers, concentrated loss) that compose the
          OMS between its link termination points.";
       container oms-elements {
         presence
           "When present, it indicates that the list of OMS elements
            is reported.";
         description
           "The top level container for the list of OMS elements.";
         list oms-element {
           key "elt-index";
           description
             "The list of OMS elements.";
           leaf elt-index {
             type uint16;
             description
               "An index allowing sorting the elements in their physical
                order along the link without constraining their position
                in the list.";
           }
           leaf oms-element-uid {
             type union {
               type string;
               type l0-types:unknown-value;
             }
             description
               "Unique identifier of the OMS element, when known.";
           }
           container reverse-element-ref {
             description
               "It contains references to the elements which are
                associated with this element in the reverse
                direction.";
             leaf link-ref {
               type leafref {
                 path "../../../../../../../../nt:link/nt:link-id";
               }
               description
                 "The reference to the OMS link which the OMS elements
                  belongs to.";
             }
             leaf-list oms-element-ref {
               type leafref {
                 path "../../../../../../../../nt:link[nt:link-id="
                    + "current()/../link-ref]/tet:te/"
                    + "tet:te-link-attributes/oms-attributes/"
```

```
                    + "oms-elements/oms-element/elt-index";
               }
               description
                 "The references to the OMS elements.";
             }
           }
           choice element {
             mandatory true;
             description
               "OMS element type";
             case amplifier {
               uses tet:geolocation-container;
               uses amplifier-params;
             }
             case fiber {
               uses fiber-params;
             }
             case concentrated-loss {
               uses concentrated-loss-params;
             }
           }
         }
       }
     }

     grouping otsi-ref {
       description
         "References to an OTSi.

          This grouping is intended to be reused within the
          transceiver's list only.";
       leaf otsi-group-ref {
         type leafref {
           path "../../../../../../otsis/otsi-group/"
              + "otsi-group-id";
         }
         description
           "The OTSiG the referenced OTSi belongs to.";
       }
       leaf otsi-ref {
         type leafref {
           path "../../../../../../otsis/otsi-group"
              + "[otsi-group-id=current()/../otsi-group-ref]/otsi/"
              + "carrier-id";
         }
         description
           "The referenced OTSi.";
       }
```

```
     }

     /*
      * 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.";
         reference
           "RFC8345: A YANG Data Model for Network Topologies.";
       }
     }

     augment "/nw:networks/nw:network" {
       when './nw:network-types/tet:te-topology'
          + '/oit:optical-impairment-topology' {
         description
           "This augment is only valid for Optical Impairment
            topology.";
       }
       description
         "Network augmentation for optical impairments data.";
       container otsis {
         presence "When present, it indicates that OTSi information is
                   reported.";
         config false;
         description
           "The information about the OTSis configured on the WDM-TE
            link.";
         list otsi-group {
           key "otsi-group-id";
           description
             "the list of possible OTSiG representing client digital
              stream.";
           leaf otsi-group-id {
             type string;
             description
               "A network-wide unique identifier of otsi-group element.
                It could be structured, e.g., as a URI or as a UUID.";
           }
           uses otsi-group;
```

```
      } // list of OTSiG
    }
    container templates {
      config false;
      description
        "Templates for set of parameters which can be common to
         multiple elements.";
      container roadm-path-impairments-sets {
        description
          "The top level container for the list of the set of
           optical impairments related to ROADM paths.";
        list roadm-path-impairments-set {
          key "roadm-path-impairments-set-id";
          description
            "The list of the set of optical impairments related to a
             ROADM path.";
          leaf roadm-path-impairments-set-id {
            type string;
            description
              "The identifier of an element in the list of the set of
               optical impairments related to a ROADM path.";
          }
          leaf description {
            type string;
            description
              "The textual description of the set of optical
               impairments related to a ROADM path.";
          }
          choice impairment-type {
            description
              "Type path impairment.";
            case roadm-express-path {
              list roadm-express-path {
                key "frequency-range-id";
                description
                  "The list of optical impairments on a ROADM express
                   path for different frequency ranges.

                   Two elements in the list MUST NOT have the same
                   range or overlapping ranges.";
                uses l0-types:frequency-range-with-identifier;
                uses roadm-common-path;
              }
            }
            case roadm-add-path {
              list roadm-add-path {
                key "frequency-range-id";
                description
```

```
                     "The list of optical impairments on a ROADM add
                      path for different frequency ranges.

                      Two elements in the list MUST NOT have the same
                      range or overlapping ranges.";
                   uses l0-types:frequency-range-with-identifier;
                   uses roadm-add-path;
                 }
               }
               case roadm-drop-path {
                 list roadm-drop-path {
                   key "frequency-range-id";
                   description
                     "The list of optical impairments on a ROADM add
                      path for different frequency ranges.

                      Two elements in the list MUST NOT have the same
                      range or overlapping ranges.";
                   uses l0-types:frequency-range-with-identifier;
                   uses roadm-drop-path;
                 }
               }
             }
           } // list roadm-path-impairments-set
         } // container roadm-path-impairments-sets
         container explicit-transceiver-modes {
           description
             "The top level container for the list of the
              transceivers' explicit modes.";
           list explicit-transceiver-mode {
             key "explicit-transceiver-mode-id";
             description
               "The list of the transceivers' explicit modes.";
             leaf explicit-transceiver-mode-id {
               type string;
               description
                 "The identifier of the transceivers' explicit mode.";
             }
             uses l0-types:explicit-mode;
           } // list explicit-transceiver-mode
         } // container explicit-transceiver-modes
       } // container templates
     } // augment network

     augment "/nw:networks/nw:network/nw:node" {
       when '../nw:network-types/tet:te-topology'
          + '/oit:optical-impairment-topology' {
         description
```

```
           "This augment is only valid for Optical Impairment.";
       }
       description
         "Node augmentation for optical impairments data.";
       container transponders {
         presence
           "If present, it indicates that the list of transponders is
            reported.";
         config false;
         description
           "The top level container for the list of transponders.";
         list transponder {
           key "transponder-id";
           description
             "The list of transponders.";
           leaf transponder-id {
             type uint32;
             description
               "Transponder identifier.";
           }
           leaf termination-type-capabilities {
             type enumeration {
               enum tunnel-only {
                 description
                   "The transponder can only be used in an Optical
                    Tunnel termination configuration.";
               }
               enum 3r-only {
                 description
                   "The transponder can only be used in a 3R
                    configuration.";
               }
               enum 3r-or-tunnel {
                 description
                   "The transponder can be used either in an Optical
                    Tunnel termination configuration or in a 3R
                    configuration.";
               }
             }
             description
               "Describes whether the transponder can be used in an
                Optical Tunnel termination configuration or in a 3R
                configuration (or both).";
           }
           leaf supported-3r-mode {
             when '(../termination-type-capabilities = "3r-only") '
                + 'or (../termination-type-capabilities = '
                + '"3r-or-tunnel")' {
```

```
              description
                "Applies only when the transponder supports 3R
                 configuration.";
            }
            type enumeration {
              enum unidir {
                description
                  "Unidirectional 3R configuration.";
              }
              enum bidir {
                description
                  "Bidirectional 3R configuration.";
              }
            }
            description
              "Describes the supported 3R configuration type.";
          }
          list transceiver {
            key "transceiver-id";
            min-elements 1;
            description
              "List of transceiver related to a transponder.";
            leaf transceiver-id {
              type uint32;
              description
                "Transceiver identifier.";
            }
            uses l0-types:transceiver-capabilities {
              augment "supported-modes/supported-mode/mode/"
                    + "explicit-mode/explicit-mode" {
                description
                  "Augment the explicit-mode container with the
                   proper leafref.";
                leaf explicit-transceiver-mode-ref {
                  type leafref {
                    path "../../../../../../../../oit:templates"
                       + "/oit:explicit-transceiver-modes"
                       + "/oit:explicit-transceiver-mode"
                       + "/oit:explicit-transceiver-mode-id";
                  }
                  description
                    "The reference to the explicit transceiver
                     mode template.";
                }
              }
            }
            leaf configured-mode {
              type union {
```

```
                  type l0-types:unknown-value;
                  type leafref {
                    path "../supported-modes/supported-mode/mode-id";
                  }
                }
                description
                  "Reference to the configured mode for transceiver
                   compatibility approach.

                   The 'unknown' value is used to report that no mode has
                   been configured and there is no default mode.

                   When not present, the configured-mode is not reported
                   by the server.";
              }
              uses l0-types:common-transceiver-param;
              container outgoing-otsi {
                when '../../../../../otsis' {
                  description
                    "It applies only when the OTSi information is
                     reported.";
                }
                description
                  "The OTSi generated by the transceiver's transmitter.";
                uses otsi-ref;
              }
              container incoming-otsi {
                when '../../../../../otsis' {
                  description
                    "It applies only when the OTSi information is
                     reported.";
                }
                description
                  "The OTSi received by the transceiver's receiver.";
                uses otsi-ref;
              }
              leaf configured-termination-type {
                type enumeration {
                  enum unused-transceiver {
                    description
                      "The transcevier is not used.";
                  }
                  enum tunnel-termination {
                    description
                      "The transceiver is currently used in an Optical
                       Tunnel termination configuration.";
                  }
                  enum 3r-regeneration {
```

```
                   description
                     "The transceiver is currently used in a 3R
                      configuration.";
                 }
               }
               description
                 "Describes whether the current configuration of the
                  transceiver is used in an Optical Tunnel termination
                  configuration or in a 3R configuration.

                  If empty, it means that the information about the
                  configured-termination-type is not reported.";
             }
           } // end of list of transceiver
         } // end list of transponder
       }
       container regen-groups {
         presence "When present, it indicates that the list of 3R groups
                   is reported.";
         config false;
         description
           "The top level container for the list of 3R groups.";
         list regen-group {
           key "group-id";
           description
             "The list of 3R groups.

              Any 3R group represent a group of transponder in which an
              electrical connectivity is either in place or could
              be dynamically provided, to associated transponders used
              for 3R regeneration.";
           leaf group-id {
             type uint32;
             description
               "Group identifier used an index to access elements in the
                list of 3R groups.";
           }
           leaf regen-metric {
             type uint32;
             description
               "The cost permits choice among different groups of
                transponders during path computation.";
           }
           leaf-list transponder-ref {
             type leafref {
               path "../../../transponders/transponder/transponder-id";
             }
             description
```

```
               "The list of transponders belonging to this 3R group.";
           }
         } // end 3R-group
       }
     }

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

     augment "/nw:networks/nw:network/nw:node/tet:te"
           + "/tet:tunnel-termination-point" {
       when '../../../nw:network-types/tet:te-topology/'
          + 'oit:optical-impairment-topology' {
         description
           "This augment is only valid for Optical Impairment
            topology.";
       }
       description
         "Tunnel termination point augmentation for impairment data.";
       list ttp-transceiver {
         when '../../../transponders' {
           description
             "It applies only when the list of transponders is
              reported.";
         }
         key "transponder-ref transceiver-ref";
         config false;
         min-elements 1;
         description
           "The list of the transceivers used by the TTP.";
         leaf transponder-ref {
```

```
           type leafref {
             path "../../../../transponders/transponder/transponder-id";
           }
           description
             "The reference to the transponder hosting the transceiver
              of the TTP.";
         }
         leaf transceiver-ref {
           type leafref {
             path "../../../../transponders/transponder"
                + "[transponder-id=current()/../transponder-ref]/"
                + "transceiver/transceiver-id";
           }
           description
             "The reference to the transceiver of the TTP.";
         }
       } // list of transceivers
     } // end of augment

     augment "/nw:networks/nw:network/nw:node/nt:termination-point" {
       when '../../nw:network-types/tet:te-topology/'
          + 'oit:optical-impairment-topology' {
         description
           "This augment is only valid for Optical Impairment
            topology.";
       }
       description
         "Augment LTP";
       leaf protection-type {
         type identityref {
           base te-types:lsp-protection-type;
         }
         config false;
         description
           "The protection type that this LTP is capable of.

            When not present it indicates that the information about
            the protection type is not reported.";
       }
     }

     augment "/nw:networks/nw:network/nw:node/nt:termination-point"
           + "/tet:te" {
       when '../../../nw:network-types/tet:te-topology/'
          + 'oit:optical-impairment-topology' {
         description
           "This augment is only valid for Optical Impairment
            topology.";
```

```
        }
        description
          "Augment TE attributes of an LTP";
        leaf inter-layer-sequence-number {
          type uint32;
          config false;
          description
            "The inter-layer-sequence-number (ILSN) is used to report
             additional connectivity constraints between a client layer
             Link Termination Point (LTP), such as a muxponder port, and
             the server layer Tunnel Termination Point (TTP).

             A client service cannot be setup between two client layer
             LTPs which report different values of the ILSN.

             This attribute is not reported when there are no additional
             connectivity constraints.

             Therefore, a client service can be setup when at least one
             of the two client layer LTPs does not report any ILSN or
             both client layer LTPs report the same ILSN value and the
             corresponding server layer TTPs have at least one common
             server-layer switching capability and at least one common
             client-layer switching capability.";
        }
      }

      augment "/nw:networks/nw:network/nw:node/tet:te/"
            + "tet:information-source-entry/tet:connectivity-matrices" {
        when '../../../../nw:network-types/tet:te-topology/'
           + 'oit:optical-impairment-topology' {
          description
            "This augment is only valid for Optical Impairment
             topology.";
        }
        description
          "Augment default TE node connectivity matrix information
           source.";
        leaf roadm-path-impairments-set {
          type leafref {
            path "../../../../../oit:templates"
               + "/oit:roadm-path-impairments-sets"
               + "/oit:roadm-path-impairments-set"
               + "/oit:roadm-path-impairments-set-id";
          }
          config false;
          description
            "Pointer to optical impairments of the associated ROADM
```

```
           path.";
       }
     } // augmentation connectivity-matrices information-source

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:information-source-entry/tet:connectivity-matrices/"
           + "tet:connectivity-matrix" {
       when '../../../../../nw:network-types/tet:te-topology/'
          + 'oit:optical-impairment-topology' {
         description
           "This augment is only valid for Optical Impairment
            topology.";
       }
       description
         "Augment TE node connectivity matrix entry information
          source.";
       leaf roadm-path-impairments-set {
         type leafref {
           path "../../../../../../oit:templates"
              + "/oit:roadm-path-impairments-sets"
              + "/oit:roadm-path-impairments-set"
              + "/oit:roadm-path-impairments-set-id";
         }
         config false;
         description
           "Pointer to optical impairments of the associated ROADM
            path.";
       }
     } // augmentation connectivity-matrix information-source

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices" {
       when '../../../../nw:network-types/tet:te-topology/'
          + 'oit:optical-impairment-topology' {
         description
           "This augment is only valid for Optical Impairment
            topology.";
       }
       description
         "Augment default TE node connectivity matrix.";
       leaf roadm-path-impairments-set {
         type leafref {
           path "../../../../../oit:templates"
              + "/oit:roadm-path-impairments-sets"
              + "/oit:roadm-path-impairments-set"
              + "/oit:roadm-path-impairments-set-id";
         }
         config false;
```

```
         description
           "Pointer to optical impairments of the associated ROADM
            path.";
       }
     } // augmentation connectivity-matrices

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/"
           + "tet:connectivity-matrices/tet:connectivity-matrix" {
       when '../../../../../nw:network-types/tet:te-topology/'
          + 'oit:optical-impairment-topology' {
         description
           "This augment is only valid for Optical Impairment
            topology.";
       }
       description
         "Augment TE node connectivity matrix entry.";
       leaf roadm-path-impairments-set {
         type leafref {
           path "../../../../../../oit:templates"
              + "/oit:roadm-path-impairments-sets"
              + "/oit:roadm-path-impairments-set"
              + "/oit:roadm-path-impairments-set-id";
         }
         config false;
         description
           "Pointer to optical impairments of the associated ROADM
            path.";
       }
     } // augmentation connectivity-matrix

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:connectivity-matrix/tet:from" {
       when '../../../../../../nw:network-types/tet:te-topology/'
          + 'oit:optical-impairment-topology' {
         description
           "This augment is only valid for Optical Impairment
            topology.";
       }
       description
         "Augment the attributes for the 'from' LTP for the TE node
          connectivity matrix entry.";
       list additional-ltp {
         when "derived-from-or-self(../../../../../../"
            + "nt:termination-point"
            + "[nt:tp-id=current()/../../tet:to/tet:tp-ref]/"
            + "oit:protection-type,"
```

```
            + "'oit:otsi-protection')" {
           description
             "This list applies only when the 'to' LTP for this
              connectivity matrix entry supports individual OTSi(G)
              protection.";
         }
         key "ltp-ref";
         config false;
         description
           "The restricted list of the potential secondary LTPs that
            can be selected when the 'from' LTP of this connectivity
            matrix entry is selected as a working LTP.

            If this list is empty, all the other LTPs that can reach
            the 'to' LTP of this connectivity matrix entry can be
            selected as secondary LTPs.";
         leaf ltp-ref {
           type leafref {
             path "../../../../../../../nt:termination-point/nt:tp-id";
           }
           description
             "The reference to the potential secondary LTP that can be
              selected when the 'from' LTP of this connectivity matrix
              entry is selected as a working LTP.";
         }
         leaf roadm-path-impairments-set {
           type leafref {
             path "../../../../../../../../../oit:templates"
                + "/oit:roadm-path-impairments-sets"
                + "/oit:roadm-path-impairments-set"
                + "/oit:roadm-path-impairments-set-id";
           }
           description
             "Pointer to optical impairments of the ROADM path between
              this secondary 'from' LTP and the 'to' LTP of this
              connectivity matrix entry.";
         }
       }
     } // augmentation connectivity-matrix from

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:connectivity-matrix/tet:to" {
       when '../../../../../../nw:network-types/tet:te-topology/'
          + 'oit:optical-impairment-topology' {
         description
           "This augment is only valid for Optical Impairment
            topology.";
```

```
        }
        description
          "Augment the attributes for the 'to' LTP for the TE node
           connectivity matrix entry.";
        list additional-ltp {
          when "derived-from-or-self(../../../../../../"
             + "nt:termination-point"
             + "[nt:tp-id=current()/../../tet:from/tet:tp-ref]/"
             + "oit:protection-type,"
             + "'oit:otsi-protection')" {
            description
              "This list applies only when the 'from' LTP for this
               connectivity matrix entry supports individual OTSi(G)
               protection.";
          }
          key "ltp-ref";
          config false;
          description
            "The restricted list of the potential secondary LTPs that
             can be selected when the 'to' LTP of this connectivity
             matrix entry is selected as a working LTP.

             If this list is empty, all the other LTPs that can be
             reached from the 'from' LTP of this connectivity matrix
             entry can be selected as secondary LTPs.";
          leaf ltp-ref {
            type leafref {
              path "../../../../../../../nt:termination-point/nt:tp-id";
            }
            description
              "The reference to the potential secondary LTP that can be
               selected when the 'to' LTP of this connectivity matrix
               entry is selected as a working LTP.";
          }
          leaf roadm-path-impairments-set {
            type leafref {
              path "../../../../../../../../oit:templates"
                 + "/oit:roadm-path-impairments-sets"
                 + "/oit:roadm-path-impairments-set"
                 + "/oit:roadm-path-impairments-set-id";
            }
            description
              "Pointer to optical impairments of the ROADM path between
               the 'from' LTP of this connectivity matrix entry and this
               secondary LTP.";
          }
        }
      } // augmentation connectivity-matrix to
```

```
     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:tunnel-termination-point/"
           + "tet:local-link-connectivities" {
       when '../../../../nw:network-types/tet:te-topology/'
          + 'oit:optical-impairment-topology' {
         description
           "This augment is only valid for Optical Impairment
            topology.";
       }
       description
         "Augment default TTP LLC.";
       leaf add-path-impairments-set {
         type leafref {
           path "../../../../../oit:templates"
              + "/oit:roadm-path-impairments-sets"
              + "/oit:roadm-path-impairments-set"
              + "/oit:roadm-path-impairments-set-id";
         }
         config false;
         description
           "Pointer to optical impairments of the associated ROADM
            path.";
       }
       leaf drop-path-impairments-set {
         type leafref {
           path "../../../../../oit:templates"
              + "/oit:roadm-path-impairments-sets"
              + "/oit:roadm-path-impairments-set"
              + "/oit:roadm-path-impairments-set-id";
         }
         config false;
         description
           "Pointer to optical impairments of the associated ROADM
            path.";
       }
     } // augmentation local-link-connectivities

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:tunnel-termination-point/"
           + "tet:local-link-connectivities/"
           + "tet:local-link-connectivity" {
       when '../../../../../nw:network-types/tet:te-topology/'
          + 'oit:optical-impairment-topology' {
         description
           "This augment is only valid for Optical Impairment
            topology.";
       }
       description
```

```
          "Augment TTP LLC entry.";
        leaf add-path-impairments-set {
          type leafref {
            path "../../../../../../oit:templates"
               + "/oit:roadm-path-impairments-sets"
               + "/oit:roadm-path-impairments-set"
               + "/oit:roadm-path-impairments-set-id";
          }
          config false;
          description
            "Pointer to optical impairments of the associated ROADM
             path.";
        }
        leaf drop-path-impairments-set {
          type leafref {
            path "../../../../../../oit:templates"
               + "/oit:roadm-path-impairments-sets"
               + "/oit:roadm-path-impairments-set"
               + "/oit:roadm-path-impairments-set-id";
          }
          config false;
          description
            "Pointer to optical impairments of the associated ROADM
             path.";
        }
        list llc-transceiver {
          key "ttp-transponder-ref ttp-transceiver-ref";
          config false;
          description
            "The list of transceivers having an LLC different from the
             default LLC.";
          leaf ttp-transponder-ref {
            type leafref {
              path "../../../../ttp-transceiver/transponder-ref";
            }
            description
              "The reference to the transponder hosting the transceiver
               of this LLCL entry.";
          }
          leaf ttp-transceiver-ref {
            type leafref {
              path "../../../../ttp-transceiver/transceiver-ref";
            }
            description
              "The reference to the transceiver of this LLCL entry.";
          }
          leaf is-allowed {
            type boolean;
```

```
            description
              "'true' - connectivity from this transceiver is allowed;
               'false' - connectivity from this transceiver is
               disallowed.";
          }
          leaf add-path-impairments-set {
            type leafref {
              path "../../../../../../../oit:templates"
                 + "/oit:roadm-path-impairments-sets"
                 + "/oit:roadm-path-impairments-set"
                 + "/oit:roadm-path-impairments-set-id";
            }
            description
              "Pointer to optical impairments of the associated ROADM
               path.";
          }
          leaf drop-path-impairments-set {
            type leafref {
              path "../../../../../../../oit:templates"
                 + "/oit:roadm-path-impairments-sets"
                 + "/oit:roadm-path-impairments-set"
                 + "/oit:roadm-path-impairments-set-id";
            }
            description
              "Pointer to optical impairments of the associated ROADM
               path.";
          }
        }
        list additional-ltp {
          when "derived-from-or-self(../../../tet:protection-type,"
             + "'oit:otsi-protection')" {
            description
              "This list applies only to TTPs that support individual
               OTSi(G) protection.";
          }
          key "ltp-ref";
          config false;
          description
            "The restricted list of the potential secondary LTPs that
             can be selected when the LTP associated with this LLCP
             entry is selected as a working LTP.

             If this list is empty, all the other LTPs that can be
             reached by this TTP can be selected as secondary LTPs.";
          leaf ltp-ref {
            type leafref {
              path "../../../../../../nt:termination-point/nt:tp-id";
            }
```

```
           description
             "The reference to potential secondary LTP that can be
              selected when the LTP associated with this LLCP entry is
              selected as a working LTP.";
         }
         leaf add-path-impairments-set {
           type leafref {
             path "../../../../../../../oit:templates"
                + "/oit:roadm-path-impairments-sets"
                + "/oit:roadm-path-impairments-set"
                + "/oit:roadm-path-impairments-set-id";
           }
           description
             "Pointer to optical impairments of the associated ROADM
              path.";
         }
         leaf drop-path-impairments-set {
           type leafref {
             path "../../../../../../../oit:templates"
                + "/oit:roadm-path-impairments-sets"
                + "/oit:roadm-path-impairments-set"
                + "/oit:roadm-path-impairments-set-id";
           }
           description
             "Pointer to optical impairments of the associated ROADM
              path.";
         }
       }
     } // augmentation local-link-connectivity

   }
   <CODE ENDS>
```

3.1. YANG Model Explanations

As indicated in [RFC8345], section 4.1, "When a network is of a certain type, it will contain a corresponding data node. Network types SHOULD always be represented using presence containers". The YANG model is in fact augmenting "nw:network-types/tet:te-topology" with the new presence container "optical-impairment-topology" representing an impairment-aware topology type.

As described in Section 2.3.1, the OTSi signals in the YANG model are described by augmenting the "nw:network" data node and each OTSi signal is uniquely identified by its otsi-carrier-id, which is unique within the scope the OTSiG the OTSi belongs to.

As described in Section 2.3.2, all OTSiGs are described in the YANG model by augmenting the "nw:network" data node and each OTSiG is uniquely identified by its otsi-group-id, which is unique within the network. Each OTSiG also contains a list of the OTSi signals belonging to the OTSiG.

Any OTSi signal is terminated by a transceiver and that is modeled as a function of the tunnel termination point (TTP) and a "ttp-transceiver" list of transceivers augmenting the "tunnel-termination-point".

The relationship between OTSi and the related transceiver is provided in the YANG model by the containers "incoming-otsi" for the OTSi received by the transceiver's receiver and "outgoing-otsi" for the OTSi generated by the transceiver's transmitter.

As described in Section 2.7, transponders are usually used to terminate a layer 0 tunnel. But, they also can be used to regenerate the signal and form a 3R regenerator. No new entity is needed in the model since 3R functionality is provided by an optical transponder pair. The YANG model provides two attributes related to 3R regenerators: "supported-termination-type" and "supported-3r-mode".

supported-termination-type is describing if an optical transponder is supporting tunnel termination only, or 3R regenerator only, or both.

supported-3r-mode gives the configuration of transponder pair providing the 3R functionality, if back-to-back (see Figure 6) or Cross-3R (see Figure 7).

The model also provides a "regen-group" list and each list entry represents a group of transponders that support the 3R functionality. "transponder-ref" is pointing to the transponders belonging to any specific group.

The data node "inter-layer-sequence-number" augments the termination point attribute to describe additional constraints between a client layer Link Termination Point (LTP), e.g., a muxponder port and a server layer LTP.

To improve scalability, the model is defining templates for both, "roadm-path-impairments-set", the list of the set of optical impairments related to ROADM paths (express, add and drop paths) and "explicit-transceiver-mode",the list of optical parameters related to a transceiver's explicit mode providing the capability attributes and optical impairment limits of an explicit transceiver mode. These templates are also defined as "network" augmentation.

As stated in Section 2.6, the model defines three types of approaches to describes the transceiver capabilities (called "modes"):

* Standard Modes

* Organizational Modes

* Explicit Modes

These different modes (described in Section 2.6.1, Section 2.6.2, and Section 2.6.3) are defined under the "transponders" presence container augmenting the data node "node" as defined in [RFC8345]. If present, this container will indicate that the set of transponders/transceivers in a node is described with all the impairments attribute depending on the supported mode type of any specific transponder. The YANG model permits to describe the transponder capabilities in a mixed way (a transceiver can support more than one mode out of the three mode types).

Section 2.3 followed by Section 2.3.3, and Section 2.3.4 describe the OMS MCG and the OTS MCG and the model represents this entity as a WDM TE-link interconnecting two WDM-TE-nodes. The model augments the te-link-attributes defined in [RFC8795] with the optical impairments for the WDM TE-link of the layer-0 topology related to a specific network controller domain.

As described in detail in Section 2.10, the optical impairments imposed by passive or active optical ROADM components for the three different ROADM path types have to be taken into account when an OTSi signal crosses a ROADM node. The following two entities defined in [RFC8795] are used to describe the optical impairments for the 3 MC path types: "connectivity-matrix" for express paths and "local-link-connectivity-list" for Add/Drop paths crossing the ROADM.

A list of optical impairment sets "roadm-path-impairments-set" is defined under "templates", and this parameter set list entries will contain the optical impairments for express, add, and drop paths.

The connectivity-matrix is augmented with the optical impairment sets for the ROADM’s express-path contained in the "roadm-path-impairments-set", while the LLCL is augmented with the optical impairment sets contained in the "roadm-path-impairments-set" for the ROADM’s add-path and drop-path by using leafref "add-path-impairments-set" and leafref "drop-path-impairments-set".

In case OTSi protection is supported, a list of additional line LTPs is defined in the model to represent potential connectivity between an add-drop LTP/TTP and multiple line LTPs including the related optical impairments. See Section 2.11.1.2 for more details). Additional OTSi protection architectures are described in detail in Section 2.11.1.1 and Section 2.11.1.3.

4. Security Considerations

This section is based on the template in Section 3.7 of [I-D.ietf-netmod-rfc8407bis].

The "ietf-optical-impairment-topology" YANG module defines a data model that is designed to be accessed via YANG-based management protocols, such as NETCONF [RFC6241] and RESTCONF [RFC8040]. These YANG-based management protocols

(1) have to use a secure transport layer (e.g., SSH [RFC4252], TLS [RFC8446], and QUIC [RFC9000] and

(2) have to use mutual authentication.

The Network Configuration Access Control Model (NACM) [RFC8341] provides the means to restrict access for particular NETCONF or RESTCONF users to a preconfigured subset of all available NETCONF or RESTCONF protocol operations and content.

There are no particularly sensitive readable data nodes.

This YANG module uses groupings from other YANG modules that define nodes that may be considered sensitive or vulnerable in network environments. Refer to the Security Considerations of [I-D.ietf-ccamp-rfc9093-bis] for information as to which nodes may be considered sensitive or vulnerable in network environments.

Finally, the YANG module described in this document augments the "ietf-network" YANG module [RFC8345] and the "ietf-te-topology" YANG module [RFC8795] by adding data nodes. The security considerations for the subtrees described in those RFCs apply equally to the new data nodes that this module adds.

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 module in the YANG Module Names registry [RFC7950]:

```
--------------------------------------------------------------------
name:      ietf-optical-impairment-topology
namespace: urn:ietf:params:xml:ns:yang:ietf-optical-impairment-
topology
prefix:    oit
maintained by IANA? N
reference: RFC XXXX (TDB)
--------------------------------------------------------------------
```

6. Acknowledgments

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

7. References

7.1. Normative References

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7.2. Informative References

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Appendix A. YANG Model Tree Structure

```
   module: ietf-optical-impairment-topology

     augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
       +--rw optical-impairment-topology!
     augment /nw:networks/nw:network:
       +--ro otsis!
       |  +--ro otsi-group* [otsi-group-id]
       |     +--ro otsi-group-id    string
       |     +--ro otsi* [carrier-id]
       |        +--ro carrier-id           uint16
       |        +--ro carrier-frequency?   union
       |        +--ro e2e-mc-path-id*      uint16
       +--ro templates
          +--ro roadm-path-impairments-sets
          |  +--ro roadm-path-impairments-set*
          |          [roadm-path-impairments-set-id]
          |     +--ro roadm-path-impairments-set-id    string
          |     +--ro description?                     string
          |     +--ro (impairment-type)?
          |        +--:(roadm-express-path)
          |        |  +--ro roadm-express-path* [frequency-range-id]
          |        |     +--ro frequency-range-id        uint16
          |        |     +--ro frequency-range
          |        |     |  +--ro lower-frequency    frequency-thz
          |        |     |  +--ro upper-frequency    frequency-thz
          |        |     +--ro roadm-pmd?                union
          |        |     +--ro roadm-cd?
          |        |     |       l0-types:decimal-5-or-unknown
          |        |     +--ro roadm-pdl?
          |        |     |       l0-types:power-loss-or-unknown
          |        |     +--ro roadm-inband-crosstalk?
          |        |     |       l0-types:decimal-2-or-unknown
          |        |     +--ro roadm-maxloss?
          |        |             l0-types:power-loss-or-unknown
          |        +--:(roadm-add-path)
          |        |  +--ro roadm-add-path* [frequency-range-id]
          |        |     +--ro frequency-range-id        uint16
          |        |     +--ro frequency-range
          |        |     |  +--ro lower-frequency    frequency-thz
          |        |     |  +--ro upper-frequency    frequency-thz
          |        |     +--ro roadm-pmd?                union
          |        |     +--ro roadm-cd?
          |        |     |       l0-types:decimal-5-or-unknown
          |        |     +--ro roadm-pdl?
          |        |     |       l0-types:power-loss-or-unknown
          |        |     +--ro roadm-inband-crosstalk?
```

```
     |        |     |       l0-types:decimal-2-or-unknown
     |        |     +--ro roadm-maxloss?
     |        |     |       l0-types:power-loss-or-unknown
     |        |     +--ro roadm-pmax?
     |        |     |       l0-types:power-dbm-or-unknown
     |        |     +--ro roadm-osnr?
     |        |     |       l0-types:snr-or-unknown
     |        |     +--ro roadm-noise-figure?
     |        |             l0-types:decimal-5-or-unknown
     |        +--:(roadm-drop-path)
     |           +--ro roadm-drop-path* [frequency-range-id]
     |              +--ro frequency-range-id        uint16
     |              +--ro frequency-range
     |              |  +--ro lower-frequency    frequency-thz
     |              |  +--ro upper-frequency    frequency-thz
     |              +--ro roadm-pmd?                union
     |              +--ro roadm-cd?
     |              |       l0-types:decimal-5-or-unknown
     |              +--ro roadm-pdl?
     |              |       l0-types:power-loss-or-unknown
     |              +--ro roadm-inband-crosstalk?
     |              |       l0-types:decimal-2-or-unknown
     |              +--ro roadm-maxloss?
     |              |       l0-types:power-loss-or-unknown
     |              +--ro roadm-minloss?
     |              |       l0-types:power-loss-or-unknown
     |              +--ro roadm-typloss?
     |              |       l0-types:power-loss-or-unknown
     |              +--ro roadm-pmin?
     |              |       l0-types:power-dbm-or-unknown
     |              +--ro roadm-pmax?
     |              |       l0-types:power-dbm-or-unknown
     |              +--ro roadm-ptyp?
     |              |       l0-types:power-dbm-or-unknown
     |              +--ro roadm-osnr?
     |              |       l0-types:snr-or-unknown
     |              +--ro roadm-noise-figure?
     |                      l0-types:decimal-5-or-unknown
     +--ro explicit-transceiver-modes
        +--ro explicit-transceiver-mode*
                [explicit-transceiver-mode-id]
           +--ro explicit-transceiver-mode-id        string
           +--ro line-coding-bitrate?                identityref
           +--ro bitrate?                            uint16
           +--ro max-diff-group-delay?               decimal-2
           +--ro max-chromatic-dispersion?           decimal-2
           +--ro cd-penalty* [cd-value]
           |  +--ro cd-value         decimal-2
```

```
             |  +--ro penalty-value    union
             +--ro max-polarization-mode-dispersion?   decimal-2
             +--ro pmd-penalty* [pmd-value]
             |  +--ro pmd-value        decimal-2
             |  +--ro penalty-value    union
             +--ro max-polarization-dependent-loss
             |       power-loss-or-unknown
             +--ro pdl-penalty* [pdl-value]
             |  +--ro pdl-value        power-loss
             |  +--ro penalty-value    union
             +--ro available-modulation-type?          identityref
             +--ro min-OSNR?                           snr
             +--ro rx-ref-channel-power?               power-dbm
             +--ro rx-channel-power-penalty* [rx-channel-power-value]
             |  +--ro rx-channel-power-value    power-dbm
             |  +--ro penalty-value             union
             +--ro min-Q-factor?                       decimal-2
             +--ro available-baud-rate?                decimal64
             +--ro roll-off?                           decimal64
             +--ro min-carrier-spacing?                frequency-ghz
             +--ro available-fec-type?                 identityref
             +--ro fec-code-rate?                      decimal64
             +--ro fec-threshold?                      decimal64
             +--ro in-band-osnr?                       snr
             +--ro out-of-band-osnr?                   snr
             +--ro tx-polarization-power-difference?   power-ratio
             +--ro polarization-skew?                  decimal-2
  augment /nw:networks/nw:network/nw:node:
    +--ro transponders!
    |  +--ro transponder* [transponder-id]
    |     +--ro transponder-id                  uint32
    |     +--ro termination-type-capabilities?   enumeration
    |     +--ro supported-3r-mode?              enumeration
    |     +--ro transceiver* [transceiver-id]
    |        +--ro transceiver-id                uint32
    |        +--ro supported-modes!
    |        |  +--ro supported-mode* [mode-id]
    |        |     +--ro mode-id                          string
    |        |     +--ro (mode)
    |        |        +--:(g.698.2)
    |        |        |  +--ro g.698.2
    |        |        |     +--ro standard-mode
    |        |        |     |       standard-mode
    |        |        |     +--ro line-coding-bitrate*
    |        |        |     |       identityref
    |        |        |     +--ro transceiver-tuning-range
    |        |        |     |  +--ro min-central-frequency?
    |        |        |     |  |       frequency-thz
```

```
     |        |        |     |  +--ro max-central-frequency?
     |        |        |     |  |       frequency-thz
     |        |        |     |  +--ro transceiver-tunability-granular\
ity?
     |        |        |     |          frequency-ghz
     |        |        |     +--ro tx-channel-power-min?
     |        |        |     |       power-dbm
     |        |        |     +--ro tx-channel-power-max?
     |        |        |     |       power-dbm
     |        |        |     +--ro rx-channel-power-min?
     |        |        |     |       power-dbm
     |        |        |     +--ro rx-channel-power-max?
     |        |        |     |       power-dbm
     |        |        |     +--ro rx-total-power-max?
     |        |        |             power-dbm
     |        |        +--:(organizational-mode)
     |        |        |  +--ro organizational-mode
     |        |        |     +--ro operational-mode
     |        |        |     |       operational-mode
     |        |        |     +--ro organization-identifier
     |        |        |     |       organization-identifier
     |        |        |     +--ro line-coding-bitrate*
     |        |        |     |       identityref
     |        |        |     +--ro transceiver-tuning-range
     |        |        |     |  +--ro min-central-frequency?
     |        |        |     |  |       frequency-thz
     |        |        |     |  +--ro max-central-frequency?
     |        |        |     |  |       frequency-thz
     |        |        |     |  +--ro transceiver-tunability-granular\
ity?
     |        |        |     |          frequency-ghz
     |        |        |     +--ro tx-channel-power-min?
     |        |        |     |       power-dbm
     |        |        |     +--ro tx-channel-power-max?
     |        |        |     |       power-dbm
     |        |        |     +--ro rx-channel-power-min?
     |        |        |     |       power-dbm
     |        |        |     +--ro rx-channel-power-max?
     |        |        |     |       power-dbm
     |        |        |     +--ro rx-total-power-max?
     |        |        |             power-dbm
     |        |        +--:(explicit-mode)
     |        |           +--ro explicit-mode
     |        |              +--ro transceiver-tuning-range
     |        |              |  +--ro min-central-frequency?
     |        |              |  |       frequency-thz
     |        |              |  +--ro max-central-frequency?
     |        |              |  |       frequency-thz
```

```
     |        |              |  +--ro transceiver-tunability-granular\
  ity?
     |        |              |          frequency-ghz
     |        |              +--ro tx-channel-power-min?
     |        |              |       power-dbm
     |        |              +--ro tx-channel-power-max?
     |        |              |       power-dbm
     |        |              +--ro rx-channel-power-min?
     |        |              |       power-dbm
     |        |              +--ro rx-channel-power-max?
     |        |              |       power-dbm
     |        |              +--ro rx-total-power-max?
     |        |              |       power-dbm
     |        |              +--ro compatible-modes
     |        |              |  +--ro supported-application-code*
     |        |              |  |       leafref
     |        |              |  +--ro supported-organizational-mode*
     |        |              |          leafref
     |        |              +--ro explicit-transceiver-mode-ref?
     |        |                      leafref
     |        +--ro configured-mode?               union
     |        +--ro line-coding-bitrate?           identityref
     |        +--ro tx-channel-power?
     |        |       power-dbm-or-unknown
     |        +--ro rx-channel-power?
     |        |       power-dbm-or-unknown
     |        +--ro rx-total-power?
     |        |       power-dbm-or-unknown
     |        +--ro outgoing-otsi
     |        |  +--ro otsi-group-ref?   leafref
     |        |  +--ro otsi-ref?         leafref
     |        +--ro incoming-otsi
     |        |  +--ro otsi-group-ref?   leafref
     |        |  +--ro otsi-ref?         leafref
     |        +--ro configured-termination-type?   enumeration
     +--ro regen-groups!
        +--ro regen-group* [group-id]
           +--ro group-id           uint32
           +--ro regen-metric?      uint32
           +--ro transponder-ref*
                   -> ../../../transponders/transponder/transponder-id
    augment /nw:networks/nw:network/nt:link/tet:te
              /tet:te-link-attributes:
      +--ro oms-attributes
         +--ro generalized-snr?        l0-types:snr
         +--ro equalization-mode?      identityref
         +--ro power-param
         |  +--ro nominal-carrier-power?
```

```
     |  |       l0-types:power-dbm-or-unknown
     |  +--ro nominal-psd?            l0-types:psd-or-unknown
     +--ro media-channel-groups!
     |  +--ro media-channel-group* [otsi-group-ref]
     |     +--ro otsi-group-ref    leafref
     |     +--ro media-channel* [media-channel-id]
     |        +--ro media-channel-id    int16
     |        +--ro flexi-n?            flexi-n
     |        +--ro flexi-m?            flexi-m
     |        +--ro otsi-ref* [carrier-ref]
     |        |  +--ro carrier-ref        leafref
     |        |  +--ro e2e-mc-path-ref*   leafref
     |        +--ro delta-power?
     |                l0-types:power-ratio-or-unknown
     +--ro oms-elements!
        +--ro oms-element* [elt-index]
           +--ro elt-index                  uint16
           +--ro oms-element-uid?           union
           +--ro reverse-element-ref
           |  +--ro link-ref?
           |  |       -> ../../../../../../../../nt:link/link-id
           |  +--ro oms-element-ref*   leafref
           +--ro (element)
              +--:(amplifier)
              |  +--ro geolocation
              |  |  +--ro altitude?    int64
              |  |  +--ro latitude?    geographic-coordinate-degree
              |  |  +--ro longitude?   geographic-coordinate-degree
              |  +--ro amplifier
              |     +--ro type-variety    string
              |     +--ro operational
              |        +--ro amplifier-element*
              |                [frequency-range-id stage-order]
              |           +--ro frequency-range-id
              |           |       uint16
              |           +--ro frequency-range
              |           |  +--ro lower-frequency    frequency-thz
              |           |  +--ro upper-frequency    frequency-thz
              |           +--ro stage-order
              |           |       uint8
              |           +--ro name?
              |           |       string
              |           +--ro type-variety?
              |           |       string
              |           +--ro power-param
              |           |  +--ro (power-param)
              |           |     +--:(channel-power)
              |           |     |  +--ro nominal-carrier-power
```

```
                 |            |     |          l0-types:power-dbm-or-u\
   nknown
                 |            |     +--:(power-spectral-density)
                 |            |        +--ro nominal-psd
                 |            |                l0-types:psd-or-unknown
                 |            +--ro pdl?
                 |            |       l0-types:power-loss-or-unknown
                 |            +--ro (amplifier-element-type)
                 |               +--:(optical-amplifier)
                 |               |  +--ro optical-amplifier
                 |               |     +--ro actual-gain
                 |               |     |       l0-types:power-gain-or-\
   unknown
                 |               |     +--ro in-voa?
                 |               |     |       l0-types:power-loss-or-\
   unknown
                 |               |     +--ro out-voa?
                 |               |     |       l0-types:power-loss-or-\
   unknown
                 |               |     +--ro tilt-target
                 |               |     |       l0-types:decimal-2-or-u\
   nknown
                 |               |     +--ro total-output-power
                 |               |     |       l0-types:power-dbm-or-u\
   nknown
                 |               |     +--ro raman-direction?
                 |               |     |       enumeration
                 |               |     +--ro raman-pump* [pump-id]
                 |               |        +--ro pump-id      uint16
                 |               |        +--ro frequency?
                 |               |        |       l0-types:frequency-t\
   hz
                 |               |        +--ro power?
                 |               |                l0-types:decimal-2-o\
   r-unknown
                 |               +--:(dynamic-gain-equalizer)
                 |                  +--ro dynamic-gain-equalizer!
                 |                     +--ro media-channel* [flexi-n]
                 |                        +--ro flexi-n        flexi-n
                 |                        +--ro flexi-m        flexi-m
                 |                        +--ro delta-power?
                 |                                l0-types:power-ratio\
   -or-unknown
                 +--:(fiber)
                 |  +--ro fiber
                 |     +--ro type-variety    string
                 |     +--ro length
                 |     |       l0-types:decimal-2-or-unknown
```

```
                 |     +--ro loss-coef
                 |     |       l0-types:decimal-2-or-unknown
                 |     +--ro total-loss?
                 |     |       l0-types:power-loss-or-unknown
                 |     +--ro pmd?
                 |     |       l0-types:decimal-2-or-unknown
                 |     +--ro conn-in?
                 |     |       l0-types:power-loss-or-unknown
                 |     +--ro conn-out?
                 |             l0-types:power-loss-or-unknown
                 +--:(concentrated-loss)
                    +--ro concentrated-loss
                       +--ro loss    l0-types:power-loss-or-unknown
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:tunnel-termination-point:
    +--ro ttp-transceiver* [transponder-ref transceiver-ref]
       +--ro transponder-ref
       |       -> ../../../../transponders/transponder/transponder-id
       +--ro transceiver-ref    leafref
  augment /nw:networks/nw:network/nw:node/nt:termination-point:
    +--ro protection-type?   identityref
  augment /nw:networks/nw:network/nw:node/nt:termination-point
            /tet:te:
    +--ro inter-layer-sequence-number?   uint32
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:information-source-entry/tet:connectivity-matrices:
    +--ro roadm-path-impairments-set?   leafref
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:information-source-entry/tet:connectivity-matrices
            /tet:connectivity-matrix:
    +--ro roadm-path-impairments-set?   leafref
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:te-node-attributes/tet:connectivity-matrices:
    +--ro roadm-path-impairments-set?   leafref
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:te-node-attributes/tet:connectivity-matrices
            /tet:connectivity-matrix:
    +--ro roadm-path-impairments-set?   leafref
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:te-node-attributes/tet:connectivity-matrices
            /tet:connectivity-matrix/tet:from:
    +--ro additional-ltp* [ltp-ref]
       +--ro ltp-ref
       |       -> ../../../../../../../nt:termination-point/tp-id
       +--ro roadm-path-impairments-set?   leafref
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:te-node-attributes/tet:connectivity-matrices
            /tet:connectivity-matrix/tet:to:
```

```
       +--ro additional-ltp* [ltp-ref]
          +--ro ltp-ref
          |       -> ../../../../../../../nt:termination-point/tp-id
          +--ro roadm-path-impairments-set?   leafref
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:tunnel-termination-point
               /tet:local-link-connectivities:
       +--ro add-path-impairments-set?    leafref
       +--ro drop-path-impairments-set?   leafref
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:tunnel-termination-point
               /tet:local-link-connectivities
               /tet:local-link-connectivity:
       +--ro add-path-impairments-set?    leafref
       +--ro drop-path-impairments-set?   leafref
       +--ro llc-transceiver* [ttp-transponder-ref ttp-transceiver-ref]
       |  +--ro ttp-transponder-ref
       |  |       -> ../../../../ttp-transceiver/transponder-ref
       |  +--ro ttp-transceiver-ref
       |  |       -> ../../../../ttp-transceiver/transceiver-ref
       |  +--ro is-allowed?                  boolean
       |  +--ro add-path-impairments-set?    leafref
       |  +--ro drop-path-impairments-set?   leafref
       +--ro additional-ltp* [ltp-ref]
          +--ro ltp-ref
          |       -> ../../../../../../nt:termination-point/tp-id
          +--ro add-path-impairments-set?    leafref
          +--ro drop-path-impairments-set?   leafref
```

Appendix B. JSON Code Examples for Optical Protection Uses Cases

(1) JSON example for use case in Section 2.11.1.1 with full and with restricted connectivity:

The JSON example below addresses the optical protection use case for TTPs associated with local optical transponders (integrated WDM-TE-node):

* where full connectivity exists between the ROADM add-drop ports and the ROADM ports for the different ROADM degrees illustrated in Figure 27 below.
* where restricted connectivity exists between the ROADM add-drop ports and the ROADM ports for the different ROADM degrees illustrated in Figure 28 below.

Note that Figure 27 and Figure 28 illustrate the connectivity for a single TTP only, i.e., the figures are not showing TTP-1, TTP-2, TTP-3, and TTP-4, which are used in the JSON code example below.

The connectivity is reflected in the local-link-connectivities between the TTP associated with the transceiver of the local OT and the LTPs that can be reached including the optical impairments for the different paths.

```
      +--------------------------------------------------------------+
      |                                       ROADM                  |
      |                         +--------------------------------+  |
      |  Local OT     Splitter   |                        ___     |  |
      |  +-------+   +-------+  AD1      ___             |   \  Line |
      |  |    TTP|   |    ---o-->o-     /   |       /----o    | LTP 1|
      |  |  +----|   |   /   |   | \   |    o------/     | 1  o------o->
    --o->|  | Tx o-->o--o  5 |   |  \  |    |           -o    |   |  |
      |  |  +----|   |   \   |  AD2  --o  4 o-\        / |___/    |  |
    <-o--|  | Rx o   |    ---o-->o-    |    |  \      /       DEG1|  |
      |  |  +----|   +-------+   | \   |    o-  \    /    ___     |  |
      |  |       |               |  |   \___| \  \  /    |   \  Line |
      |  +-------+      internal |  |          \  \------o    | LTP 2|
      |                 AD ports |  |           \ /      | 2  o------o->
      |                          |  |    ___     \   /---o    |   |  |
      |                          o  |   /   |   / \ /    |___/    |  |
      |                          |  |  |    o--/   \          DEG2|  |
      |                          |   \ |    |     / \     ___     |  |
      |                          |    -o  6 o----/   \   |   \  Line |
      |                          |     |    |         \--o    | LTP 3|
      |                          |     |    o----\       | 3  o------o->
      |                          o      \___|     \------o    |   |  |
      |                          |                       |___/    |  |
      |                          |                            DEG3|  |
      |                          +--------------------------------+  |
      +--------------------------------------------------------------+
```

Figure 27: Protected TTP with Full Connectivity between ROADM Add-Drop Ports and ROADM Degree Ports

```
      +--------------------------------------------------------------+
      |                                       ROADM                  |
      |                          +--------------------------------+  |
      |  Local OT     Splitter   |                        ___     |  |
      |  +-------+   +-------+  AD1       ___            |   \  Line |
      |  |    TTP|   |    ---o-->o--     /   |       /---o    | LTP 1|
      |  |  +----|   |   /   |   |  \   |    o------/    | 1  o------o->
    --o->|  | Tx o-->o--o  5 |   |   ---o  4 |         /-o    |   |  |
      |  |  +----|   |   \   |  AD2     |    o-\      /  |___/    |  |
    <-o--|  | Rx o   |    ---o-->o--     \___|  \    /        DEG1|  |
      |  |  +----|   +-------+   |  \     ___    \   |    ___     |  |
      |  |       |               |   \   /   |    \  |   |   \  Line |
      |  +-------+      internal |    \ |    o-------/   o    | LTP 2|
      |                 AD ports |     -o  6 |      \    | 2  o------o->
      |                          |      |    o-------\---o    |   |  |
      |                          o       \___|        |  |___/    |  |
      |                          |                    |       DEG2|  |
      |                          |                    |   ___     |  |
      |                          |                    |  |   \  Line |
      |                          |                    \--o    | LTP 3|
      |                          |                       | 3  o------o->
      |                          o                       o    |   |  |
      |                          |                       |___/    |  |
      |                          |                            DEG3|  |
      |                          +--------------------------------+  |
      +--------------------------------------------------------------+
```

Figure 28: Protected TTP with Restricted Connectivity between ROADM Add-Drop Ports and ROADM Degree Ports

```
=============== NOTE: '\\' line wrapping per RFC 8792 ===============

{
  "ietf-network:networks": {
    "network": [
      {
        "network-id": "example:WDM-Network-2",
        "network-types": {
          "ietf-te-topology:te-topology": {
            "ietf-optical-impairment-topology:optical-impairment-top\
\ology": {}
          }
        },
        "ietf-te-topology:te-topology-identifier": {
          "topology-id": "WDM-Network-1"
        },
        "ietf-te-topology:te": {},
```

```
          "ietf-optical-impairment-topology:templates": {
            "roadm-path-impairments-sets": {
                "roadm-path-impairments-set": [
                    {
                      "roadm-path-impairments-set-id": "1",
                      "description": "Add path impairments from TTP 1 \
   \or TTP 2 to any LTP",

                      "roadm-add-path": [
                        {
                          "frequency-range-id": 0,
                          "frequency-range": {
                              "lower-frequency": "191.3",
                              "upper-frequency": "196.1"
                          }
                        }
                      ]
                    },
                    {
                      "roadm-path-impairments-set-id": "2",
                       "description": "Add path impairments from TTP 3\
   \ or TTP 4 to LTP1 or LTP3, thorugh AD1",

                      "roadm-add-path": [
                        {
                          "frequency-range-id": 0,
                            "frequency-range": {
                              "lower-frequency": "191.3",
                              "upper-frequency": "196.1"
                            }
                        }
                      ]
                    },
                    {
                      "roadm-path-impairments-set-id": "3",
                      "description": "Add path impairments from TTP 3 \
   \or TTP 4 to LTP1 or LTP2, thorugh AD2",

                      "roadm-add-path": [
                        {
                          "frequency-range-id": 0,
                          "frequency-range": {
                              "lower-frequency": "191.3",
                              "upper-frequency": "196.1"
                          }
                        }
                      ]
                    }
```

```
                ]
              }
            },
            "node": [
              {
                "node-id": "example:WDM-TE-Node-1",
                "ietf-te-topology:te-node-id": "192.0.2.1",
                "ietf-te-topology:te": {
                  "tunnel-termination-point": [
                    {
                      "tunnel-tp-id": "MQ==",
                      "protection-type": "ietf-optical-impairment-topolo\
   \gy:otsi-protection",
                      "local-link-connectivities": {
                        "is-allowed": true,
                        "ietf-optical-impairment-topology:add-path-impai\
   \rments-set": "1"
                      }
                    },
                    {
                      "tunnel-tp-id": "Mg==",
                      "protection-type": "ietf-optical-impairment-topolo\
   \gy:otsi-protection",
                      "local-link-connectivities": {
                        "is-allowed": true,
                        "ietf-optical-impairment-topology:add-path-impai\
   \rments-set": "1",
                        "local-link-connectivity": [
                          {
                            "link-tp-ref": "example:LTP-1",
                            "ietf-optical-impairment-topology:additional\
   \-ltp": [
                              {
                                "ltp-ref": "example:LTP-2"
                              },
                              {
                                "ltp-ref": "example:LTP-3"
                              }
                            ]
                          },
                          {
                            "link-tp-ref": "example:LTP-2",
                            "ietf-optical-impairment-topology:additional\
   \-ltp": [
                              {
                                "ltp-ref": "example:LTP-1"
                              },
                              {
```

```
                                "ltp-ref": "example:LTP-3"
                              }
                            ]
                          },
                          {
                          "link-tp-ref": "example:LTP-3",
                            "ietf-optical-impairment-topology:additional\
   \-ltp": [
                              {
                                "ltp-ref": "example:LTP-1"
                              },
                              {
                                "ltp-ref": "example:LTP-2"
                              }
                            ]
                          }
                        ]
                      }
                    },
                    {
                      "tunnel-tp-id": "Mw==",
                      "protection-type": "ietf-optical-impairment-topolo\
   \gy:otsi-protection",
                      "local-link-connectivities": {
                        "is-allowed": false,
                        "local-link-connectivity": [
                          {
                            "link-tp-ref": "example:LTP-1",
                            "is-allowed": true,
                            "ietf-optical-impairment-topology:add-path-i\
   \mpairments-set": "2",
                            "ietf-optical-impairment-topology:additional\
   \-ltp": [
                              {
                                "ltp-ref": "example:LTP-3",
                                "add-path-impairments-set": "2"
                              },
                              {
                                "ltp-ref": "example:LTP-2",
                                "add-path-impairments-set": "3"
                              }
                            ]
                          },
                          {
                            "link-tp-ref": "example:LTP-3",
                            "is-allowed": true,
                            "ietf-optical-impairment-topology:add-path-i\
   \mpairments-set": "2",
```

```
                          "ietf-optical-impairment-topology:additional\
   \-ltp": [
                            {
                              "ltp-ref": "example:LTP-1",
                              "add-path-impairments-set": "3"
                            },
                            {
                              "ltp-ref": "example:LTP-2",
                              "add-path-impairments-set": "3"
                            }
                          ]
                        }
                      ]
                    }
                  },
                  {
                    "tunnel-tp-id": "NA==",
                    "protection-type": "ietf-optical-impairment-topolo\
   \gy:otsi-protection",
                    "local-link-connectivities": {
                      "is-allowed": false,
                      "local-link-connectivity": [
                        {
                          "link-tp-ref": "example:LTP-1",
                          "is-allowed": true,
                          "ietf-optical-impairment-topology:add-path-i\
   \mpairments-set": "3",
                          "ietf-optical-impairment-topology:additional\
   \-ltp": [
                            {
                              "ltp-ref": "example:LTP-3",
                              "add-path-impairments-set": "2"
                            },
                            {
                              "ltp-ref": "example:LTP-2",
                              "add-path-impairments-set": "3"
                            }
                          ]
                        },
                        {
                          "link-tp-ref": "example:LTP-2",
                          "is-allowed": true,
                          "ietf-optical-impairment-topology:add-path-i\
   \mpairments-set": "3",
                          "ietf-optical-impairment-topology:additional\
   \-ltp": [
                            {
                              "ltp-ref": "example:LTP-1",
```

```
                              "add-path-impairments-set": "3"
                            },
                            {
                              "ltp-ref": "example:LTP-3",
                              "add-path-impairments-set": "2"
                            }
                          ]
                        },
                        {
                          "link-tp-ref": "example:LTP-3",
                          "is-allowed": true,
                          "ietf-optical-impairment-topology:add-path-i\
\mpairments-set": "2",
                          "ietf-optical-impairment-topology:additional\
\-ltp": [
                            {
                              "ltp-ref": "example:LTP-1",
                              "add-path-impairments-set": "3"
                            },
                            {
                              "ltp-ref": "example:LTP-2",
                              "add-path-impairments-set": "3"
                            }
                          ]
                        }
                      ]
                    }
                  }
                ]
              },
              "ietf-network-topology:termination-point": [
                {
                  "tp-id": "example:LTP-1"
                },
                {
                  "tp-id": "example:LTP-2"
                },
                {
                  "tp-id": "example:LTP-3"
                }
              ]
            }
          ]
        }
      ]
    }
  }
```

(2) JSON example for use case in Section 2.11.1.2 with restricted connectivity:

The JSON example below addresses the optical protection use case where the optical transponder is not part of the WDM-TE-node containing the ROADM function (WDM-TE-node-2) but is part of a separate WDM-TE-node (WDM-TE-node-1) containing one or more optical transponders (remote OTs). As described in Section 2.11.1.2, a TE-link interconnects the remote OT with an add-drop port of WDM-TE-node-2. This is illustrated in Figure 29.

In this use case, the connectivity is reflected in the connectivity-matrix describing the connectivity between the LTPs representing an add-drop port in WDM-TE-node-2 connected to the transceiver of a remote OT and the LTPs associated with the different ROADM degrees including the optical impairments for the different paths.

```
     WDM-TE-node 1                  WDM-TE-node 2

                  +--------------------------------------------------+
                  |  LTP 20                               ___        |
      +-------+   |  +-------+     AD 1  ___             |   \  Line |
      |   TTP1|   |  |    ---o-----     /   |       /----o    | LTP 1|
      |  +----|   |  |   /   |     \   |    o------/     | 1  o------o->
    --o->| Tx o---o->o--o  5 |      \--o    |           -o    |      |
      |  +----|   |  |   \   |         |  4 |          / |___/       |
    <-o--| Rx o   |  |    ---o-\    /--o    |         /         DEG 1|
      |  +----|   |  +-------+  \   |  |    o-       /    ___        |
      |       |   |   Splitter   \  |   \___| \     /    |   \  Line |
      |       |   |  +-------+   |  |          \         o    | LTP 2|
      |   TTP2|   |  |    ---o---|--/           \ /      | 2  o------o->
      |  +----|   |  |   /   |   |       ___     \   /---o    |      |
    --o->| Tx o---o->o--o  5 |    \     /   |   / \ /    |___/       |
      |  +----|   |  |   \   |     \   |    o--/   \           DEG 2 |
    <-o--| Rx o   |  |    ---o--\   \--o    |     / \     ___        |
      |  +----|   |  +-------+   \     |    |    /   \   |   \  Line |
      |       |   |  LTP 30       \----o  6 |   /     \--o    | LTP 3|
      |   TTP3|   |                    |    o--/         | 3  o------o->
      |  +----|   |          /-------->o    |            o    |      |
    --o->| Tx o---o---------/          |    |            |___/       |
      |  +----|   |  LTP 40             \___|                  DEG 3 |
    <-o--| Rx o   |                AD 2                              |
      |  +----|   |                                                  |
      |       |   |                                                  |
      +-------+   |                                                  |
                  |                                                  |
                  +--------------------------------------------------+
```

Figure 29: JSON Example for Restricted Connectivity between ROADM Add-Drop Ports and ROADM Degree Ports


```
=============== NOTE: '\\' line wrapping per RFC 8792 ===============

{
  "ietf-network:networks": {
    "network": [
      {
        "network-id": "example:WDM-Network-2",
        "network-types": {
          "ietf-te-topology:te-topology": {
            "ietf-optical-impairment-topology:optical-impairment-top\
\ology": {}
          }
        },
        "ietf-te-topology:te-topology-identifier": {
          "topology-id": "WDM-Network-1"
        },
        "ietf-te-topology:te": {},
        "ietf-optical-impairment-topology:templates": {
          "roadm-path-impairments-sets": {
              "roadm-path-impairments-set": [
                  {
                    "roadm-path-impairments-set-id": "1",

                    "roadm-add-path": [
                      {
                        "frequency-range-id": 0,
                        "frequency-range": {
                            "lower-frequency": "191.3",
                            "upper-frequency": "196.1"
                        }
                      }
                    ]
                  },
                  {
                    "roadm-path-impairments-set-id": "2",
                    "description": "Add path impairments from LTP 20\
\ or LTP 30 to LTP 1 or LTP3, through AD1",

                    "roadm-add-path": [
                      {
                        "frequency-range-id": 0,
                          "frequency-range": {
                            "lower-frequency": "191.3",
                            "upper-frequency": "196.1"
                          }
```

```
                      }
                    ]
                  },
                  {
                    "roadm-path-impairments-set-id": "3",
                    "description": "Add path impairments from LTP 20\
   \ or LTP 30 or LTP 40 to LTP 1 or LTP 2, through AD2",

                    "roadm-add-path": [
                      {
                        "frequency-range-id": 0,
                        "frequency-range": {
                            "lower-frequency": "191.3",
                            "upper-frequency": "196.1"
                        }
                      }
                    ]
                  }
                ]
              }
            },
            "node": [
              {
                "node-id": "example:WDM-TE-Node-1",
                "ietf-te-topology:te-node-id": "192.0.2.1",
                "ietf-te-topology:te": {
                   "te-node-attributes": {
                      "connectivity-matrices": {
                         "connectivity-matrix": [
                            {
                                "id": 1,
                                "from": {
                                   "tp-ref": "example:20"
                                },
                                "to": {
                                   "tp-ref": "example:1",
                                   "ietf-optical-impairment-topology:add\
   \itional-ltp": [
                                      {
                                        "ltp-ref": "example:1",
                                        "ietf-optical-impairment-topolog\
   \y:roadm-path-impairments-set": "3"
                                      },
                                      {
                                        "ltp-ref": "example:2",
                                        "ietf-optical-impairment-topolog\
   \y:roadm-path-impairments-set": "3"
                                      }
```

```
                                ]
                             },
                             "is-allowed": true,
                             "ietf-optical-impairment-topology:roadm-\
   \path-impairments-set": "2"
                          },
                          {
                             "id": 2,
                             "from": {
                                "tp-ref": "example:20"
                             },
                             "to": {
                                "tp-ref": "example:3",
                                "ietf-optical-impairment-topology:add\
   \itional-ltp": [
                                   {
                                     "ltp-ref": "example:1",
                                     "ietf-optical-impairment-topolog\
   \y:roadm-path-impairments-set": "3"
                                   },
                                   {
                                     "ltp-ref": "example:2",
                                     "ietf-optical-impairment-topolog\
   \y:roadm-path-impairments-set": "3"
                                   }
                                ]
                             },
                             "is-allowed": true,
                             "ietf-optical-impairment-topology:roadm-\
   \path-impairments-set": "2"
                          },
                          {
                             "id": 3,
                             "from": {
                                "tp-ref": "example:30"
                             },
                             "to": {
                                "tp-ref": "example:1",
                                "ietf-optical-impairment-topology:add\
   \itional-ltp": [
                                   {
                                     "ltp-ref": "example:1",
                                     "ietf-optical-impairment-topolog\
   \y:roadm-path-impairments-set": "3"
                                   },
                                   {
                                     "ltp-ref": "example:2",
                                     "ietf-optical-impairment-topolog\
```

```
   \y:roadm-path-impairments-set": "3"
                                     }
                                  ]
                               },
                               "is-allowed": true,
                               "ietf-optical-impairment-topology:roadm-\
   \path-impairments-set": "2"
                           },
                           {
                               "id": 4,
                               "from": {
                                  "tp-ref": "example:30"
                               },
                               "to": {
                                  "tp-ref": "example:2",
                                  "ietf-optical-impairment-topology:add\
   \itional-ltp": [
                                     {
                                       "ltp-ref": "example:1",
                                       "ietf-optical-impairment-topolog\
   \y:roadm-path-impairments-set": "2"
                                     },
                                     {
                                       "ltp-ref": "example:3",
                                       "ietf-optical-impairment-topolog\
   \y:roadm-path-impairments-set": "2"
                                     }
                                  ]
                               },
                               "is-allowed": true,
                               "ietf-optical-impairment-topology:roadm-\
   \path-impairments-set": "3"
                           },
                           {
                               "id": 5,
                               "from": {
                                  "tp-ref": "example:30"
                               },
                               "to": {
                                  "tp-ref": "example:3",
                                  "ietf-optical-impairment-topology:add\
   \itional-ltp": [
                                     {
                                       "ltp-ref": "example:1",
                                       "ietf-optical-impairment-topolog\
   \y:roadm-path-impairments-set": "3"
                                     },
                                     {
```

```
                                 "ltp-ref": "example:2",
                                 "ietf-optical-impairment-topolog\
   \y:roadm-path-impairments-set": "3"
                               }
                            ]
                         },
                         "is-allowed": true,
                         "ietf-optical-impairment-topology:roadm-\
   \path-impairments-set": "2"
                     },
                     {
                         "id": 6,
                         "from": {
                            "tp-ref": "example:40"
                         },
                         "to": {
                            "tp-ref": "example:1"
                         },
                         "is-allowed": true,
                         "ietf-optical-impairment-topology:roadm-\
   \path-impairments-set": "3"
                     },
                     {
                         "id": 7,
                         "from": {
                            "tp-ref": "example:40"
                         },
                         "to": {
                            "tp-ref": "example:2"
                         },
                         "is-allowed": true,
                         "ietf-optical-impairment-topology:roadm-\
   \path-impairments-set": "3"
                     }
                  ]
               }
            }
         },
         "ietf-network-topology:termination-point": [
           {
             "tp-id": "example:20",
             "ietf-optical-impairment-topology:protection-type": \
   \"ietf-optical-impairment-topology:otsi-protection"
           },
           {
             "tp-id": "example:30",
             "ietf-optical-impairment-topology:protection-type": \
   \"ietf-optical-impairment-topology:otsi-protection"
```

```
                  },
                  {
                    "tp-id": "example:40"
                  },
                  {
                    "tp-id": "example:1",
                    "ietf-optical-impairment-topology:protection-type": \
   \"ietf-optical-impairment-topology:otsi-protection"
                  },
                  {
                    "tp-id": "example:2",
                    "ietf-optical-impairment-topology:protection-type": \
   \"ietf-optical-impairment-topology:otsi-protection"
                  },
                  {
                    "tp-id": "example:3",
                    "ietf-optical-impairment-topology:protection-type": \
   \"ietf-optical-impairment-topology:otsi-protection"
                  }

                ]

              }
            ]
          }
        ]
      }
    }
```


Appendix C. Optical Transponders in a Remote Shelf (Remote OTs)

Figure 30 illustrates a configuration where the optical transponders and the ROADM are located in a different WDM-TE-nodes.

```
           WDM-TE-node-1                    WDM-TE-node-2
        +----------------+           +--------------------------+
        |     Remote OTs |           |         ROADM            |
        |   +------------+           |     +------------+       |
        |   |            |           | AD  |            |       |
        |   |       +----|           | LTP |            | Line  |
      --o-->|       | Tx o---------->o---->o            | LTP 1 |
        |   | OT 1  +----|           |     |            o-------o<--->
      <-o---|       | Rx o<----------o<----o            |       |
        |   |       +----|           | AD  |            |       |
        |   |            |           | LTP |            |       |
        |   +------------+           |     |            |       |
        |                |           |     |            | Line  |
        |   +------------+           |     |            | LTP 2 |
        |   |            |           | AD  |            o-------o<--->
        |   |       +----|           | LTPs|            |       |
      --o-->|       | Tx o---------->o---->o            |       |
        |   |       +----|           |     |            |       |
      <-o---|       | Rx o<----------o<----o            |       |
        |   | OT 2  +----|           |     |            | Line  |
      --o-->|       | Tx o---------->o---->o            | LTP 3 |
        |   |       +----|           |     |            o-------o<--->
      <-o---|       | Rx o<----------o<----o            |       |
        |   |       +----|           |     |            |       |
        |   |            |           |     |            |       |
        |   +------------+           |     +------------+       |
        |                |           |                          |
        +----------------+           +--------------------------+
```

Figure 30: Optical Transponders in a Remote Shelf (Remote OTs)

As described in Section 2.3, the external shelf can be modeled as WDM-TE-node with termination capability only (not switching) and the add/drop link between a remote optical transceiver and a ROADM add/drop port can be modeled as a WDM TE-link with the same optical impairments as those defined for a WDM TE-link between WDM-TE-nodes (OMS MCG).

If the two WDM-TE-nodes are reported in different network topology instances, the plug-id attribute, defined in [RFC8795], can be used to discover the adjacency for add/drop TE-links.

It is worth noting that there are no standard protocols for automatic discovery of the adjacency between an external transceiver and a ROADM add/drop port and therefore the information reported in the plug-id can be either statically configured or provided through vendor-specific discovery mechanisms.

Each add/drop TE-link carries a single OTSi between the transceiver and ROADM add/drop port and one or more OTSis in the reverse direction (between the ROADM add/drop and the transceiver).

Depending on control architecture (e.g., when the two WDM-TE-nodes are reported in different network topology instances by different controllers), the controller reporting the WDM-TE-node, abstracting the external OT shelf, may be not able to provide the information about the end-to-end MC configuration (i.e.,flexi-n and flexi-m) nor of all the received OTSis, within the end-to-end MC, besides the configured incoming OTSi, since the end-to-end MC configuration depends on how the ROADM network is configured and the remote OT shelf is not aware of that.

In this case only the incoming-otsi and outgoing-otsi can be reported within an end-to-end MC with an unspecified frequency-slot (i.e., without reporting flexi-n and flexi-m configuration of the end-to-end MC).

When an OTSiG has more than one OTSi, its OTSis are carried by different parallel add/drop TE-links. In order to represent the fact that these OTSis are co-routed, the add/drop TE-links are bundled together in a bundled add/drop TE-link. The finest granularity for the bundled add/drop TE-link is the set of all the add/drop TE-links terminating on the same OT.

For example, in Figure 30, it is possible to define two bundled add/drop TE-links, one for OT1 and one for OT2 or just one add/drop TE-link both OTs.

The model for a bundled add/drop TE-link and the relationship with its component TE-links is already defined in the bundled-links container of [RFC8795].

In the general case, the optical impairments and connectivity constraints are reported for each add/drop TE-link and therefore no optical impairments are reported in the bundled add/drop TE-link that is used just to model the co-routing aspects of the OTSis belonging to the same OTSiG.

The per-transceiver Local Link Connectivity (LLC) is used in the WDM-TE-node which abstracts the remote OT shelf (e.g., WDM-TE-node-1 in Figure 30), to represent the association between each transceiver and each LTP terminating the add/drop TE-link which models the transceiver port.

The connectivity matrix in the WDM-TE-node which abstract the edge ROADM (e.g., WDM-TE-node-2 in Figure 30) references the LTPs terminating the add/drop TE-links which models the ROADM add/drop ports.

C.1. JSON Examples for Optical Transponders in a Remote Shelf (Remote OTs)

The JSON example below describes a topology where the optical transponders are located in a remote WDM-TE-node as depicted in Figure 30).

Line-folding as defined in [RFC8792] has been used for the JSON code example below.


```
=============== NOTE: '\\' line wrapping per RFC 8792 ===============

{
  "ietf-network:networks": {
    "network": [
      {
        "network-id": "example:WDM-Network-1",
        "network-types": {
          "ietf-te-topology:te-topology": {
            "ietf-optical-impairment-topology:optical-impairment-top\
\ology": {}
          }
        },
        "ietf-te-topology:te-topology-identifier": {
          "topology-id": "example:WDM-Network-1"
        },
        "ietf-te-topology:te": {},
        "ietf-optical-impairment-topology:otsis": {
          "otsi-group": [
            {
              "otsi-group-id": "Red OTSiG (Forward)",
              "otsi": [
                {
                  "carrier-id": 1
                }
              ]
            },
            {
              "otsi-group-id": "Red OTSiG (Reverse)",
              "otsi": [
                {
                  "carrier-id": 1
                }
```

```
                  ]
                },
                {
                  "otsi-group-id": "Green OTSiG (Forward)",
                  "otsi": [
                    {
                      "carrier-id": 1
                    },
                    {
                      "carrier-id": 2
                    }
                  ]
                },
                {
                  "otsi-group-id": "Green OTSiG (Reverse)",
                  "otsi": [
                    {
                      "carrier-id": 1
                    },
                    {
                      "carrier-id": 2
                    }
                  ]
                }
              ]
            },
            "node": [
              {
                "node-id": "example:WDM-TE-Node-1",
                "ietf-te-topology:te-node-id": "192.0.2.1",
                "ietf-te-topology:te": {
                  "ietf-te-topology:tunnel-termination-point": [
                    {
                      "tunnel-tp-id": "AQ==",
                      "ietf-optical-impairment-topology:ttp-transceiver"\
   \: [
                        {
                          "transponder-ref": 1,
                          "transceiver-ref": 1
                        }
                      ],
                      "local-link-connectivities": {
                        "is-allowed": false,
                        "local-link-connectivity": [
                          {
                            "link-tp-ref": "example:1",
                            "ietf-optical-impairment-topology:llc-transc\
   \eiver": [
```

```
                              {
                                "ttp-transponder-ref": 1,
                                "ttp-transceiver-ref": 1,
                                "is-allowed": true
                              }
                            ]
                          }
                        ]
                      }
                    },
                    {
                      "tunnel-tp-id": "Ag==",
                      "ietf-optical-impairment-topology:ttp-transceiver"\
   \: [
                        {
                          "transponder-ref": 2,
                          "transceiver-ref": 1
                        },
                        {
                          "transponder-ref": 2,
                          "transceiver-ref": 2
                        }
                      ],
                      "local-link-connectivities": {
                        "is-allowed": false,
                        "local-link-connectivity": [
                          {
                            "link-tp-ref": "example:2",
                            "ietf-optical-impairment-topology:llc-transc\
   \eiver": [
                              {
                                "ttp-transponder-ref": 2,
                                "ttp-transceiver-ref": 1,
                                "is-allowed": true
                              }
                            ]
                          },
                          {
                            "link-tp-ref": "example:3",
                            "ietf-optical-impairment-topology:llc-transc\
   \eiver": [
                              {
                                "ttp-transponder-ref": 2,
                                "ttp-transceiver-ref": 2,
                                "is-allowed": true
                              }
                            ]
                          }
```

```
                  ]
                }
              }
            ]
          },
          "ietf-network-topology:termination-point": [
            {
              "tp-id": "example:1",
              "ietf-te-topology:te-tp-id": 1,
              "ietf-te-topology:te": {
                "inter-domain-plug-id": "AQ=="
              }
            },
            {
              "tp-id": "example:2",
              "ietf-te-topology:te-tp-id": 2,
              "ietf-te-topology:te": {
                "inter-domain-plug-id": "Ag=="
              }
            },
            {
              "tp-id": "example:3",
              "ietf-te-topology:te-tp-id": 3,
              "ietf-te-topology:te": {
                "inter-domain-plug-id": "Awo="
              }
            },
            {
              "tp-id": "example:23",
              "ietf-te-topology:te-tp-id": 23
            }
          ],
          "ietf-optical-impairment-topology:transponders": {
            "transponder": [
              {
                "transponder-id": 1,
                "transceiver": [
                  {
                    "transceiver-id": 1,
                    "outgoing-otsi": {
                      "otsi-group-ref": "Red OTSiG (Forward)",
                      "otsi-ref": 1
                    },
                    "incoming-otsi": {
                      "otsi-group-ref": "Red OTSiG (Reverse)",
                      "otsi-ref": 1
                    }
                  }
```

```
                    ]
                  },
                  {
                    "transponder-id": 2,
                    "transceiver": [
                      {
                        "transceiver-id": 1,
                        "outgoing-otsi": {
                          "otsi-group-ref": "Green OTSiG (Forward)",
                          "otsi-ref": 1
                        },
                        "incoming-otsi": {
                          "otsi-group-ref": "Green OTSiG (Reverse)",
                          "otsi-ref": 1
                        }
                      },
                      {
                        "transceiver-id": 2,
                        "outgoing-otsi": {
                          "otsi-group-ref": "Green OTSiG (Forward)",
                          "otsi-ref": 2
                        },
                        "incoming-otsi": {
                          "otsi-group-ref": "Green OTSiG (Reverse)",
                          "otsi-ref": 2
                        }
                      }
                    ]
                  }
                ]
              }
            }
          ],
          "ietf-network-topology:link": [
            {
              "link-id": "example:Add-Drop-Link-1-Forward",
              "source": {
                "source-node": "example:WDM-TE-Node-1",
                "source-tp": "example:1"
              },
              "ietf-te-topology:te": {
                "te-link-attributes": {
                  "ietf-optical-impairment-topology:oms-attributes": {
                    "media-channel-groups": {
                      "media-channel-group": [
                        {
                          "otsi-group-ref": "Red OTSiG (Forward)",
                          "media-channel": [
```

```
                        {
                          "media-channel-id": 1,
                          "otsi-ref": [
                            {
                              "carrier-ref": 1
                            }
                          ]
                        }
                      ]
                    }
                  ]
                }
              }
            }
          }
        },
        {
          "link-id": "example:Add-Drop-Link-1-Reverse",
          "destination": {
            "dest-node": "example:WDM-TE-Node-1",
            "dest-tp": "example:1"
          },
          "ietf-te-topology:te": {
            "te-link-attributes": {
              "ietf-optical-impairment-topology:oms-attributes": {
                "media-channel-groups": {
                  "media-channel-group": [
                    {
                      "otsi-group-ref": "Red OTSiG (Reverse)",
                      "media-channel": [
                        {
                          "media-channel-id": 2,
                          "otsi-ref": [
                            {
                              "carrier-ref": 1
                            }
                          ]
                        }
                      ]
                    }
                  ]
                }
              }
            }
          }
        },
        {
          "link-id": "example:Add-Drop-Link-2-Forward",
```

```
              "source": {
                "source-node": "example:WDM-TE-Node-1",
                "source-tp": "example:2"
              },
              "ietf-te-topology:te": {
                "te-link-attributes": {
                  "ietf-optical-impairment-topology:oms-attributes": {
                    "media-channel-groups": {
                      "media-channel-group": [
                        {
                          "otsi-group-ref": "Green OTSiG (Forward)",
                          "media-channel": [
                            {
                              "media-channel-id": 2,
                              "otsi-ref": [
                                {
                                  "carrier-ref": 1
                                }
                              ]
                            }
                          ]
                        }
                      ]
                    }
                  }
                }
              }
            },
            {
              "link-id": "example:Add-Drop-Link-2-Reverse",
              "destination": {
                "dest-node": "example:WDM-TE-Node-1",
                "dest-tp": "example:2"
              },
              "ietf-te-topology:te": {
                "te-link-attributes": {
                  "ietf-optical-impairment-topology:oms-attributes": {
                      "media-channel-groups": {
                        "media-channel-group": [
                          {
                            "otsi-group-ref": "Green OTSiG (Reverse)",
                            "media-channel": [
                              {
                                "media-channel-id": 3,
                                "otsi-ref": [
                                  {
                                    "carrier-ref": 1
                                  }
```

```
                        ]
                      }
                    ]
                  }
                ]
              }
            }
          }
        }
      },
      {
        "link-id": "example:Add-Drop-Link-3-Forward",
        "source": {
          "source-node": "example:WDM-TE-Node-1",
          "source-tp": "example:3"
        },
        "ietf-te-topology:te": {
          "te-link-attributes": {
            "ietf-optical-impairment-topology:oms-attributes": {
              "media-channel-groups": {
                "media-channel-group": [
                  {
                    "otsi-group-ref": "Green OTSiG (Forward)",
                    "media-channel": [
                      {
                        "media-channel-id": 4,
                        "otsi-ref": [
                          {
                            "carrier-ref": 2
                          }
                        ]
                      }
                    ]
                  }
                ]
              }
            }
          }
        }
      },
      {
        "link-id": "example:Add-Drop-Link-3-Reverse",
        "destination": {
          "dest-node": "example:WDM-TE-Node-1",
          "dest-tp": "example:3"
        },
        "ietf-te-topology:te": {
          "ietf-te-topology:te-link-attributes": {
```

```
                "ietf-optical-impairment-topology:oms-attributes": {
                  "media-channel-groups": {
                    "media-channel-group": [
                      {
                        "otsi-group-ref": "Green OTSiG (Reverse)",
                        "media-channel": [
                          {
                            "media-channel-id": 5,
                            "otsi-ref": [
                              {
                                "carrier-ref": 2
                              }
                            ]
                          }
                        ]
                      }
                    ]
                  }
                }
              }
            }
          },
          {
            "link-id": "example:Add-Drop-Bundled-Link-Forward",
            "source": {
              "source-node": "example:WDM-TE-Node-1",
              "source-tp": "example:23"
            },
            "ietf-te-topology:te": {
              "bundled-links": {
                "bundled-link": [
                  {
                    "sequence": 1,
                    "src-tp-ref": "example:2"
                  },
                  {
                    "sequence": 2,
                    "src-tp-ref": "example:3"
                  }
                ]
              }
            }
          },
          {
            "link-id": "example:Add-Drop-Bundled-Link-Reverse",
            "destination": {
              "dest-node": "example:WDM-TE-Node-1",
              "dest-tp": "example:23"
```

```
              },
              "ietf-te-topology:te": {
                "bundled-links": {
                  "bundled-link": [
                    {
                      "sequence": 1,
                      "des-tp-ref": "example:2"
                    },
                    {
                      "sequence": 2,
                      "des-tp-ref": "example:3"
                    }
                  ]
                }
              }
            }
          ]
        },
        {
          "network-id": "example:WDM-Network-2",
          "network-types": {
            "ietf-te-topology:te-topology": {
              "ietf-optical-impairment-topology:optical-impairment-top\
   \ology": {}
            }
          },
          "ietf-te-topology:te-topology-identifier": {
            "topology-id": "example:WDM-Network-2"
          },
          "ietf-te-topology:te": {},
          "ietf-optical-impairment-topology:otsis": {
            "otsi-group": [
              {
                "otsi-group-id": "Red OTSiG (Forward)",
                "otsi": [
                  {
                    "carrier-id": 1
                  }
                ]
              },
              {
                "otsi-group-id": "Red OTSiG (Reverse)",
                "otsi": [
                  {
                    "carrier-id": 1
                  }
                ]
              },
```

```
                {
                  "otsi-group-id": "Green OTSiG (Forward)",
                  "otsi": [
                    {
                      "carrier-id": 1
                    },
                    {
                      "carrier-id": 2
                    }
                  ]
                },
                {
                  "otsi-group-id": "Green OTSiG (Reverse)",
                  "otsi": [
                    {
                      "carrier-id": 1
                    },
                    {
                      "carrier-id": 2
                    }
                  ]
                }
              ]
            },
            "node": [
              {
                "node-id": "example:WDM-TE-Node-2",
                "ietf-te-topology:te-node-id": "192.0.2.2",
                "ietf-te-topology:te": {},
                "ietf-network-topology:termination-point": [
                  {
                    "tp-id": "example:1",
                    "ietf-te-topology:te-tp-id": 1,
                    "ietf-te-topology:te": {}
                  },
                  {
                    "tp-id": "example:2",
                    "ietf-te-topology:te-tp-id": 2,
                    "ietf-te-topology:te": {}
                  },
                  {
                    "tp-id": "example:3",
                    "ietf-te-topology:te-tp-id": 3,
                    "ietf-te-topology:te": {}
                  },
                  {
                    "tp-id": "example:4",
                    "ietf-te-topology:te-tp-id": 4,
```

```
                  "ietf-te-topology:te": {
                    "inter-domain-plug-id": "AQ=="
                  }
                },
                {
                  "tp-id": "example:5",
                  "ietf-te-topology:te-tp-id": 5,
                  "ietf-te-topology:te": {
                    "inter-domain-plug-id": "Ag=="
                  }
                },
                {
                  "tp-id": "example:6",
                  "ietf-te-topology:te-tp-id": 6,
                  "ietf-te-topology:te": {
                    "inter-domain-plug-id": "Awo="
                  }
                }
              ]
            }
          ],
          "ietf-network-topology:link": [
            {
              "link-id": "example:Add-Drop-Link-1-Forward",
              "destination": {
                "dest-node": "example:WDM-TE-Node-2",
                "dest-tp": "example:4"
              },
              "ietf-te-topology:te": {
                "te-link-attributes": {
                  "ietf-optical-impairment-topology:oms-attributes": {
                    "media-channel-groups": {
                      "media-channel-group": [
                        {
                          "otsi-group-ref": "Red OTSiG (Forward)",    \
\
                          "media-channel": [
                            {
                              "media-channel-id": -10,
                              "flexi-n": -10,
                              "otsi-ref": [
                                {
                                  "carrier-ref": 1
                                }
                              ]
                            }
                          ]
                        }
```

```
                    ]
                  }
                }
              }
            }
          },
          {
            "link-id": "example:Add-Drop-Link-1-Reverse",
            "source": {
              "source-node": "example:WDM-TE-Node-2",
              "source-tp": "example:4"
            },
            "ietf-te-topology:te": {
              "te-link-attributes": {
                "ietf-optical-impairment-topology:oms-attributes": {
                  "media-channel-groups": {
                    "media-channel-group": [
                      {
                        "otsi-group-ref": "Red OTSiG (Reverse)",
                        "media-channel": [
                          {
                            "media-channel-id": 10,
                            "flexi-n": 10,
                            "otsi-ref": [
                              {
                                "carrier-ref": 1
                              }
                            ]
                          }
                        ]
                      },
                      {
                        "otsi-group-ref": "Green OTSiG (Reverse)",
                        "media-channel": [
                          {
                            "media-channel-id": 20,
                            "flexi-n": 20,
                            "otsi-ref": [
                              {
                                "carrier-ref": 1
                              },
                              {
                                "carrier-ref": 2
                              }
                            ]
                          }
                        ]
                      }
```

```
                  ]
                }
              }
            }
          }
        },
        {
          "link-id": "example:Add-Drop-Link-2-Forward",
          "destination": {
            "dest-node": "example:WDM-TE-Node-2",
            "dest-tp": "example:5"
          },
          "ietf-te-topology:te": {
            "te-link-attributes": {
              "ietf-optical-impairment-topology:oms-attributes": {
                "media-channel-groups": {
                  "media-channel-group": [
                    {
                      "otsi-group-ref": "Green OTSiG (Forward)",
                      "media-channel": [
                        {
                          "media-channel-id": -20,
                          "flexi-n": -20,
                          "otsi-ref": [
                            {
                              "carrier-ref": 1
                            }
                          ]
                        }
                      ]
                    }
                  ]
                }
              }
            }
          }
        },
        {
          "link-id": "example:Add-Drop-Link-2-Reverse",
          "source": {
            "source-node": "example:WDM-TE-Node-2",
            "source-tp": "example:5"
          },
          "ietf-te-topology:te": {
            "te-link-attributes": {
              "ietf-optical-impairment-topology:oms-attributes": {
                "media-channel-groups": {
                  "media-channel-group": [
```

```
                         {
                           "otsi-group-ref": "Red OTSiG (Reverse)",
                           "media-channel": [
                             {
                               "media-channel-id": 10,
                               "flexi-n": 10,
                               "otsi-ref": [
                                 {
                                   "carrier-ref": 1
                                 }
                               ]
                             }
                           ]
                         },
                         {
                           "otsi-group-ref": "Green OTSiG (Reverse)",
                           "media-channel": [
                             {
                               "media-channel-id": 20,
                               "flexi-n": 20,
                               "otsi-ref": [
                                 {
                                   "carrier-ref": 1
                                 },
                                 {
                                   "carrier-ref": 2
                                 }
                               ]
                             }
                           ]
                         }
                       ]
                     }
                   }
                 }
               }
             },
             {
               "link-id": "example:Add-Drop-Link-3-Forward",
               "destination": {
                 "dest-node": "example:WDM-TE-Node-2",
                 "dest-tp": "example:6"
               },
               "ietf-te-topology:te": {
                 "te-link-attributes": {
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```

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```

```
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```

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```

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                          }
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                      }
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                  }
                }
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            }
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                          }
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                     }
                   }
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                    ]
```

```
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          ]
        }
```

```
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8 November 2024

A YANG Data Model for Optical Transport Network Topology
draft-ietf-ccamp-otn-topo-yang-20

Abstract

This document defines a YANG data model for representing, retrieving, and manipulating Optical Transport Network (OTN) topologies. It is independent of control plane protocols and captures topological and resource-related information pertaining to OTN.

About This Document

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

The latest revision of this draft can be found at https://haomianzheng.github.io/ccamp-client-pm-yang/draft-zheng-ccamp-client-pm-yang.html. Status information for this document may be found at https://datatracker.ietf.org/doc/draft-ietf-ccamp-otn-topo-yang/.

Discussion of this document takes place on the Common Control and Measurement Plane Working Group mailing list (mailto:ccamp@ietf.org), which is archived at https://mailarchive.ietf.org/arch/browse/ccamp/. Subscribe at https://www.ietf.org/mailman/listinfo/ccamp/.

Source for this draft and an issue tracker can be found at https://github.com/haomianzheng/ccamp-client-pm-yang.

Status of This Memo

This Internet-Draft will expire on 12 May 2025.

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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. A transport network typically utilizes several different transport technologies such as the Optical Transport Networks (OTN) or packet transport such as provided by the MPLS-Transport Profile (MPLS-TP).

This document defines a data model of an OTN topology, using YANG version 1.1 [RFC7950]. The model can be used by an application communicating with a transport controller. Furthermore, it can be used by an application for the following purposes (but not limited to):

* To obtain a whole view of the network topology information of its interest;

* To receive notifications with regard to the information change of the OTN topology;

* To enforce the establishment and update to the network topology with the characteristics specified in the data model;

The YANG model defined in this document is independent of control plane protocols and captures topology-related information pertaining to OTN electrical layer, as the scope specified by [RFC7062] . Furthermore, it is not a stand-alone model, but augments from the TE topology YANG model defined in [RFC8795], and importing from the generic Layer 1 types defined in [I-D.ietf-ccamp-layer1-types]. Following TE topology YANG model, the YANG model defined in this document is interface independent. The model is included in [I-D.ietf-teas-actn-yang], which indicates the typical usage of IETF YANG models in ACTN architecture specified by [RFC8453]. More specifically, the usage of this model between controllers is described in [I-D.ietf-ccamp-transport-nbi-app-statement].

This model supports both client-configured and system-controlled OTN topologies, as described [RFC8345]. These OTN topologies can be used as overlay or underlay topologies, using the mechanisms defined in [RFC8345] and [RFC8795].

The reader of this document is assumed to be familiar with the OTN technology, as specified in [ITU-T_G.709] and with the TE topology YANG data model, as defined in [RFC8795].

[RFC7062] also provides a framework to allow the development of protocol extensions to support GMPLS and Path Computation Element (PCE) control of OTN.

Section 6 of [RFC8795] provides guidelines for writing technology-specific TE topology augmentations.

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

1.1. Terminology and Notations

Some of the key terms used in this document are listed as follows.

TS: Tributary Slot.

TSG: Tributary Slot Granularity.

TPN: Tributary Port Number.

Refer to [RFC7062] 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. 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.

1.3. Tree Diagram

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

1.4. Prefix in Data Node Names

In this document, the 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
l1-types	ietf-layer1-types	[RFCYYYY]
otnt	ietf-otn-topology	RFC XXXX
nw	ietf-network	[RFC8345]
nt	ietf-network-topology	[RFC8345]
tet	ietf-te-topology	[RFC8795]

Table 1: Prefixes and corresponding YANG modules

RFC Editor Note: Please replace XXXX with the number assigned to the RFC once this draft becomes an RFC. Please replace YYYY with the RFC numbers assigned to [I-D.ietf-ccamp-layer1-types].

2. YANG Data Model for OTN Topology

2.1. OTN Topology Data Model Overview

This document aims to describe the data model for OTN topology. As a classic Traffic-engineering (TE) technology, OTN provides TDM switching in transport network [ITU-T_G.709]. Therefore, the YANG module presented in this document augments from a more generic Traffic Engineered (TE) network topology data model, i.e., the ietf-te-topology, as specified in [RFC8795]. In Section 6 of [RFC8795], the guideline for augmenting TE topology model was provided, and in this draft, we augment the TE topology model to describe the topology in OTN. Common types, identities and groupings defined in [I-D.ietf-ccamp-layer1-types] is reused in this document. [RFC8345] describes a network topology model and provides the fundamental model for [RFC8795]. However, this work is not directly augmenting [RFC8345]. Figure 1 shows the augmentation relationship.

```
                   +------------------+
      TE generic   | ietf-te-topology |
                   +------------------+
                             ^
                             |
                             | Augments
                             |
                   +---------+---------+
      OTN          | ietf-otn-topology |
                   +-------------------+
```

Figure 1: Relationship between OTN and TE topology models

The entities and TE attributes, such as node, termination points and links, are still applicable for describing an OTN topology and the model presented in this document only specifies technology-specific attributes/information. The OTN-specific attributes in [RFC7139], including the TPN, TS and TSG, can be used to represent the bandwidth and label information. These attributes have been specified in [I-D.ietf-ccamp-layer1-types], and used in this document for augmentation of the generic TE topology model.

2.2. Attributes Augmentation

There are a few characteristics augmenting the generic TE topology.

Following the guidelines described in [RFC8795], an otn-topology network-type is specified as the indicator of OTN in the topology.

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

Three OTN technology-specific parameters that augment the generic TE link attributes are specified.

```
      augment /nw:networks/nw:network/nt:link/tet:te
                /tet:te-link-attributes:
        +--rw otn-link
          +--rw odtu-flex-type?   l1-types:odtu-flex-type
          +--rw tsg?              identityref
          +--rw distance?         uint32
```

In OTN the resources is measured by the tributary slots (TS), as specified in [RFC7139]. The tributary slot granularity (TSG) attribute defines the granularity, such as 1.25G, 2.5G and 5G, used by the TSs of a given OTN link. The distance attribute describes the geographical distance between a pair of OTN link termination points. This is usually measured by the length of the fibre.

The OTN topology model also includes information about the access links that support the transparent client signals, defined in [I-D.ietf-ccamp-layer1-types]. These links can also be multi-function access links that can support one or more transparent client signals and OTN.

A client-svc presence container is specified to augment the generic TE link termination point to describe if the point is capable of carrying a client signal and what kind of signal can be carried as follows. The same presence container is also specified for the TE link.

```
      augment /nw:networks/nw:network/nw:node/nt:termination-point
                /tet:te:
        +--rw client-svc!
            +--rw supported-client-signal*   identityref
```

The list of supported-client-signal is used to provide the capabilities of the client signal specified in [I-D.ietf-ccamp-layer1-types].

2.3. Bandwidth Augmentation

Following the guidelines in [RFC8795], the model augments all the occurrences of the te-bandwidth container with the OTN technology-specific attributes using the otn-link-bandwidth and otn-path-bandwidth groupings defined in [I-D.ietf-ccamp-layer1-types].

The odtu-flex-type attribute of a given OTN Link (or Link Termination Point - LTP), shown in Section 2.2, is used, together with the OTN technology-specific attributes defined in the otn-link-bandwidth and otn-path-bandwidth groupings, to compute the number of Tributary Slots (TS) required by the ODUflex LSPs set up on that OTN Link (or LTP).

In order to compute the number of Tributary Slots (TS) required by the ODUflex LSPs set up on an underlay path (e.g., the underlay path of a connectivity matrix entry), the odtu-flex-type attribute is added to the OTN technology-specific attributes defined in the otn-link-bandwidth and otn-path-bandwidth groupings.

2.4. Label Augmentation

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

Moreover, following the guidelines in [RFC8795], the model augments all the occurrences of the te-label container with the OTN technology specific attributes using the otn-label-start-end, otn-label-hop and otn-label-step groupings defined in [I-D.ietf-ccamp-layer1-types].

3. The YANG Model

This YANG module references [RFC8345], [RFC8795], [I-D.ietf-ccamp-layer1-types] and [ITU-T_G.709].

```
<CODE BEGINS> file "ietf-otn-topology@2024-06-21.yang"
module ietf-otn-topology {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-otn-topology";
  prefix "otnt";

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

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

  import ietf-te-topology {
    prefix "tet";
    reference
      "RFC 8795: YANG Data Model for Traffic Engineering
```

```
          (TE) Topologies";
     }

     import ietf-layer1-types {
       prefix "l1-types";
       reference
         "RFC YYYY: A YANG Data Model for Layer 1 Types";
     }
     // RFC Editor: replace YYYY with actual RFC number assigned to
     // [I-D.ietf-ccamp-layer1-types] and remove this note

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

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

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

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

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

     description
       "This module defines a protocol independent Layer 1/ODU topology
        data model. The model fully conforms
        to the Network Management Datastore Architecture (NMDA).

        Copyright (c) 2024 IETF Trust and the persons identified
        as authors of the code.  All rights reserved.

        Redistribution and use in source and binary forms, with or
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        set forth in Section 4.c of the IETF Trust's Legal Provisions
        Relating to IETF Documents
        (https://trustee.ietf.org/license-info).

        This version of this YANG module is part of RFC XXXX; see
```

```
        the RFC itself for full legal notices.

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

     revision 2024-06-21 {
       description
         "Initial Revision";
       reference
         "RFC XXXX: A YANG Data Model for Optical Transport Network
         Topology";
     }
     // RFC Editor: replace XXXX with actual RFC number, update date
     // information and remove this note

     /*
      * Groupings
      */

     grouping label-range-info {
       description
         "OTN technology-specific label range related information with
         a presence container indicating that the label range is an
         OTN technology-specific label range.

         This grouping SHOULD be used together with the
         otn-label-start-end and otn-label-step groupings to provide
         OTN technology-specific label information to the models which
         use the label-restriction-info grouping defined in the module
         ietf-te-types.";
       uses l1-types:otn-label-range-info {
         refine otn-label-range {
           presence
             "Indicates the label range is an OTN label range.

             This container MUST NOT be present if there are other
             presence containers or attributes indicating another type
             of label range.";
         }
       }
     }

    /*
     * Data nodes
     */
```

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

     augment "/nw:networks/nw:network/nw:node/tet:te"
           + "/tet:te-node-attributes" {
       when "../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description "Augment only for OTN.";
       }
       description "Augment TE node attributes.";
       container otn-node {
         presence "The TE node is an OTN node.";
         description
           "Introduce new TE node type for OTN node.";
       }
     }

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

       container otn-link {
         description
           "Attributes of the OTN Link.";
         leaf odtu-flex-type {
           type l1-types:odtu-flex-type;
           description
             "The type of Optical Data Tributary Unit (ODTU)
             whose nominal bitrate is used to compute the number of
             Tributary Slots (TS) required by the ODUflex LSPs set up
             on this OTN Link.";
         }
         leaf tsg {
           type identityref {
             base l1-types:tributary-slot-granularity;
           }
           description "Tributary slot granularity.";
```

```
          reference
            "ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
            Transport Network (OTN)";
        }
        leaf distance {
          type uint32;
          description "distance in the unit of kilometers";
        }
      }
      container client-svc {
        presence
          "When present, indicates that the Link supports Constant
          Bit Rate (CBR) client signals.";
        description
          "Attributes of the Link supporting CBR client signals.";
        leaf-list supported-client-signal {
          type identityref {
            base l1-types:client-signal;
          }
          min-elements 1;
          description
            "List of client signal types supported by the Link.";
        }
      }
    }

    augment "/nw:networks/nw:network/nw:node/nt:termination-point/"
          + "tet:te" {
      when "../../../nw:network-types/tet:te-topology/"
         + "otnt:otn-topology" {
        description "Augment only for OTN.";
      }
      description
        "Augment link termination point (LTP) configuration.";

      container otn-link-tp {
        description
          "Attributes of the OTN Link Termination Point (LTP).";
        leaf odtu-flex-type {
          type l1-types:odtu-flex-type;
          description
            "The type of Optical Data Tributary Unit (ODTU)
            whose nominal bitrate is used to compute the number of
            Tributary Slots (TS) required by the ODUflex LSPs set up
            on this OTN Link Termination Point (LTP).";
        }
      }
      container client-svc {
```

```
         presence
           "When present, indicates that the Link Termination Point
           (LTP) supports Constant Bit Rate (CBR) client signals.";
         description
           "OTN LTP Service attributes.";
         leaf-list supported-client-signal {
           type identityref {
             base l1-types:client-signal;
           }
           description
             "List of client signal types supported by the LTP.";
         }
       }
     }

     /*
      * Augment TE bandwidth
      */

     augment "/nw:networks/nw:network/nw:node/nt:termination-point/"
           + "tet:te/"
           + "tet:interface-switching-capability/tet:max-lsp-bandwidth/"
           + "tet:te-bandwidth/tet:technology" {
       when "../../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment maximum LSP TE bandwidth for the link termination
          point (LTP).";
       case otn {
         uses l1-types:otn-max-path-bandwidth {
           description
             "The odtu-flex-type attribute of the OTN Link Termination
             Point (LTP) is used to compute the number of Tributary
             Slots (TS) required by the ODUflex LSPs set up on this
             OTN LTP.";
         }
       }
     }

     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/"
          + "otnt:otn-topology" {
```

```
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment TE bandwidth path constraints of the TE node
           connectivity matrices.";
        case otn {
          uses l1-types:otn-link-bandwidth {
            augment otn-bandwidth {
              description
                "Augment OTN link bandwidth information.";
              leaf odtu-flex-type {
                type l1-types:odtu-flex-type;
                description
                  "The type of Optical Data Tributary Unit (ODTU)
                  whose nominal bitrate is used to compute the number of
                  Tributary Slots (TS) required by the ODUflex LSPs
                  set up along the underlay paths of these OTN
                  connectivity matrices.";
              }
            }
          }
        }
      }

      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/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment TE bandwidth path constraints of the
           connectivity matrix entry.";
        case otn {
          uses l1-types:otn-link-bandwidth {
            augment otn-bandwidth {
              description
                "Augment OTN link bandwidth information.";
              leaf odtu-flex-type {
                type l1-types:odtu-flex-type;
                description
                  "The type of Optical Data Tributary Unit (ODTU)
```

```
                whose nominal bitrate is used to compute the number of
                Tributary Slots (TS) required by the ODUflex LSPs
                set up along the underlay path of this OTN
                connectivity matrix entry.";
            }
          }
        }
      }
    }

    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/"
         + "otnt:otn-topology" {
        description
          "Augmentation parameters apply only for networks with
           OTN topology type.";
      }
      description
        "Augment TE bandwidth path constraints of the TE node
         connectivity matrices information source.";
      case otn {
        uses l1-types:otn-link-bandwidth {
          augment otn-bandwidth {
            description
              "Augment OTN link bandwidth information.";
            leaf odtu-flex-type {
              type l1-types:odtu-flex-type;
              description
                "The type of Optical Data Tributary Unit (ODTU)
                whose nominal bitrate is used to compute the number of
                Tributary Slots (TS) required by the ODUflex LSPs
                set up along the underlay paths of these OTN
                connectivity matrices.";
            }
          }
        }
      }
    }

    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/"
         + "otnt:otn-topology" {
        description
```

```
           "Augmentation parameters apply only for networks with
            OTN topology type.";
        }
        description
          "Augment TE bandwidth path constraints of the
           connectivity matrix entry information source";
        case otn {
          uses l1-types:otn-link-bandwidth {
            augment otn-bandwidth {
              description
                "Augment OTN link bandwidth information.";
              leaf odtu-flex-type {
                type l1-types:odtu-flex-type;
                description
                  "The type of Optical Data Tributary Unit (ODTU)
                  whose nominal bitrate is used to compute the number of
                  Tributary Slots (TS) required by the ODUflex LSPs
                  set up along the underlay path of this OTN
                  connectivity matrix entry.";
              }
            }
          }
        }
      }

      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/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment client TE bandwidth of the tunnel termination point
           (TTP)";
        case otn {
          uses l1-types:otn-link-bandwidth {
            augment otn-bandwidth {
              description
                "Augment OTN link bandwidth information.";
              leaf odtu-flex-type {
                type l1-types:odtu-flex-type;
                description
                  "The type of Optical Data Tributary Unit (ODTU)
                  whose nominal bitrate is used to compute the number of
```

```
                 Tributary Slots (TS) required by the ODUflex LSPs
                 terminated on this OTN Tunnel Termination Point
                 (TTP).";
             }
           }
         }
       }
     }

     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/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE bandwidth path constraints for the TTP
          Local Link Connectivities.";
       case otn {
         uses l1-types:otn-link-bandwidth {
           augment otn-bandwidth {
             description
               "Augment OTN link bandwidth information.";
             leaf odtu-flex-type {
               type l1-types:odtu-flex-type;
               description
                 "The type of Optical Data Tributary Unit (ODTU)
                 whose nominal bitrate is used to compute the number of
                 Tributary Slots (TS) required by the ODUflex LSPs
                 set up along the underlay paths of these OTN Local
                 Link Connectivities.";
             }
           }
         }
       }
     }

     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/"
          + "otnt:otn-topology" {
```

```
        description
          "Augmentation parameters apply only for networks with
           OTN topology type.";
      }
      description
        "Augment TE bandwidth path constraints for the TTP
         Local Link Connectivity entry.";
      case otn {
        uses l1-types:otn-link-bandwidth {
          augment otn-bandwidth {
            description
              "Augment OTN link bandwidth information.";
            leaf odtu-flex-type {
              type l1-types:odtu-flex-type;
              description
                "The type of Optical Data Tributary Unit (ODTU)
                whose nominal bitrate is used to compute the number of
                Tributary Slots (TS) required by the ODUflex LSPs
                set up along the underlay path of this OTN Local
                Link Connectivity entry.";
            }
          }
        }
      }
    }

    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/"
         + "otnt:otn-topology" {
        description
          "Augmentation parameters apply only for networks with
           OTN topology type.";
      }
      description
        "Augment maximum LSP TE bandwidth for the TE link.";
      case otn {
        uses l1-types:otn-max-path-bandwidth {
          description
            "The odtu-flex-type attribute of the OTN Link is used
            to compute the number of Tributary Slots (TS) required
            by the ODUflex LSPs set up on this OTN Link.";
        }
      }
    }
```

```
     augment "/nw:networks/nw:network/nt:link/tet:te/"
           + "tet:te-link-attributes/"
           + "tet:max-link-bandwidth/"
           + "tet:te-bandwidth" {
       when "../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment maximum TE bandwidth for the TE link";
       uses l1-types:otn-link-bandwidth {
         description
           "The odtu-flex-type attribute of the OTN Link is used
           to compute the number of Tributary Slots (TS) required
           by the ODUflex LSPs set up on this OTN Link.";
       }
     }

     augment "/nw:networks/nw:network/nt:link/tet:te/"
           + "tet:te-link-attributes/"
           + "tet:max-resv-link-bandwidth/"
           + "tet:te-bandwidth" {
       when "../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment maximum reservable TE bandwidth for the TE link";
       uses l1-types:otn-link-bandwidth {
         description
           "The odtu-flex-type attribute of the OTN Link is used
           to compute the number of Tributary Slots (TS) required
           by the ODUflex LSPs set up on this OTN Link.";
       }
     }

     augment "/nw:networks/nw:network/nt:link/tet:te/"
           + "tet:te-link-attributes/"
           + "tet:unreserved-bandwidth/"
           + "tet:te-bandwidth" {
       when "../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
```

```
             OTN topology type.";
        }
        description
          "Augment unreserved TE bandwidth for the TE Link";
        uses l1-types:otn-link-bandwidth {
          description
            "The odtu-flex-type attribute of the OTN Link is used
            to compute the number of Tributary Slots (TS) required
            by the ODUflex LSPs set up on this OTN Link.";
        }
      }

      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/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment maximum LSP TE bandwidth for the TE link
           information source";
        case otn {
          uses l1-types:otn-max-path-bandwidth {
            description
              "The odtu-flex-type attribute of the OTN Link is used
              to compute the number of Tributary Slots (TS) required
              by the ODUflex LSPs set up on this OTN Link.";
          }
        }
      }

      augment "/nw:networks/nw:network/nt:link/tet:te/"
            + "tet:information-source-entry/"
            + "tet:max-link-bandwidth/"
            + "tet:te-bandwidth" {
        when "../../../../../nw:network-types/tet:te-topology/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment maximum TE bandwidth for the TE link
```

```
          information source";
       uses l1-types:otn-link-bandwidth {
         description
           "The odtu-flex-type attribute of the OTN Link is used
           to compute the number of Tributary Slots (TS) required
           by the ODUflex LSPs set up on this OTN Link.";
       }
     }

     augment "/nw:networks/nw:network/nt:link/tet:te/"
           + "tet:information-source-entry/"
           + "tet:max-resv-link-bandwidth/"
           + "tet:te-bandwidth" {
       when "../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment maximum reservable TE bandwidth for the TE link
          information-source";
       uses l1-types:otn-link-bandwidth {
         description
           "The odtu-flex-type attribute of the OTN Link is used
           to compute the number of Tributary Slots (TS) required
           by the ODUflex LSPs set up on this OTN Link.";
       }
     }

     augment "/nw:networks/nw:network/nt:link/tet:te/"
           + "tet:information-source-entry/"
           + "tet:unreserved-bandwidth/"
           + "tet:te-bandwidth" {
       when "../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment unreserved TE bandwidth of the TE link
          information source";
       uses l1-types:otn-link-bandwidth {
         description
           "The odtu-flex-type attribute of the OTN Link is used
           to compute the number of Tributary Slots (TS) required
           by the ODUflex LSPs set up on this OTN Link.";
```

```
       }
     }

     augment "/nw:networks/tet:te/tet:templates/"
           + "tet:link-template/tet:te-link-attributes/"
           + "tet:interface-switching-capability/"
           + "tet:max-lsp-bandwidth/"
           + "tet:te-bandwidth/tet:technology" {
       description
         "Augment maximum LSP TE bandwidth of the TE link
          template";
       case otn {
         uses l1-types:otn-max-path-bandwidth {
           description
             "The odtu-flex-type attribute of the OTN Link is used
             to compute the number of Tributary Slots (TS) required
             by the ODUflex LSPs set up on the OTN Link that uses this
             Link Template.";
         }
       }
     }

     augment "/nw:networks/tet:te/tet:templates/"
           + "tet:link-template/tet:te-link-attributes/"
           + "tet:max-link-bandwidth/"
           + "tet:te-bandwidth" {
       description
         "Augment maximum TE bandwidth the TE link template";
       uses l1-types:otn-link-bandwidth {
         description
           "The odtu-flex-type attribute of the OTN Link is used
           to compute the number of Tributary Slots (TS) required
           by the ODUflex LSPs set up on the OTN Link that uses this
           Link Template.";
       }
     }

     augment "/nw:networks/tet:te/tet:templates/"
           + "tet:link-template/tet:te-link-attributes/"
           + "tet:max-resv-link-bandwidth/"
           + "tet:te-bandwidth" {
       description
         "Augment maximum reservable TE bandwidth for the TE link
          template.";
       uses l1-types:otn-link-bandwidth {
         description
           "The odtu-flex-type attribute of the OTN Link is used
           to compute the number of Tributary Slots (TS) required
```

```
           by the ODUflex LSPs set up on the OTN Link that uses this
           Link Template.";
       }
     }

     augment "/nw:networks/tet:te/tet:templates/"
           + "tet:link-template/tet:te-link-attributes/"
           + "tet:unreserved-bandwidth/"
           + "tet:te-bandwidth" {
       description
         "Augment unreserved TE bandwidth the TE link template";
       uses l1-types:otn-link-bandwidth {
         description
           "The odtu-flex-type attribute of the OTN Link is used
           to compute the number of Tributary Slots (TS) required
           by the ODUflex LSPs set up on the OTN Link that uses this
           Link Template.";
       }
     }

     /*
      * Augment TE label range information
      */

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:label-restrictions/tet:label-restriction" {
       when "../../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label range information for the TE node
          connectivity matrices.";
       uses label-range-info;
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:connectivity-matrix/tet:from/"
           + "tet:label-restrictions/tet:label-restriction" {
       when "../../../../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
```

```
       }
       description
         "Augment TE label range information for the source LTP
          of the connectivity matrix entry.";
       uses label-range-info;
     }

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

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:information-source-entry/"
           + "tet:connectivity-matrices/tet:label-restrictions/"
           + "tet:label-restriction" {
       when "../../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label range information for the TE node
          connectivity matrices information source.";
       uses label-range-info;
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:information-source-entry/tet:connectivity-matrices/"
           + "tet:connectivity-matrix/"
           + "tet:from/tet:label-restrictions/tet:label-restriction" {
       when "../../../../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
```

```
       }
       description
         "Augment TE label range information for the source LTP
          of the connectivity matrix entry information source.";
       uses label-range-info;
     }

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

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

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:tunnel-termination-point/"
           + "tet:local-link-connectivities/"
           + "tet:local-link-connectivity/"
           + "tet:label-restrictions/tet:label-restriction" {
       when "../../../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
```

```
            OTN topology type.";
       }
       description
         "Augment TE label range information for the TTP
          Local Link Connectivity entry.";
       uses label-range-info;
     }

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

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

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

     /*
      * Augment TE label
      */
```

```
     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:label-restrictions/tet:label-restriction/"
           + "tet:label-start/"
           + "tet:te-label/tet:technology" {
       when "../../../../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label range start for the TE node
          connectivity matrices";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:label-restrictions/"
           + "tet:label-restriction/tet:label-end/"
           + "tet:te-label/tet:technology" {
       when "../../../../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label range end for the TE node
          connectivity matrices";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:label-restrictions/"
           + "tet:label-restriction/tet:label-step/"
           + "tet:technology" {
       when "../../../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
```

```
      }
      description
        "Augment TE label range step for the TE node
         connectivity matrices";
      case otn {
        uses l1-types:otn-label-step;
      }
    }

    augment "/nw:networks/nw:network/nw:node/tet:te/"
          + "tet:te-node-attributes/tet:connectivity-matrices/"
          + "tet:underlay/tet:primary-path/tet:path-element/"
          + "tet:type/tet:label/tet:label-hop/"
          + "tet:te-label/tet:technology" {
      when "../../../../../../../../../../"
         + "nw:network-types/tet:te-topology/"
         + "otnt:otn-topology" {
        description
          "Augmentation parameters apply only for networks with
           OTN topology type.";
      }
      description
        "Augment TE label hop for the underlay primary path of the
         TE node connectivity matrices";
      case otn {
        uses l1-types:otn-label-hop;
      }
    }

    augment "/nw:networks/nw:network/nw:node/tet:te/"
          + "tet:te-node-attributes/tet:connectivity-matrices/"
          + "tet:underlay/tet:backup-path/tet:path-element/"
          + "tet:type/tet:label/tet:label-hop/"
          + "tet:te-label/tet:technology" {
      when "../../../../../../../../../../"
         + "nw:network-types/tet:te-topology/"
         + "otnt:otn-topology" {
        description
          "Augmentation parameters apply only for networks with
           OTN topology type.";
      }
      description
        "Augment TE label hop for the underlay backup path of the
         TE node connectivity matrices";
      case otn {
        uses l1-types:otn-label-hop;
      }
    }
```

```
     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:optimizations/tet:algorithm/tet:metric/"
           + "tet:optimization-metric/"
           + "tet:explicit-route-exclude-objects/"
           + "tet:route-object-exclude-object/"
           + "tet:type/tet:label/tet:label-hop/"
           + "tet:te-label/tet:technology" {
       when "../../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label hop for the explicit route objects excluded
          by the path computation of the TE node connectivity
          matrices";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:optimizations/tet:algorithm/tet:metric/"
           + "tet:optimization-metric/"
           + "tet:explicit-route-include-objects/"
           + "tet:route-object-include-object/"
           + "tet:type/tet:label/tet:label-hop/"
           + "tet:te-label/tet:technology" {
       when "../../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label hop for the explicit route objects included
          by the path computation of the TE node connectivity
          matrices";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }
```

```
     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:path-properties/tet:path-route-objects/"
           + "tet:path-route-object/tet:type/tet:label/tet:label-hop/"
           + "tet:te-label/tet:technology" {
       when "../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label hop for the computed path route objects
          of the TE node connectivity matrices";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:connectivity-matrix/tet:from/"
           + "tet:label-restrictions/tet:label-restriction/"
           + "tet:label-start/"
           + "tet:te-label/tet:technology" {
       when "../../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label range start for the source LTP
          of the connectivity matrix entry.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:connectivity-matrix/tet:from/"
           + "tet:label-restrictions/tet:label-restriction/"
           + "tet:label-end/"
           + "tet:te-label/tet:technology" {
       when "../../../../../../../../../../../"
```

```
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label range end for the source LTP
          of the connectivity matrix entry.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:connectivity-matrix/tet:from/"
           + "tet:label-restrictions/tet:label-restriction/"
           + "tet:label-step/"
           + "tet:technology" {
       when "../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label range step for the source LTP
          of the connectivity matrix entry.";
       case otn {
         uses l1-types:otn-label-step;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:connectivity-matrix/tet:to/"
           + "tet:label-restrictions/tet:label-restriction/"
           + "tet:label-start/"
           + "tet:te-label/tet:technology" {
       when "../../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
```

```
       description
         "Augment TE label range start for the destination LTP
          of the connectivity matrix entry.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:connectivity-matrix/tet:to/"
           + "tet:label-restrictions/tet:label-restriction/"
           + "tet:label-end/"
           + "tet:te-label/tet:technology" {
       when "../../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label range end for the destination LTP
          of the connectivity matrix entry.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:connectivity-matrix/tet:to/"
           + "tet:label-restrictions/tet:label-restriction/"
           + "tet:label-step/"
           + "tet:technology" {
       when "../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label range step for the destination LTP
          of the connectivity matrix entry.";
       case otn {
         uses l1-types:otn-label-step;
       }
```

```
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:connectivity-matrix/"
           + "tet:underlay/tet:primary-path/tet:path-element/"
           + "tet:type/tet:label/tet:label-hop/"
           + "tet:te-label/tet:technology" {
       when "../../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label hop for the underlay primary path
          of the connectivity matrix entry.";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:connectivity-matrix/"
           + "tet:underlay/tet:backup-path/tet:path-element/"
           + "tet:type/tet:label/tet:label-hop/"
           + "tet:te-label/tet:technology" {
       when "../../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label hop for the underlay backup path
          of the connectivity matrix entry.";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:te-node-attributes/tet:connectivity-matrices/"
           + "tet:connectivity-matrix/tet:optimizations/"
           + "tet:algorithm/tet:metric/tet:optimization-metric/"
```

```
            + "tet:explicit-route-exclude-objects/"
            + "tet:route-object-exclude-object/tet:type/"
            + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
        when "../../../../../../../../../../../../"
           + "nw:network-types/tet:te-topology/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment TE label hop for the explicit route objects excluded
           by the path computation of the connectivity matrix entry.";
        case otn {
          uses l1-types:otn-label-hop;
        }
      }

      augment "/nw:networks/nw:network/nw:node/tet:te/"
            + "tet:te-node-attributes/tet:connectivity-matrices/"
            + "tet:connectivity-matrix/tet:optimizations/"
            + "tet:algorithm/tet:metric/tet:optimization-metric/"
            + "tet:explicit-route-include-objects/"
            + "tet:route-object-include-object/tet:type/"
            + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
        when "../../../../../../../../../../../../"
           + "nw:network-types/tet:te-topology/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment TE label hop for the explicit route objects included
           by the path computation of the connectivity matrix entry.";
        case otn {
          uses l1-types:otn-label-hop;
        }
      }

      augment "/nw:networks/nw:network/nw:node/tet:te/"
            + "tet:te-node-attributes/tet:connectivity-matrices/"
            + "tet:connectivity-matrix/"
            + "tet:path-properties/tet:path-route-objects/"
            + "tet:path-route-object/tet:type/"
            + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
        when "../../../../../../../../../../../"
           + "nw:network-types/tet:te-topology/"
```

```
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment TE label hop for the computed path route objects
           of the connectivity matrix entry.";
        case otn {
          uses l1-types:otn-label-hop;
        }
      }

      augment "/nw:networks/nw:network/nw:node/tet:te/"
            + "tet:information-source-entry/"
            + "tet:connectivity-matrices/tet:label-restrictions/"
            + "tet:label-restriction/"
            + "tet:label-start/tet:te-label/tet:technology" {
        when "../../../../../../../../"
           + "nw:network-types/tet:te-topology/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment TE label range start for the TE node connectivity
           matrices information source.";
        case otn {
          uses l1-types:otn-label-start-end;
        }
      }

      augment "/nw:networks/nw:network/nw:node/tet:te/"
            + "tet:information-source-entry/"
            + "tet:connectivity-matrices/tet:label-restrictions/"
            + "tet:label-restriction/"
            + "tet:label-end/tet:te-label/tet:technology" {
        when "../../../../../../../../"
           + "nw:network-types/tet:te-topology/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment TE label range end for the TE node connectivity
           matrices information source.";
```

```
        case otn {
          uses l1-types:otn-label-start-end;
        }
      }

      augment "/nw:networks/nw:network/nw:node/tet:te/"
            + "tet:information-source-entry/"
            + "tet:connectivity-matrices/tet:label-restrictions/"
            + "tet:label-restriction/"
            + "tet:label-step/tet:technology" {
        when "../../../../../../../../"
           + "nw:network-types/tet:te-topology/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment TE label range step for the TE node connectivity
           matrices information source.";
        case otn {
          uses l1-types:otn-label-step;
        }
      }

      augment "/nw:networks/nw:network/nw:node/tet:te/"
            + "tet:information-source-entry/tet:connectivity-matrices/"
            + "tet:underlay/tet:primary-path/tet:path-element/tet:type/"
            + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
        when "../../../../../../../../../../"
           + "nw:network-types/tet:te-topology/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment TE label hop for the underlay primary path
           of the TE node connectivity matrices of the information
           source entry.";
        case otn {
          uses l1-types:otn-label-hop;
        }
      }

      augment "/nw:networks/nw:network/nw:node/tet:te/"
            + "tet:information-source-entry/tet:connectivity-matrices/"
            + "tet:underlay/tet:backup-path/tet:path-element/tet:type/"
```

```
           + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
       when "../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label hop for the underlay backup path
          of the TE node connectivity matrices of the information
          source entry.";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:information-source-entry/tet:connectivity-matrices/"
           + "tet:optimizations/tet:algorithm/tet:metric/"
           + "tet:optimization-metric/"
           + "tet:explicit-route-exclude-objects/"
           + "tet:route-object-exclude-object/tet:type/"
           + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
       when "../../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label hop for the explicit route objects excluded
          by the path computation of the TE node connectivity matrices
          information source.";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:information-source-entry/tet:connectivity-matrices/"
           + "tet:optimizations/tet:algorithm/tet:metric/"
           + "tet:optimization-metric/"
           + "tet:explicit-route-include-objects/"
           + "tet:route-object-include-object/tet:type/"
           + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
       when "../../../../../../../../../../../"
```

```
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label hop for the explicit route objects included
          by the path computation of the TE node connectivity matrices
          information source.";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:information-source-entry/tet:connectivity-matrices/"
           + "tet:path-properties/tet:path-route-objects/"
           + "tet:path-route-object/tet:type/"
           + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
       when "../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label hop for the computed path route objects
          of the TE node connectivity matrices information source.";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:information-source-entry/tet:connectivity-matrices/"
           + "tet:connectivity-matrix/"
           + "tet:from/tet:label-restrictions/"
           + "tet:label-restriction/"
           + "tet:label-start/tet:te-label/tet:technology" {
       when "../../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
```

```
        description
          "Augment TE label range start for the source LTP
           of the connectivity matrix entry information source.";
        case otn {
          uses l1-types:otn-label-start-end;
        }
      }
      augment "/nw:networks/nw:network/nw:node/tet:te/"
            + "tet:information-source-entry/tet:connectivity-matrices/"
            + "tet:connectivity-matrix/"
            + "tet:from/tet:label-restrictions/"
            + "tet:label-restriction/"
            + "tet:label-end/tet:te-label/tet:technology" {
        when "../../../../../../../../../../../"
           + "nw:network-types/tet:te-topology/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment TE label range end for the source LTP
           of the connectivity matrix entry information source.";
        case otn {
          uses l1-types:otn-label-start-end;
        }
      }

      augment "/nw:networks/nw:network/nw:node/tet:te/"
            + "tet:information-source-entry/tet:connectivity-matrices/"
            + "tet:connectivity-matrix/"
            + "tet:from/tet:label-restrictions/"
            + "tet:label-restriction/"
            + "tet:label-step/tet:technology" {
        when "../../../../../../../../../../"
           + "nw:network-types/tet:te-topology/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment TE label range step for the source LTP
           of the connectivity matrix entry information source.";
        case otn {
          uses l1-types:otn-label-step;
        }
      }
```

```
     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:information-source-entry/tet:connectivity-matrices/"
           + "tet:connectivity-matrix/"
           + "tet:to/tet:label-restrictions/tet:label-restriction/"
           + "tet:label-start/tet:te-label/tet:technology" {
       when "../../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label range start for the destination LTP
          of the connectivity matrix entry information source.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:information-source-entry/tet:connectivity-matrices/"
           + "tet:connectivity-matrix/"
           + "tet:to/tet:label-restrictions/tet:label-restriction/"
           + "tet:label-end/tet:te-label/tet:technology" {
       when "../../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label range end for the destination LTP
          of the connectivity matrix entry information source.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:information-source-entry/tet:connectivity-matrices/"
           + "tet:connectivity-matrix/"
           + "tet:to/tet:label-restrictions/tet:label-restriction/"
           + "tet:label-step/tet:technology" {
       when "../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
```

```
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label range step for the destination LTP
          of the connectivity matrix entry information source.";
       case otn {
         uses l1-types:otn-label-step;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:information-source-entry/tet:connectivity-matrices/"
           + "tet:connectivity-matrix/"
           + "tet:underlay/tet:primary-path/tet:path-element/tet:type/"
           + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
       when "../../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label hop for the underlay primary path
          of the connectivity matrix entry information source.";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }

     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/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label hop for the underlay backup path
          of the connectivity matrix entry information source.";
       case otn {
```

```
        uses l1-types:otn-label-hop;
      }
    }

    augment "/nw:networks/nw:network/nw:node/tet:te/"
          + "tet:information-source-entry/tet:connectivity-matrices/"
          + "tet:connectivity-matrix/"
          + "tet:optimizations/tet:algorithm/tet:metric/"
          + "tet:optimization-metric/"
          + "tet:explicit-route-exclude-objects/"
          + "tet:route-object-exclude-object/tet:type/"
          + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
      when "../../../../../../../../../../../../"
         + "nw:network-types/tet:te-topology/"
         + "otnt:otn-topology" {
        description
          "Augmentation parameters apply only for networks with
           OTN topology type.";
      }
      description
        "Augment TE label hop for the explicit route objects excluded
         by the path computation of the connectivity matrix entry
         information source.";
      case otn {
        uses l1-types:otn-label-hop;
      }
    }

    augment "/nw:networks/nw:network/nw:node/tet:te/"
          + "tet:information-source-entry/tet:connectivity-matrices/"
          + "tet:connectivity-matrix/"
          + "tet:optimizations/tet:algorithm/tet:metric/"
          + "tet:optimization-metric/"
          + "tet:explicit-route-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/"
         + "otnt:otn-topology" {
        description
          "Augmentation parameters apply only for networks with
           OTN topology type.";
      }
      description
        "Augment TE label hop for the explicit route objects included
         by the path computation of the connectivity matrix entry
         information source.";
      case otn {
```

```
        uses l1-types:otn-label-hop;
      }
    }

    augment "/nw:networks/nw:network/nw:node/tet:te/"
          + "tet:information-source-entry/tet:connectivity-matrices/"
          + "tet:connectivity-matrix/"
          + "tet:path-properties/tet:path-route-objects/"
          + "tet:path-route-object/tet:type/"
          + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
      when "../../../../../../../../../../../"
         + "nw:network-types/tet:te-topology/"
         + "otnt:otn-topology" {
        description
          "Augmentation parameters apply only for networks with
           OTN topology type.";
      }
      description
        "Augment TE label hop for the computed path route objects
         of the connectivity matrix entry information source.";
      case otn {
        uses l1-types:otn-label-hop;
      }
    }

    augment "/nw:networks/nw:network/nw:node/tet:te/"
        + "tet:tunnel-termination-point/"
        + "tet:local-link-connectivities/"
        + "tet:label-restrictions/tet:label-restriction/"
        + "tet:label-start/"
        + "tet:te-label/tet:technology" {
      when "../../../../../../../../../"
         + "nw:network-types/tet:te-topology/"
         + "otnt:otn-topology" {
        description
          "Augmentation parameters apply only for networks with
           OTN topology type.";
      }
      description
        "Augment TE label range start for the TTP
         Local Link Connectivities.";
      case otn {
        uses l1-types:otn-label-start-end;
      }
    }

    augment "/nw:networks/nw:network/nw:node/tet:te/"
          + "tet:tunnel-termination-point/"
```

```
            + "tet:local-link-connectivities/"
            + "tet:label-restrictions/tet:label-restriction/"
            + "tet:label-end/"
            + "tet:te-label/tet:technology"{
        when "../../../../../../../../../"
           + "nw:network-types/tet:te-topology/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment TE label range end for the TTP
           Local Link Connectivities.";
        case otn {
          uses l1-types:otn-label-start-end;
        }
      }

      augment "/nw:networks/nw:network/nw:node/tet:te/"
            + "tet:tunnel-termination-point/"
            + "tet:local-link-connectivities/"
            + "tet:label-restrictions/tet:label-restriction/"
            + "tet:label-step/"
            + "tet:technology"{
        when "../../../../../../../../"
           + "nw:network-types/tet:te-topology/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment TE label range step for the TTP
           Local Link Connectivities.";
        case otn {
          uses l1-types:otn-label-step;
        }
      }

      augment "/nw:networks/nw:network/nw:node/tet:te/"
            + "tet:tunnel-termination-point/"
            + "tet:local-link-connectivities/"
            + "tet:underlay/tet:primary-path/tet:path-element/tet:type/"
            + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
        when "../../../../../../../../../../"
           + "nw:network-types/tet:te-topology/"
           + "otnt:otn-topology" {
```

```
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment TE label hop for the underlay primary path
           of the TTP Local Link Connectivities.";
        case otn {
          uses l1-types:otn-label-hop;
        }
      }

      augment "/nw:networks/nw:network/nw:node/tet:te/"
            + "tet:tunnel-termination-point/"
            + "tet:local-link-connectivities/"
            + "tet:underlay/tet:backup-path/tet:path-element/tet:type/"
            + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
        when "../../../../../../../../../../"
           + "nw:network-types/tet:te-topology/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment TE label hop for the underlay backup path
           of the TTP Local Link Connectivities.";
        case otn {
          uses l1-types:otn-label-hop;
        }
      }

      augment "/nw:networks/nw:network/nw:node/tet:te/"
            + "tet:tunnel-termination-point/"
            + "tet:local-link-connectivities/"
            + "tet:optimizations/tet:algorithm/tet:metric/"
            + "tet:optimization-metric/"
            + "tet:explicit-route-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/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
```

```
          "Augment TE label hop for the explicit route objects excluded
           by the path computation of the TTP Local Link
           Connectivities.";
        case otn {
          uses l1-types:otn-label-hop;
        }
      }

      augment "/nw:networks/nw:network/nw:node/tet:te/"
            + "tet:tunnel-termination-point/"
            + "tet:local-link-connectivities/"
            + "tet:optimizations/tet:algorithm/tet:metric/"
            + "tet:optimization-metric/"
            + "tet:explicit-route-include-objects/"
            + "tet:route-object-include-object/tet:type/"
            + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
        when "../../../../../../../../../../../"
           + "nw:network-types/tet:te-topology/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment TE label hop for the explicit route objects included
           by the path computation of the TTP Local Link
           Connectivities.";
        case otn {
          uses l1-types:otn-label-hop;
        }
      }

      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/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment TE label hop for the computed path route objects
           of the TTP Local Link Connectivities.";
```

```
        case otn {
          uses l1-types:otn-label-hop;
        }
      }

      augment "/nw:networks/nw:network/nw:node/tet:te/"
            + "tet:tunnel-termination-point/"
            + "tet:local-link-connectivities/"
            + "tet:local-link-connectivity/"
            + "tet:label-restrictions/tet:label-restriction/"
            + "tet:label-start/tet:te-label/tet:technology" {
        when "../../../../../../../../../../"
           + "nw:network-types/tet:te-topology/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment TE label range start for the TTP
           Local Link Connectivity entry.";
        case otn {
          uses l1-types:otn-label-start-end;
        }
      }

      augment "/nw:networks/nw:network/nw:node/tet:te/"
            + "tet:tunnel-termination-point/"
            + "tet:local-link-connectivities/"
            + "tet:local-link-connectivity/"
            + "tet:label-restrictions/tet:label-restriction/"
            + "tet:label-end/tet:te-label/tet:technology" {
        when "../../../../../../../../../../"
           + "nw:network-types/tet:te-topology/"
           + "otnt:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment TE label range end for the TTP
           Local Link Connectivity entry.";
        case otn {
          uses l1-types:otn-label-start-end;
        }
      }

      augment "/nw:networks/nw:network/nw:node/tet:te/"
```

```
           + "tet:tunnel-termination-point/"
           + "tet:local-link-connectivities/"
           + "tet:local-link-connectivity/"
           + "tet:label-restrictions/tet:label-restriction/"
           + "tet:label-step/tet:technology" {
       when "../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label range step for the TTP
          Local Link Connectivity entry.";
       case otn {
         uses l1-types:otn-label-step;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:tunnel-termination-point/"
           + "tet:local-link-connectivities/"
           + "tet:local-link-connectivity/"
           + "tet:underlay/tet:primary-path/tet:path-element/tet:type/"
           + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
       when "../../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label hop for the underlay primary path
          of the TTP Local Link Connectivity entry.";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:tunnel-termination-point/"
           + "tet:local-link-connectivities/"
           + "tet:local-link-connectivity/"
           + "tet:underlay/tet:backup-path/tet:path-element/tet:type/"
           + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
       when "../../../../../../../../../../../"
```

```
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
        description
          "Augmentation parameters apply only for networks with
           OTN topology type.";
      }
      description
        "Augment TE label hop for the underlay backup path
         of the TTP Local Link Connectivity entry.";
      case otn {
        uses l1-types:otn-label-hop;
      }
    }

    augment "/nw:networks/nw:network/nw:node/tet:te/"
          + "tet:tunnel-termination-point/"
          + "tet:local-link-connectivities/"
          + "tet:local-link-connectivity/"
          + "tet:optimizations/tet:algorithm/tet:metric/"
          + "tet:optimization-metric/"
          + "tet:explicit-route-exclude-objects/"
          + "tet:route-object-exclude-object/tet:type/"
          + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
      when "../../../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
        description
          "Augmentation parameters apply only for networks with
           OTN topology type.";
      }
      description
        "Augment TE label hop for the explicit route objects excluded
         by the path computation of the TTP Local Link
         Connectivity entry.";
      case otn {
        uses l1-types:otn-label-hop;
      }
    }

    augment "/nw:networks/nw:network/nw:node/tet:te/"
          + "tet:tunnel-termination-point/"
          + "tet:local-link-connectivities/"
          + "tet:local-link-connectivity/"
          + "tet:optimizations/tet:algorithm/tet:metric/"
          + "tet:optimization-metric/"
          + "tet:explicit-route-include-objects/"
          + "tet:route-object-include-object/tet:type/"
          + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
```

```
       when "../../../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label hop for the explicit route objects included
          by the path computation of the TTP Local Link
          Connectivity entry.";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }

     augment "/nw:networks/nw:network/nw:node/tet:te/"
           + "tet:tunnel-termination-point/"
           + "tet:local-link-connectivities/"
           + "tet:local-link-connectivity/"
           + "tet:path-properties/tet:path-route-objects/"
           + "tet:path-route-object/tet:type/"
           + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
       when "../../../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label hop for the computed path route objects
          of the TTP Local Link Connectivity entry.";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }
     augment "/nw:networks/nw:network/nt:link/tet:te/"
           + "tet:te-link-attributes/"
           + "tet:underlay/tet:primary-path/tet:path-element/tet:type/"
           + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
       when "../../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
```

```
       description
         "Augment TE label hop for the underlay primary path
          of the TE link.";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }

     augment "/nw:networks/nw:network/nt:link/tet:te/"
           + "tet:te-link-attributes/"
           + "tet:underlay/tet:backup-path/tet:path-element/tet:type/"
           + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
       when "../../../../../../../../"
          + "nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label hop for the underlay backup path
          of the TE link.";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }

     augment "/nw:networks/nw:network/nt:link/tet:te/"
           + "tet:te-link-attributes/"
           + "tet:label-restrictions/tet:label-restriction/"
           + "tet:label-start/tet:te-label/tet:technology" {
       when "../../../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label range start for the TE link.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

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

```
       when "../../../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label range end for the TE link.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/nw:networks/nw:network/nt:link/tet:te/"
           + "tet:te-link-attributes/"
           + "tet:label-restrictions/tet:label-restriction/"
           + "tet:label-step/tet:technology" {
       when "../../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label range step for the TE link.";
       case otn {
         uses l1-types:otn-label-step;
       }
     }

     augment "/nw:networks/nw:network/nt:link/tet:te/"
           + "tet:information-source-entry/"
           + "tet:label-restrictions/tet:label-restriction/"
           + "tet:label-start/tet:te-label/tet:technology" {
       when "../../../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label range start for the TE link
          information source.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }
```

```
     augment "/nw:networks/nw:network/nt:link/tet:te/"
           + "tet:information-source-entry/"
           + "tet:label-restrictions/tet:label-restriction/"
           + "tet:label-end/tet:te-label/tet:technology" {
       when "../../../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label range end for the TE link
          information source.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/nw:networks/nw:network/nt:link/tet:te/"
           + "tet:information-source-entry/"
           + "tet:label-restrictions/tet:label-restriction/"
           + "tet:label-step/tet:technology" {
       when "../../../../../../nw:network-types/tet:te-topology/"
          + "otnt:otn-topology" {
         description
           "Augmentation parameters apply only for networks with
            OTN topology type.";
       }
       description
         "Augment TE label range step for the TE link
          information source.";
       case otn {
         uses l1-types:otn-label-step;
       }
     }

     augment "/nw:networks/tet:te/tet:templates/"
           + "tet:link-template/tet:te-link-attributes/"
           + "tet:underlay/tet:primary-path/tet:path-element/tet:type/"
           + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
       description
         "Augment TE label hop for the underlay primary path
          of the TE link template.";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }
```

```
     augment "/nw:networks/tet:te/tet:templates/"
           + "tet:link-template/tet:te-link-attributes/"
           + "tet:underlay/tet:backup-path/tet:path-element/tet:type/"
           + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
       description
         "Augment TE label hop for the underlay backup path
          of the TE link template.";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }

     augment "/nw:networks/tet:te/tet:templates/"
           + "tet:link-template/tet:te-link-attributes/"
           + "tet:label-restrictions/tet:label-restriction/"
           + "tet:label-start/tet:te-label/tet:technology" {
       description
         "Augment TE label range start for the TE link template.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/nw:networks/tet:te/tet:templates/"
           + "tet:link-template/tet:te-link-attributes/"
           + "tet:label-restrictions/tet:label-restriction/"
           + "tet:label-end/tet:te-label/tet:technology" {
       description
         "Augment TE label range end for the TE link template.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/nw:networks/tet:te/tet:templates/"
           + "tet:link-template/tet:te-link-attributes/"
           + "tet:label-restrictions/tet:label-restriction/"
           + "tet:label-step/tet:technology" {
       description
         "Augment TE label range step for the TE link template.";
       case otn {
         uses l1-types:otn-label-step;
       }
     }
   }
   <CODE ENDS>
```

4. IANA Considerations

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

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

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

```
name:         ietf-otn-topology
namespace:    urn:ietf:params:xml:ns:yang:ietf-otn-topology
prefix:       otnt
reference:    RFC XXXX
```

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

5. Security Considerations

This section is modeled after the template described in Section 3.7 of [I-D.ietf-netmod-rfc8407bis].

The "ietf-te-types" and the "ietf-te-packet-types" YANG modules define data models that are designed to be accessed via YANG-based management protocols, such as NETCONF [RFC6241] and RESTCONF [RFC8040]. These protocols have to use a secure transport layer (e.g., SSH [RFC4252], TLS [RFC8446], and QUIC [RFC9000]) and have to use mutual authentication.

The Network Configuration Access Control Model (NACM) [RFC8341] provides the means to restrict access for particular NETCONF or RESTCONF users to a preconfigured subset of all available NETCONF or RESTCONF protocol operations and content.

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 can 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. Specifically, the following subtrees and data nodes have particular sensitivities/vulnerabilities:

* "/nw:networks/nw:network/nw:network-types/tet:te-topology/otnt:otn-topology"

This subtree specifies the OTN topology type. Modifying the configurations can render the OTN topology type invalid. By making such modifications, a malicious attacker may disable the OTN capabilities on the related networks and cause traffic to be disrupted or misrouted.

* "/nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes/otnt:otn-node"

  This subtree specifies the OTN node type. By configuring the OTN node type, an attacker may create an unauthorized OTN traffic path. By removing it, a malicious attacker may cause OTN traffic to be disabled or misrouted. Such traffic changes may also affect the traffic on the surrounding OTN nodes and OTN links in this OTN topology and the connected OTN topologies.

* "/nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/otnt:otn-link/otnt:odtu-flex-type"

  This node is used, together with the other attributes in the otn-bandwidth container, to compute the OTN bandwidth information for an OTN link, as described in Section 2.3. By configuring, modifying or removing this data node, a malicious attacker may modify the OTN bandwidth. The consequences of modifying the OTN bandwidth are reported below for the otn-bandwidth container.

* "/nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/otnt:otn-link/otnt:tsg"

  This node represents the TSG of the OTN link, as described in Section 2.2. By configuring, modifying or removing this data node, a malicious attacker may modify the resouces assigned to the OTN LSPs setup over that OTN link. The consequences of modifying the TSG would be to disrupt the traffic carried by the OTN LSPs setup over that OTN link.

* "/nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/otnt:otn-link/otnt:distance"

  This node is describes the geographical distance between a pair of OTN link termination points. By configuring, modifying or removing the distance, an attacker may cause OTN traffic to be misrouted. Such traffic changes may also affect the traffic on the surrounding OTN nodes and OTN links in this OTN topology and the connected OTN topologies.

* "/nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/otnt:client-svc"

This subtree specifies the client traffic type supported by a link. By configuring it, an attacker may create an unauthorized client traffic path. By removing it, a malicious attacker may cause client traffic to be disabled or misrouted. Such traffic changes may also affect the traffic on the surrounding OTN nodes and OTN links in this OTN topology and the connected OTN topologies.

* "/nw:networks/nw:network/nw:node/nt:termination-point/tet:te/otnt:otn-link-tp/otnt:odtu-flex-type"

  This node is used, together with the other attributes in the otn-bandwidth container, to compute the OTN bandwidth information for an OTN link termination point, as described in Section 2.3. By configuring, modifying or removing this data node, a malicious attacker may modify the OTN bandwidth. The consequences of modifying the OTN bandwidth are reported below for the otn-bandwidth container.

* "/nw:networks/nw:network/nw:node/nt:termination-point/tet:te/otnt:client-svc"

  This subtree specifies the client traffic type supported by a link termination point. By configuring it, an attacker may create an unauthorized client traffic path. By removing it, a malicious attacker may cause client traffic to be disabled or misrouted. Such traffic changes may also affect the traffic on the surrounding OTN nodes and OTN links in this OTN topology and the connected topologies.

* "otnt:otn-bandwidth"

  This subtree specifies the configurations of OTN technology-specific information under any occurrence of the tet:te-bandwidth container, as defined in [RFC8795] (e.g., "/nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/tet:max-resv-link-bandwidth/tet:te-bandwidth/otnt:otn-bandwidth"). By configuring the OTN bandwidth attributes, an attacker may create an unauthorized OTN traffic path. By removing or modifying it, a malicious attacker may cause OTN traffic to be disabled or misrouted. Such traffic changes may also affect the traffic on the surrounding OTN nodes and OTN links in this OTN topology and the connected OTN topologies.

* "otnt:otn-label-range"

This subtree specifies the configurations of OTN technology-specific label range information under any occurrence of the tet:te-label-restriction container, as defined in [RFC8795] (e.g., "/nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/tet:label-restrictions/tet:label-restriction\otnt:otn-label-range"). By configuring the OTN label range attributes, an attacker may create an unauthorized OTN traffic path. By removing or modifying, a malicious attacker may cause OTN traffic to be disabled or misrouted. Such traffic changes may also affect the traffic on the surrounding OTN nodes and OTN links in this OTN topology and the connected OTN topologies.

* "otnt:otn-label"

  This subtree specifies the configurations of OTN technology-specific label information under any occurrence of the tet:te-label container, as defined in [RFC8795] (e.g., "/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/otnt:otn-label"). By configuring, removing or modifying the OTN label attributes, a malicious attacker may cause OTN traffic to be disabled or misrouted. Such traffic changes may also affect the traffic on the surrounding OTN nodes and OTN links in this OTN topology and the connected OTN topologies.

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. Specifically, the following subtrees and data nodes have particular sensitivities/vulnerabilities:

* "/nw:networks/nw:network/nw:network-types/tet:te-topology/otnt:otn-topology"

  Unauthorized access to this subtree can disclose the OTN topology type.

* "/nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes/otnt:otn-node"

  Unauthorized access to this subtree can disclose the OTN nodes.

* "/nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/otnt:otn-link/otnt:odtu-flex-type"

This node is used, together with the other attributes in the otn-bandwidth container, to compute the OTN bandwidth information for an OTN link, as described in Section 2.3. Unauthorized access to this data node can disclose the OTN bandwidth information of OTN links.

* "/nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/otnt:otn-link/otnt:tsg"

  Unauthorized access to this data node can disclose configuration information of OTN links.

* "/nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/otnt:otn-link/otnt:distance"

  Unauthorized access to this data node can disclose state information of OTN links.

* "/nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/otnt:client-svc"

  Unauthorized access to this data node can disclose capabilities of OTN links.

* "/nw:networks/nw:network/nw:node/nt:termination-point/tet:te/otnt:otn-link-tp/otnt:odtu-flex-type"

  This node is used, together with the other attributes in the otn-bandwidth container, to compute the OTN bandwidth information for an OTN link termination point, as described in Section 2.3. Unauthorized access to this data node can disclose the OTN bandwidth information of OTN link termination points.

* "/nw:networks/nw:network/nw:node/nt:termination-point/tet:te/otnt:client-svc"

  Unauthorized access to this data node can disclose capabilities of OTN link termination points.

* "otnt:otn-bandwidth"

  This subtree specifies the configurations of OTN technology-specific information under any occurrence of the tet:te-bandwidth container, as defined in [RFC8795] (e.g., "/nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/tet:max-resv-link-bandwidth/tet:te-bandwidth/otnt:otn-bandwidth"). Unauthorized access to this data node can disclose the OTN bandwidth information of OTN links and link termination points.

* "otnt:otn-label-range"

  This subtree specifies the configurations of OTN technology-specific label range information under any occurrence of the tet:te-label-restriction container, as defined in [RFC8795] (e.g., "/nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes/tet:label-restrictions/tet:label-restriction\otnt:otn-label-range"). Unauthorized access to this data node can disclose the state information of OTN links and link termination points.

* "otnt:otn-label"

  This subtree specifies the configurations of OTN technology-specific label information under any occurrence of the tet:te-label container, as defined in [RFC8795] (e.g., "/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/otnt:otn-label"). Unauthorized access to this data node can disclose the state information of OTN links and link termination points.

This YANG module does not define RPC operations.

This YANG module uses groupings from other YANG modules that define nodes that may be considered sensitive or vulnerable in network environments. Refer to the Security Considerations of [I-D.ietf-ccamp-layer1-types] for information as to which nodes may be considered sensitive or vulnerable in network environments.

Finally, the YANG module described in this document augments the "ietf-network" YANG module [RFC8345] and the "ietf-te-topology" YANG module [RFC8795] by adding data nodes. The security considerations for the subtrees described in those RFCs apply equally to the new data nodes that this module adds.

6. References

6.1. Normative References

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6.2. Informative References

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Appendix A. YANG Tree

This section provides the YANG Tree of the OTN topology data model.

```
module: ietf-otn-topology

  augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
    +--rw otn-topology!
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:te-node-attributes:
    +--rw otn-node!
  augment /nw:networks/nw:network/nt:link/tet:te
            /tet:te-link-attributes:
    +--rw otn-link
    |  +--rw odtu-flex-type?   l1-types:odtu-flex-type
    |  +--rw tsg?              identityref
    |  +--rw distance?         uint32
    +--rw client-svc!
       +--rw supported-client-signal*   identityref
  augment /nw:networks/nw:network/nw:node/nt:termination-point
            /tet:te:
    +--rw otn-link-tp
    |  +--rw odtu-flex-type?   l1-types:odtu-flex-type
    +--rw client-svc!
       +--rw supported-client-signal*   identityref
  augment /nw:networks/nw:network/nw:node/nt:termination-point/tet:te
```

```
               /tet:interface-switching-capability/tet:max-lsp-bandwidth
               /tet:te-bandwidth/tet:technology:
       +--:(otn)
          +--rw otn-bandwidth
             +--rw odu-type?        identityref
             +--rw max-ts-number?   uint16
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:path-constraints/tet:te-bandwidth/tet:technology:
       +--:(otn)
          +--rw otn-bandwidth
             +--rw odulist* [odu-type]
             |  +--rw odu-type     identityref
             |  +--rw number?      uint16
             |  +--rw ts-number?   uint16
             +--rw odtu-flex-type?   l1-types:odtu-flex-type
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:path-constraints
               /tet:te-bandwidth/tet:technology:
       +--:(otn)
          +--rw otn-bandwidth
             +--rw odulist* [odu-type]
             |  +--rw odu-type     identityref
             |  +--rw number?      uint16
             |  +--rw ts-number?   uint16
             +--rw odtu-flex-type?   l1-types:odtu-flex-type
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:path-constraints/tet:te-bandwidth/tet:technology:
       +--:(otn)
          +--ro otn-bandwidth
             +--ro odulist* [odu-type]
             |  +--ro odu-type     identityref
             |  +--ro number?      uint16
             |  +--ro ts-number?   uint16
             +--ro odtu-flex-type?   l1-types:odtu-flex-type
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:path-constraints
               /tet:te-bandwidth/tet:technology:
       +--:(otn)
          +--ro otn-bandwidth
             +--ro odulist* [odu-type]
             |  +--ro odu-type     identityref
             |  +--ro number?      uint16
             |  +--ro ts-number?   uint16
             +--ro odtu-flex-type?   l1-types:odtu-flex-type
```

```
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:tunnel-termination-point/tet:client-layer-adaptation
               /tet:switching-capability/tet:te-bandwidth
               /tet:technology:
       +--:(otn)
          +--rw otn-bandwidth
             +--rw odulist* [odu-type]
             |  +--rw odu-type     identityref
             |  +--rw number?      uint16
             |  +--rw ts-number?   uint16
             +--rw odtu-flex-type?   l1-types:odtu-flex-type
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:tunnel-termination-point
               /tet:local-link-connectivities/tet:path-constraints
               /tet:te-bandwidth/tet:technology:
       +--:(otn)
          +--rw otn-bandwidth
             +--rw odulist* [odu-type]
             |  +--rw odu-type     identityref
             |  +--rw number?      uint16
             |  +--rw ts-number?   uint16
             +--rw odtu-flex-type?   l1-types:odtu-flex-type
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:tunnel-termination-point
               /tet:local-link-connectivities
               /tet:local-link-connectivity/tet:path-constraints
               /tet:te-bandwidth/tet:technology:
       +--:(otn)
          +--rw otn-bandwidth
             +--rw odulist* [odu-type]
             |  +--rw odu-type     identityref
             |  +--rw number?      uint16
             |  +--rw ts-number?   uint16
             +--rw odtu-flex-type?   l1-types:odtu-flex-type
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:te-link-attributes
               /tet:interface-switching-capability/tet:max-lsp-bandwidth
               /tet:te-bandwidth/tet:technology:
       +--:(otn)
          +--rw otn-bandwidth
             +--rw odu-type?         identityref
             +--rw max-ts-number?    uint16
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:te-link-attributes/tet:max-link-bandwidth
               /tet:te-bandwidth:
       +--rw otn-bandwidth
          +--rw odulist* [odu-type]
             +--rw odu-type     identityref
```

```
             +--rw number?      uint16
             +--rw ts-number?   uint16
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:te-link-attributes/tet:max-resv-link-bandwidth
               /tet:te-bandwidth:
       +--rw otn-bandwidth
          +--rw odulist* [odu-type]
             +--rw odu-type     identityref
             +--rw number?      uint16
             +--rw ts-number?   uint16
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:te-link-attributes/tet:unreserved-bandwidth
               /tet:te-bandwidth:
       +--rw otn-bandwidth
          +--rw odulist* [odu-type]
             +--rw odu-type     identityref
             +--rw number?      uint16
             +--rw ts-number?   uint16
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:information-source-entry
               /tet:interface-switching-capability/tet:max-lsp-bandwidth
               /tet:te-bandwidth/tet:technology:
       +--:(otn)
          +--ro otn-bandwidth
             +--ro odu-type?        identityref
             +--ro max-ts-number?   uint16
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:information-source-entry/tet:max-link-bandwidth
               /tet:te-bandwidth:
       +--ro otn-bandwidth
          +--ro odulist* [odu-type]
             +--ro odu-type     identityref
             +--ro number?      uint16
             +--ro ts-number?   uint16
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:information-source-entry/tet:max-resv-link-bandwidth
               /tet:te-bandwidth:
       +--ro otn-bandwidth
          +--ro odulist* [odu-type]
             +--ro odu-type     identityref
             +--ro number?      uint16
             +--ro ts-number?   uint16
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:information-source-entry/tet:unreserved-bandwidth
               /tet:te-bandwidth:
       +--ro otn-bandwidth
          +--ro odulist* [odu-type]
             +--ro odu-type     identityref
```

```
             +--ro number?      uint16
             +--ro ts-number?   uint16
     augment /nw:networks/tet:te/tet:templates/tet:link-template
               /tet:te-link-attributes
               /tet:interface-switching-capability/tet:max-lsp-bandwidth
               /tet:te-bandwidth/tet:technology:
       +--:(otn)
          +--rw otn-bandwidth
             +--rw odu-type?        identityref
             +--rw max-ts-number?   uint16
     augment /nw:networks/tet:te/tet:templates/tet:link-template
               /tet:te-link-attributes/tet:max-link-bandwidth
               /tet:te-bandwidth:
       +--rw otn-bandwidth
          +--rw odulist* [odu-type]
             +--rw odu-type     identityref
             +--rw number?      uint16
             +--rw ts-number?   uint16
     augment /nw:networks/tet:te/tet:templates/tet:link-template
               /tet:te-link-attributes/tet:max-resv-link-bandwidth
               /tet:te-bandwidth:
       +--rw otn-bandwidth
          +--rw odulist* [odu-type]
             +--rw odu-type     identityref
             +--rw number?      uint16
             +--rw ts-number?   uint16
     augment /nw:networks/tet:te/tet:templates/tet:link-template
               /tet:te-link-attributes/tet:unreserved-bandwidth
               /tet:te-bandwidth:
       +--rw otn-bandwidth
          +--rw odulist* [odu-type]
             +--rw odu-type     identityref
             +--rw number?      uint16
             +--rw ts-number?   uint16
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:label-restrictions/tet:label-restriction:
       +--rw otn-label-range!
          +--rw range-type?      otn-label-range-type
          +--rw tsg?             identityref
          +--rw odu-type-list*   identityref
          +--rw priority?        uint8
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:from/tet:label-restrictions
               /tet:label-restriction:
       +--rw otn-label-range!
          +--rw range-type?      otn-label-range-type
```

```
         +--rw tsg?             identityref
         +--rw odu-type-list*   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:
      +--rw otn-label-range!
         +--rw range-type?      otn-label-range-type
         +--rw tsg?             identityref
         +--rw odu-type-list*   identityref
         +--rw priority?        uint8
    augment /nw:networks/nw:network/nw:node/tet:te
              /tet:information-source-entry/tet:connectivity-matrices
              /tet:label-restrictions/tet:label-restriction:
      +--ro otn-label-range!
         +--ro range-type?      otn-label-range-type
         +--ro tsg?             identityref
         +--ro odu-type-list*   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:
      +--ro otn-label-range!
         +--ro range-type?      otn-label-range-type
         +--ro tsg?             identityref
         +--ro odu-type-list*   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:
      +--ro otn-label-range!
         +--ro range-type?      otn-label-range-type
         +--ro tsg?             identityref
         +--ro odu-type-list*   identityref
         +--ro 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:
      +--rw otn-label-range!
         +--rw range-type?      otn-label-range-type
         +--rw tsg?             identityref
         +--rw odu-type-list*   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:
       +--rw otn-label-range!
          +--rw range-type?      otn-label-range-type
          +--rw tsg?             identityref
          +--rw odu-type-list*   identityref
          +--rw priority?        uint8
     augment /nw:networks/nw:network/nt:link/tet:te
                /tet:te-link-attributes/tet:label-restrictions
                /tet:label-restriction:
       +--rw otn-label-range!
          +--rw range-type?      otn-label-range-type
          +--rw tsg?             identityref
          +--rw odu-type-list*   identityref
          +--rw priority?        uint8
     augment /nw:networks/nw:network/nt:link/tet:te
                /tet:information-source-entry/tet:label-restrictions
                /tet:label-restriction:
       +--ro otn-label-range!
          +--ro range-type?      otn-label-range-type
          +--ro tsg?             identityref
          +--ro odu-type-list*   identityref
          +--ro priority?        uint8
     augment /nw:networks/tet:te/tet:templates/tet:link-template
                /tet:te-link-attributes/tet:label-restrictions
                /tet:label-restriction:
       +--rw otn-label-range!
          +--rw range-type?      otn-label-range-type
          +--rw tsg?             identityref
          +--rw odu-type-list*   identityref
          +--rw priority?        uint8
     augment /nw:networks/nw:network/nw:node/tet:te
                /tet:te-node-attributes/tet:connectivity-matrices
                /tet:label-restrictions/tet:label-restriction
                /tet:label-start/tet:te-label/tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /nw:networks/nw:network/nw:node/tet:te
                /tet:te-node-attributes/tet:connectivity-matrices
                /tet:label-restrictions/tet:label-restriction
                /tet:label-end/tet:te-label/tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
```

```
             +--rw ts?    otn-ts
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:label-restrictions/tet:label-restriction
               /tet:label-step/tet:technology:
       +--:(otn)
          +--rw otn-label-step
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:underlay/tet:primary-path/tet:path-element/tet:type
               /tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:underlay/tet:backup-path/tet:path-element/tet:type
               /tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:optimizations/tet:algorithm/tet:metric
               /tet:optimization-metric
               /tet:explicit-route-exclude-objects
               /tet:route-object-exclude-object/tet:type/tet:label
               /tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:optimizations/tet:algorithm/tet:metric
               /tet:optimization-metric
               /tet:explicit-route-include-objects
               /tet:route-object-include-object/tet:type/tet:label
               /tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--rw otn-label
```

```
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:te-node-attributes/tet:connectivity-matrices
            /tet:path-properties/tet:path-route-objects
            /tet:path-route-object/tet:type/tet:label/tet:label-hop
            /tet:te-label/tet:technology:
    +--:(otn)
       +--ro otn-label
          +--ro tpn?       otn-tpn
          +--ro tsg?       identityref
          +--ro ts-list?   string
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:te-node-attributes/tet:connectivity-matrices
            /tet:connectivity-matrix/tet:from/tet:label-restrictions
            /tet:label-restriction/tet:label-start/tet:te-label
            /tet:technology:
    +--:(otn)
       +--rw otn-label
          +--rw tpn?   otn-tpn
          +--rw ts?    otn-ts
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:te-node-attributes/tet:connectivity-matrices
            /tet:connectivity-matrix/tet:from/tet:label-restrictions
            /tet:label-restriction/tet:label-end/tet:te-label
            /tet:technology:
    +--:(otn)
       +--rw otn-label
          +--rw tpn?   otn-tpn
          +--rw ts?    otn-ts
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:te-node-attributes/tet:connectivity-matrices
            /tet:connectivity-matrix/tet:from/tet:label-restrictions
            /tet:label-restriction/tet:label-step/tet:technology:
    +--:(otn)
       +--rw otn-label-step
          +--rw tpn?   otn-tpn
          +--rw ts?    otn-ts
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:te-node-attributes/tet:connectivity-matrices
            /tet:connectivity-matrix/tet:to/tet:label-restrictions
            /tet:label-restriction/tet:label-start/tet:te-label
            /tet:technology:
    +--:(otn)
       +--rw otn-label
          +--rw tpn?   otn-tpn
          +--rw ts?    otn-ts
```

```
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:to/tet:label-restrictions
               /tet:label-restriction/tet:label-end/tet:te-label
               /tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:to/tet:label-restrictions
               /tet:label-restriction/tet:label-step/tet:technology:
       +--:(otn)
          +--rw otn-label-step
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:underlay/tet:primary-path
               /tet:path-element/tet:type/tet:label/tet:label-hop
               /tet:te-label/tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:underlay/tet:backup-path
               /tet:path-element/tet:type/tet:label/tet:label-hop
               /tet:te-label/tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:optimizations/tet:algorithm
               /tet:metric/tet:optimization-metric
               /tet:explicit-route-exclude-objects
               /tet:route-object-exclude-object/tet:type/tet:label
               /tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
```

```
             +--rw ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:optimizations/tet:algorithm
               /tet:metric/tet:optimization-metric
               /tet:explicit-route-include-objects
               /tet:route-object-include-object/tet:type/tet:label
               /tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:te-node-attributes/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:path-properties
               /tet:path-route-objects/tet:path-route-object/tet:type
               /tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--ro otn-label
             +--ro tpn?       otn-tpn
             +--ro tsg?       identityref
             +--ro ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:label-restrictions/tet:label-restriction
               /tet:label-start/tet:te-label/tet:technology:
       +--:(otn)
          +--ro otn-label
             +--ro tpn?   otn-tpn
             +--ro ts?    otn-ts
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:label-restrictions/tet:label-restriction
               /tet:label-end/tet:te-label/tet:technology:
       +--:(otn)
          +--ro otn-label
             +--ro tpn?   otn-tpn
             +--ro ts?    otn-ts
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:label-restrictions/tet:label-restriction
               /tet:label-step/tet:technology:
       +--:(otn)
          +--ro otn-label-step
             +--ro tpn?   otn-tpn
             +--ro ts?    otn-ts
     augment /nw:networks/nw:network/nw:node/tet:te
```

```
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:underlay/tet:primary-path/tet:path-element/tet:type
               /tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--ro otn-label
             +--ro tpn?       otn-tpn
             +--ro tsg?       identityref
             +--ro ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:underlay/tet:backup-path/tet:path-element/tet:type
               /tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--ro otn-label
             +--ro tpn?       otn-tpn
             +--ro tsg?       identityref
             +--ro ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:optimizations/tet:algorithm/tet:metric
               /tet:optimization-metric
               /tet:explicit-route-exclude-objects
               /tet:route-object-exclude-object/tet:type/tet:label
               /tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--ro otn-label
             +--ro tpn?       otn-tpn
             +--ro tsg?       identityref
             +--ro ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:optimizations/tet:algorithm/tet:metric
               /tet:optimization-metric
               /tet:explicit-route-include-objects
               /tet:route-object-include-object/tet:type/tet:label
               /tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--ro otn-label
             +--ro tpn?       otn-tpn
             +--ro tsg?       identityref
             +--ro ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:path-properties/tet:path-route-objects
               /tet:path-route-object/tet:type/tet:label/tet:label-hop
               /tet:te-label/tet:technology:
       +--:(otn)
          +--ro otn-label
```

```
            +--ro tpn?       otn-tpn
            +--ro tsg?       identityref
            +--ro ts-list?   string
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:information-source-entry/tet:connectivity-matrices
            /tet:connectivity-matrix/tet:from/tet:label-restrictions
            /tet:label-restriction/tet:label-start/tet:te-label
            /tet:technology:
    +--:(otn)
       +--ro otn-label
          +--ro tpn?   otn-tpn
          +--ro ts?    otn-ts
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:information-source-entry/tet:connectivity-matrices
            /tet:connectivity-matrix/tet:from/tet:label-restrictions
            /tet:label-restriction/tet:label-end/tet:te-label
            /tet:technology:
    +--:(otn)
       +--ro otn-label
          +--ro tpn?   otn-tpn
          +--ro ts?    otn-ts
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:information-source-entry/tet:connectivity-matrices
            /tet:connectivity-matrix/tet:from/tet:label-restrictions
            /tet:label-restriction/tet:label-step/tet:technology:
    +--:(otn)
       +--ro otn-label-step
          +--ro tpn?   otn-tpn
          +--ro ts?    otn-ts
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:information-source-entry/tet:connectivity-matrices
            /tet:connectivity-matrix/tet:to/tet:label-restrictions
            /tet:label-restriction/tet:label-start/tet:te-label
            /tet:technology:
    +--:(otn)
       +--ro otn-label
          +--ro tpn?   otn-tpn
          +--ro ts?    otn-ts
  augment /nw:networks/nw:network/nw:node/tet:te
            /tet:information-source-entry/tet:connectivity-matrices
            /tet:connectivity-matrix/tet:to/tet:label-restrictions
            /tet:label-restriction/tet:label-end/tet:te-label
            /tet:technology:
    +--:(otn)
       +--ro otn-label
          +--ro tpn?   otn-tpn
          +--ro ts?    otn-ts
  augment /nw:networks/nw:network/nw:node/tet:te
```

```
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:to/tet:label-restrictions
               /tet:label-restriction/tet:label-step/tet:technology:
       +--:(otn)
          +--ro otn-label-step
             +--ro tpn?   otn-tpn
             +--ro ts?    otn-ts
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:underlay/tet:primary-path
               /tet:path-element/tet:type/tet:label/tet:label-hop
               /tet:te-label/tet:technology:
       +--:(otn)
          +--ro otn-label
             +--ro tpn?       otn-tpn
             +--ro tsg?       identityref
             +--ro ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:underlay/tet:backup-path
               /tet:path-element/tet:type/tet:label/tet:label-hop
               /tet:te-label/tet:technology:
       +--:(otn)
          +--ro otn-label
             +--ro tpn?       otn-tpn
             +--ro tsg?       identityref
             +--ro ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:optimizations/tet:algorithm
               /tet:metric/tet:optimization-metric
               /tet:explicit-route-exclude-objects
               /tet:route-object-exclude-object/tet:type/tet:label
               /tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--ro otn-label
             +--ro tpn?       otn-tpn
             +--ro tsg?       identityref
             +--ro ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:information-source-entry/tet:connectivity-matrices
               /tet:connectivity-matrix/tet:optimizations/tet:algorithm
               /tet:metric/tet:optimization-metric
               /tet:explicit-route-include-objects
               /tet:route-object-include-object/tet:type/tet:label
               /tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--ro otn-label
```

```
             +--ro tpn?       otn-tpn
             +--ro tsg?       identityref
             +--ro ts-list?   string
    augment /nw:networks/nw:network/nw:node/tet:te
              /tet:information-source-entry/tet:connectivity-matrices
              /tet:connectivity-matrix/tet:path-properties
              /tet:path-route-objects/tet:path-route-object/tet:type
              /tet:label/tet:label-hop/tet:te-label/tet:technology:
      +--:(otn)
         +--ro otn-label
            +--ro tpn?       otn-tpn
            +--ro tsg?       identityref
            +--ro ts-list?   string
    augment /nw:networks/nw:network/nw:node/tet:te
              /tet:tunnel-termination-point
              /tet:local-link-connectivities/tet:label-restrictions
              /tet:label-restriction/tet:label-start/tet:te-label
              /tet:technology:
      +--:(otn)
         +--rw otn-label
            +--rw tpn?   otn-tpn
            +--rw ts?    otn-ts
    augment /nw:networks/nw:network/nw:node/tet:te
              /tet:tunnel-termination-point
              /tet:local-link-connectivities/tet:label-restrictions
              /tet:label-restriction/tet:label-end/tet:te-label
              /tet:technology:
      +--:(otn)
         +--rw otn-label
            +--rw tpn?   otn-tpn
            +--rw ts?    otn-ts
    augment /nw:networks/nw:network/nw:node/tet:te
              /tet:tunnel-termination-point
              /tet:local-link-connectivities/tet:label-restrictions
              /tet:label-restriction/tet:label-step/tet:technology:
      +--:(otn)
         +--rw otn-label-step
            +--rw tpn?   otn-tpn
            +--rw ts?    otn-ts
    augment /nw:networks/nw:network/nw:node/tet:te
              /tet:tunnel-termination-point
              /tet:local-link-connectivities/tet:underlay
              /tet:primary-path/tet:path-element/tet:type/tet:label
              /tet:label-hop/tet:te-label/tet:technology:
      +--:(otn)
         +--rw otn-label
            +--rw tpn?       otn-tpn
            +--rw tsg?       identityref
```

```
             +--rw ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:tunnel-termination-point
               /tet:local-link-connectivities/tet:underlay
               /tet:backup-path/tet:path-element/tet:type/tet:label
               /tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:tunnel-termination-point
               /tet:local-link-connectivities/tet:optimizations
               /tet:algorithm/tet:metric/tet:optimization-metric
               /tet:explicit-route-exclude-objects
               /tet:route-object-exclude-object/tet:type/tet:label
               /tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:tunnel-termination-point
               /tet:local-link-connectivities/tet:optimizations
               /tet:algorithm/tet:metric/tet:optimization-metric
               /tet:explicit-route-include-objects
               /tet:route-object-include-object/tet:type/tet:label
               /tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:tunnel-termination-point
               /tet:local-link-connectivities/tet:path-properties
               /tet:path-route-objects/tet:path-route-object/tet:type
               /tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--ro otn-label
             +--ro tpn?       otn-tpn
             +--ro tsg?       identityref
             +--ro ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:tunnel-termination-point
               /tet:local-link-connectivities
```

```
               /tet:local-link-connectivity/tet:label-restrictions
               /tet:label-restriction/tet:label-start/tet:te-label
               /tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:tunnel-termination-point
               /tet:local-link-connectivities
               /tet:local-link-connectivity/tet:label-restrictions
               /tet:label-restriction/tet:label-end/tet:te-label
               /tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:tunnel-termination-point
               /tet:local-link-connectivities
               /tet:local-link-connectivity/tet:label-restrictions
               /tet:label-restriction/tet:label-step/tet:technology:
       +--:(otn)
          +--rw otn-label-step
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:tunnel-termination-point
               /tet:local-link-connectivities
               /tet:local-link-connectivity/tet:underlay
               /tet:primary-path/tet:path-element/tet:type/tet:label
               /tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:tunnel-termination-point
               /tet:local-link-connectivities
               /tet:local-link-connectivity/tet:underlay/tet:backup-path
               /tet:path-element/tet:type/tet:label/tet:label-hop
               /tet:te-label/tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
```

```
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:tunnel-termination-point
               /tet:local-link-connectivities
               /tet:local-link-connectivity/tet:optimizations
               /tet:algorithm/tet:metric/tet:optimization-metric
               /tet:explicit-route-exclude-objects
               /tet:route-object-exclude-object/tet:type/tet:label
               /tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:tunnel-termination-point
               /tet:local-link-connectivities
               /tet:local-link-connectivity/tet:optimizations
               /tet:algorithm/tet:metric/tet:optimization-metric
               /tet:explicit-route-include-objects
               /tet:route-object-include-object/tet:type/tet:label
               /tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /nw:networks/nw:network/nw:node/tet:te
               /tet:tunnel-termination-point
               /tet:local-link-connectivities
               /tet:local-link-connectivity/tet:path-properties
               /tet:path-route-objects/tet:path-route-object/tet:type
               /tet:label/tet:label-hop/tet:te-label/tet:technology:
       +--:(otn)
          +--ro otn-label
             +--ro tpn?       otn-tpn
             +--ro tsg?       identityref
             +--ro ts-list?   string
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:te-link-attributes/tet:underlay/tet:primary-path
               /tet:path-element/tet:type/tet:label/tet:label-hop
               /tet:te-label/tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:te-link-attributes/tet:underlay/tet:backup-path
```

```
               /tet:path-element/tet:type/tet:label/tet:label-hop
               /tet:te-label/tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:te-link-attributes/tet:label-restrictions
               /tet:label-restriction/tet:label-start/tet:te-label
               /tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:te-link-attributes/tet:label-restrictions
               /tet:label-restriction/tet:label-end/tet:te-label
               /tet:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:te-link-attributes/tet:label-restrictions
               /tet:label-restriction/tet:label-step/tet:technology:
       +--:(otn)
          +--rw otn-label-step
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:information-source-entry/tet:label-restrictions
               /tet:label-restriction/tet:label-start/tet:te-label
               /tet:technology:
       +--:(otn)
          +--ro otn-label
             +--ro tpn?   otn-tpn
             +--ro ts?    otn-ts
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:information-source-entry/tet:label-restrictions
               /tet:label-restriction/tet:label-end/tet:te-label
               /tet:technology:
       +--:(otn)
          +--ro otn-label
             +--ro tpn?   otn-tpn
             +--ro ts?    otn-ts
     augment /nw:networks/nw:network/nt:link/tet:te
               /tet:information-source-entry/tet:label-restrictions
```

```
              /tet:label-restriction/tet:label-step/tet:technology:
        +--:(otn)
           +--ro otn-label-step
              +--ro tpn?   otn-tpn
              +--ro ts?    otn-ts
      augment /nw:networks/tet:te/tet:templates/tet:link-template
              /tet:te-link-attributes/tet:underlay/tet:primary-path
              /tet:path-element/tet:type/tet:label/tet:label-hop
              /tet:te-label/tet:technology:
        +--:(otn)
           +--rw otn-label
              +--rw tpn?       otn-tpn
              +--rw tsg?       identityref
              +--rw ts-list?   string
      augment /nw:networks/tet:te/tet:templates/tet:link-template
              /tet:te-link-attributes/tet:underlay/tet:backup-path
              /tet:path-element/tet:type/tet:label/tet:label-hop
              /tet:te-label/tet:technology:
        +--:(otn)
           +--rw otn-label
              +--rw tpn?       otn-tpn
              +--rw tsg?       identityref
              +--rw ts-list?   string
      augment /nw:networks/tet:te/tet:templates/tet:link-template
              /tet:te-link-attributes/tet:label-restrictions
              /tet:label-restriction/tet:label-start/tet:te-label
              /tet:technology:
        +--:(otn)
           +--rw otn-label
              +--rw tpn?   otn-tpn
              +--rw ts?    otn-ts
      augment /nw:networks/tet:te/tet:templates/tet:link-template
              /tet:te-link-attributes/tet:label-restrictions
              /tet:label-restriction/tet:label-end/tet:te-label
              /tet:technology:
        +--:(otn)
           +--rw otn-label
              +--rw tpn?   otn-tpn
              +--rw ts?    otn-ts
      augment /nw:networks/tet:te/tet:templates/tet:link-template
              /tet:te-link-attributes/tet:label-restrictions
              /tet:label-restriction/tet:label-step/tet:technology:
        +--:(otn)
           +--rw otn-label-step
              +--rw tpn?   otn-tpn
              +--rw ts?    otn-ts
```

Appendix B. JSON Examples

This appendix contains an example of an instance data tree in JSON encoding [RFC7951].

The example instantiates the "ietf-otn-topology" model for the OTN topology depicted in Figure 2 below.

The OTN topology consists of three nodes (D1, D2, and D3) with three link termination (LTPs) each: two LTPs which terminates the links that belongs to the OTN topology and one LTP which terminates inter-domain links, as defined in [RFC8795].

The OTN links within the OTN network are 100G OTN links while the links at the edge of the network are 10G links. All these OTN links support ODU4, ODU2 and ODU0 connections. The link between nodes D1 and D2 also supports ODUflex.

The OTN links within the OTN network are bidirectional and symmetrical: for this reasons, the link attributes (e.g., support for OTN switching capability or transparent client signal and the OTN maximum link bandwidth) are instantiated only on the link representing the forward direction, while the link representing the reverse direction are instantiated without any link attribute (other than the name) to indicate that the OTN links are bidirectional and symmetrical.

The link between nodes D1 and D2 is an example of a multi-function link, as defined in Section 2.2, which can support both OTN and 100G client signal (e.g., 100GE): the interface-switching-capability list indicates support for OTN switching capability and the client-svc presence container is instantiated.

For the LTPs which terminate OTN links, only the identifiers information is instantiated. All the other properties are defined in the links they terminate.

For the LTPs at the edge network, additional properties are instantiated to indicate whether the link can support OTN or transparent client signals. In particular:

* LTP 1 on Node D1 is an example of an LTP terminating a multi-function access link, as defined in Section 2.2, which can support both OTN and 10G client signals (e.g., 10GE and STM-64): the interface-switching-capability list indicates support for OTN switching capability and the client-svc presence container is instantiated;

* LTP 2 on Node D2 is an example of an LTP which can support only 10G OTN (ODU2) signal: the interface-switching-capability list indicates support for OTN switching capability and the client-svc presence container is not instantiated;

* LTP 3 on Node D3 is an example of an LTP which can support only 10G (e.g., 10GE and STM-64) client signals: the interface-switching-capability list does not indicate support for OTN switching capability and the client-svc presence container is instantiated.

```
    +------------+                   +------------+
    |     D1     |                   |     D2     |
   /-\          /-\                 /-\          /-\
   | | 1        | |---------------->| | 1        | |
   | |        2 | |<----------------| |        2 | |
   \-/    3     \-/                 \-/    3     \-/
    |   /----\   |                   |   /----\   |
    +---|    |---+                   +---|    |---+
        \----/                           \----/
         A  |                             A  |
         |  |                             |  |
         |  |                             |  |
         |  |       +------------+        |  |
         |  |       |     D3     |        |  |
         |  |      /-\          /-\       |  |
         |  +----->| | 1        | |-------+  |
         +---------| |        2 | |<---------+
                   \-/    3     \-/
                    |   /----\   |
                    +---|    |---+
                        \----/
```

Figure 2: Example of OTN topology

=============== NOTE: '\' line wrapping per RFC 8792 ================


```
{
  "ietf-network:networks": {
    "network": [
      {
        "network-id": "example:otn-topology-example",
        "network-types": {
          "ietf-te-topology:te-topology": {
            "ietf-otn-topology:otn-topology": {}
          }
        },
        "ietf-te-topology:te-topology-identifier": {
```

```
            "topology-id": "otn-topology-example"
          },
          "ietf-te-topology:te": {},
          "node": [
            {
              "node-id": "example:D1",
              "ietf-te-topology:te-node-id": "192.0.0.1",
              "ietf-te-topology:te": {
                "te-node-attributes": {
                  "name": "Node D1",
                  "ietf-otn-topology:otn-node": {}
                }
              },
              "ietf-network-topology:termination-point": [
                {
                  "tp-id": "example:D1-1",
                  "ietf-te-topology:te-tp-id": 1,
                  "ietf-te-topology:te": {
                    "name": "Interface 1 of Node D1",
                    "interface-switching-capability": [
                      {
                        "switching-capability": "ietf-te-types:switchi\
   ng-otn",
                        "encoding": "ietf-te-types:lsp-encoding-oduk"
                      }
                    ],
                    "ietf-otn-topology:client-svc": {
                      "supported-client-signal": [
                        "ietf-layer1-types:ETH-10Gb-LAN",
                        "ietf-layer1-types:STM-64"
                      ]
                    }
                  }
                },
                {
                  "tp-id": "example:D1-2",
                  "ietf-te-topology:te-tp-id": 1,
                  "ietf-te-topology:te": {
                    "name": "Interface 2 of Node D1"
                  }
                },
                {
                  "tp-id": "example:D1-3",
                  "ietf-te-topology:te-tp-id": 1,
                  "ietf-te-topology:te": {
                    "name": "Interface 3 of Node D1"
                  }
                }
```

```
              ]
            },
            {
              "node-id": "example:D2",
              "ietf-te-topology:te-node-id": "192.0.0.2",
              "ietf-te-topology:te": {
                "te-node-attributes": {
                  "name": "Node D2",
                  "ietf-otn-topology:otn-node": {}
                }
              },
              "ietf-network-topology:termination-point": [
                {
                  "tp-id": "example:D2-1",
                  "ietf-te-topology:te-tp-id": 1,
                  "ietf-te-topology:te": {
                    "name": "Interface 1 of Node D2"
                  }
                },
                {
                  "tp-id": "example:D2-2",
                  "ietf-te-topology:te-tp-id": 1,
                  "ietf-te-topology:te": {
                    "name": "Interface 2 of Node D2",
                    "interface-switching-capability": [
                      {
                        "switching-capability": "ietf-te-types:switchi\
   ng-otn",
                        "encoding": "ietf-te-types:lsp-encoding-oduk"
                      }
                    ]
                  }
                },
                {
                  "tp-id": "example:D2-3",
                  "ietf-te-topology:te-tp-id": 1,
                  "ietf-te-topology:te": {
                    "name": "Interface 3 of Node D2"
                  }
                }
              ]
            },
            {
              "node-id": "example:D3",
              "ietf-te-topology:te-node-id": "192.0.0.3",
              "ietf-te-topology:te": {
                "te-node-attributes": {
                  "name": "Node D3",
```

```
                   "ietf-otn-topology:otn-node": {}
                 }
               },
               "ietf-network-topology:termination-point": [
                 {
                   "tp-id": "example:D3-1",
                   "ietf-te-topology:te-tp-id": 1,
                   "ietf-te-topology:te": {
                     "name": "Interface 1 of Node D3"
                   }
                 },
                 {
                   "tp-id": "example:D3-2",
                   "ietf-te-topology:te-tp-id": 1,
                   "ietf-te-topology:te": {
                     "name": "Interface 2 of Node D3"
                   }
                 },
                 {
                   "tp-id": "example:D3-3",
                   "ietf-te-topology:te-tp-id": 1,
                   "ietf-te-topology:te": {
                     "name": "Interface 3 of Node D3",
                     "ietf-otn-topology:client-svc": {
                       "supported-client-signal": [
                         "ietf-layer1-types:ETH-10Gb-LAN",
                         "ietf-layer1-types:STM-64"
                       ]
                     }
                   }
                 }
               ]
             }
           ],
           "ietf-network-topology:link": [
             {
               "link-id": "example:link/D1-2/D2-1",
               "ietf-te-topology:te": {
                 "te-link-attributes": {
                   "name": "Link between Node D1 and Node D2 (forward d\
   irection)",
                   "interface-switching-capability": [
                     {
                       "switching-capability": "ietf-te-types:switching\
   -otn",
                       "encoding": "ietf-te-types:lsp-encoding-oduk"
                     }
                   ],
```

```
                   "max-link-bandwidth": {
                     "te-bandwidth": {
                       "ietf-otn-topology:otn-bandwidth": {
                         "odulist": [
                           {
                             "odu-type": "ietf-layer1-types:ODU4",
                             "number": 1
                           },
                           {
                             "odu-type": "ietf-layer1-types:ODU2",
                             "number": 10
                           },
                           {
                             "odu-type": "ietf-layer1-types:ODU0",
                             "number": 80
                           },
                           {
                             "odu-type": "ietf-layer1-types:ODUflex",
                             "number": 80,
                             "ts-number": 80
                           }
                         ]
                       }
                     }
                   },
                   "ietf-otn-topology:otn-link": {
                     "odtu-flex-type": "4"
                   },
                   "ietf-otn-topology:client-svc": {
                     "supported-client-signal": [
                       "ietf-layer1-types:ETH-100Gb"
                     ]
                   }
                 }
               }
             },
             {
               "link-id": "example:link/D2-1/D1-2",
               "ietf-te-topology:te": {
                 "te-link-attributes": {
                   "name": "Link between Node D1 and Node D2 (reverse d\
   irection)"
                 }
               }
             },
             {
               "link-id": "example:link/D2-3/D3-2",
               "ietf-te-topology:te": {
```

```
                 "te-link-attributes": {
                   "name": "Link between Node D2 and Node D3 (forward d\
   irection)",
                   "interface-switching-capability": [
                     {
                       "switching-capability": "ietf-te-types:switching\
   -otn",
                       "encoding": "ietf-te-types:lsp-encoding-oduk"
                     }
                   ],
                   "max-link-bandwidth": {
                     "te-bandwidth": {
                       "ietf-otn-topology:otn-bandwidth": {
                         "odulist": [
                           {
                             "odu-type": "ietf-layer1-types:ODU4",
                             "number": 1
                           },
                           {
                             "odu-type": "ietf-layer1-types:ODU2",
                             "number": 10
                           },
                           {
                             "odu-type": "ietf-layer1-types:ODU0",
                             "number": 80
                           }
                         ]
                       }
                     }
                   }
                 }
               }
             },
             {
               "link-id": "example:link/D3-2/D2-3",
               "ietf-te-topology:te": {
                 "te-link-attributes": {
                   "name": "Link between Node D2 and Node D3 (reverse d\
   irection)"
                 }
               }
             },
             {
               "link-id": "example:link/D3-1/D1-3",
               "ietf-te-topology:te": {
                 "te-link-attributes": {
                   "name": "Link between Node D1 and Node D3 (reverse d\
   irection)"
```

```
                }
              }
            },
            {
              "link-id": "example:link/D1-3/D3-1",
              "ietf-te-topology:te": {
                "te-link-attributes": {
                  "name": "Link between Node D1 and Node D3 (forward d\
   irection)",
                  "interface-switching-capability": [
                    {
                      "switching-capability": "ietf-te-types:switching\
   -otn",
                      "encoding": "ietf-te-types:lsp-encoding-oduk"
                    }
                  ],
                  "max-link-bandwidth": {
                    "te-bandwidth": {
                      "ietf-otn-topology:otn-bandwidth": {
                        "odulist": [
                          {
                            "odu-type": "ietf-layer1-types:ODU4",
                            "number": 1
                          },
                          {
                            "odu-type": "ietf-layer1-types:ODU2",
                            "number": 10
                          },
                          {
                            "odu-type": "ietf-layer1-types:ODU0",
                            "number": 80
                          }
                        ]
                      }
                    }
                  }
                }
              }
            }
          ]
        }
      ]
    }
  }
```

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A YANG Data Model for Optical Transport Network (OTN) Tunnels and Label Switched Paths

draft-ietf-ccamp-otn-tunnel-model-24

Abstract

This document describes the YANG data model for tunnels in OTN TE networks. The model can be used to do the configuration in order to establish the tunnel in OTN network. This work is independent with the control plane protocols.

About This Document

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

Status information for this document may be found at https://datatracker.ietf.org/doc/draft-ietf-ccamp-otn-tunnel-model/.

Discussion of this document takes place on the Common Control and Measurement Plane Working Group mailing list (mailto:ccamp@ietf.org), which is archived at https://mailarchive.ietf.org/arch/browse/ccamp/. Subscribe at https://www.ietf.org/mailman/listinfo/ccamp/.

Source for this draft and an issue tracker can be found at https://github.com/haomianzheng/IETF-ACTN-YANG-Model.

Status of This Memo

Table of Contents

1. Introduction

OTN transport networks, specified in [ITU-T_G.709], can carry various types of client signals. In many cases, the client signal is carried over an OTN tunnel across connected domains in a multi-domain network.

This document provides YANG model for creating OTN tunnel. The model augments the generic TE Tunnel model specified in [I-D.ietf-teas-yang-te].

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

1.1. Terminology and Notations

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

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

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

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

* configuration data
* state data

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

1.2. Tree Diagram

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

1.3. Prefix in Data Node Names

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

Prefix	YANG module	Reference
l1-types	ietf-layer1-types	[RFC YYYY]
otn-tnl	ietf-otn-tunnel	RFC XXXX
te	ietf-te	[RFC ZZZZ]

Table 1: Prefixes and corresponding YANG modules

RFC Editor Note: Please replace XXXX with the number assigned to the RFC once this draft becomes an RFC. Please replace YYYY with the RFC numbers assigned to [I-D.ietf-ccamp-layer1-types]. Please replace ZZZZ with the RFC numbers assigned to [I-D.ietf-teas-yang-te].

2. OTN Tunnel Model Description

2.1. Overview of OTN Tunnel Model

This document aims to describe the data model for OTN tunnel. The OTN tunnel model is using TE tunnel [I-D.ietf-teas-yang-te] as a basic model and augments it with OTN-specific parameters, including the bandwidth information and label information. Figure 1 shows the augmentation relationship.

```
                  +-----------------+
  TE generic      |     ietf-te     |
                  +-----------------+
                           ^
                           |
                           | Augments
                           |
                  +--------+--------+
  OTN             | ietf-otn-tunnel |
                  +-----------------+
```

Figure 1: Relationship between OTN and TE tunnel models

It is also worth noting that the OTN tunnel provisioning is usually based on the OTN topology. Therefore the OTN tunnel model is usually used together with OTN topology model specified in [I-D.ietf-ccamp-otn-topo-yang]. The OTN tunnel model also imports a few type modules, including ietf-layer1-types, ietf-te-types and ietf-inet-types. The OTN-specific attributes in [RFC7139], including the Tributary Slot (TS) and Tributary Port Number (TPN), can be used to represent the bandwidth and label information. These attributes have been specified in [I-D.ietf-ccamp-layer1-types] and used in this document for augmentation of the generic TE tunnel model.

More scenarios and model applications can be found in [I-D.ietf-ccamp-transport-nbi-app-statement] and [I-D.ietf-teas-actn-yang].

2.2. Bandwidth Augmentation

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

2.3. Label Augmentation

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

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

3. OTN Tunnel YANG Tree

```
module: ietf-otn-tunnel

  augment /te:te/te:globals/te:named-path-constraints
            /te:named-path-constraint/te:te-bandwidth/te:technology:
    +--:(otn)
       +--rw otn-bandwidth
          +--rw odu-type?                  identityref
          +--rw (oduflex-type)?
             +--:(generic)
             |  +--rw nominal-bit-rate       union
             +--:(cbr)
             |  +--rw client-type            identityref
             +--:(gfp-n-k)
             |  +--rw gfp-n                  uint8
             |  +--rw gfp-k?                 gfp-k
             +--:(flexe-client)
             |  +--rw flexe-client           flexe-client-rate
             +--:(flexe-aware)
             |  +--rw flexe-aware-n          uint16
             +--:(packet)
```

```
                 +--rw opuflex-payload-rate    union
     augment /te:te/te:tunnels/te:tunnel/te:te-bandwidth/te:technology:
       +--:(otn)
          +--rw otn-bandwidth
             +--rw odu-type?                   identityref
             +--rw (oduflex-type)?
                +--:(generic)
                |  +--rw nominal-bit-rate        union
                +--:(cbr)
                |  +--rw client-type             identityref
                +--:(gfp-n-k)
                |  +--rw gfp-n                   uint8
                |  +--rw gfp-k?                  gfp-k
                +--:(flexe-client)
                |  +--rw flexe-client            flexe-client-rate
                +--:(flexe-aware)
                |  +--rw flexe-aware-n           uint16
                +--:(packet)
                   +--rw opuflex-payload-rate    union
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:te-bandwidth/te:technology:
       +--:(otn)
          +--rw otn-bandwidth
             +--rw odu-type?                   identityref
             +--rw (oduflex-type)?
                +--:(generic)
                |  +--rw nominal-bit-rate        union
                +--:(cbr)
                |  +--rw client-type             identityref
                +--:(gfp-n-k)
                |  +--rw gfp-n                   uint8
                |  +--rw gfp-k?                  gfp-k
                +--:(flexe-client)
                |  +--rw flexe-client            flexe-client-rate
                +--:(flexe-aware)
                |  +--rw flexe-aware-n           uint16
                +--:(packet)
                   +--rw opuflex-payload-rate    union
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:computed-paths-properties
               /te:computed-path-properties/te:path-properties
               /te:te-bandwidth/te:technology:
       +--:(otn)
          +--ro otn-bandwidth
             +--ro odu-type?                   identityref
             +--ro (oduflex-type)?
                +--:(generic)
                |  +--ro nominal-bit-rate        union
```

```
                +--:(cbr)
                |  +--ro client-type              identityref
                +--:(gfp-n-k)
                |  +--ro gfp-n                    uint8
                |  +--ro gfp-k?                   gfp-k
                +--:(flexe-client)
                |  +--ro flexe-client             flexe-client-rate
                +--:(flexe-aware)
                |  +--ro flexe-aware-n            uint16
                +--:(packet)
                   +--ro opuflex-payload-rate    union
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:primary-reverse-path/te:te-bandwidth
               /te:technology:
       +--:(otn)
          +--rw otn-bandwidth
             +--rw odu-type?                      identityref
             +--rw (oduflex-type)?
                +--:(generic)
                |  +--rw nominal-bit-rate         union
                +--:(cbr)
                |  +--rw client-type              identityref
                +--:(gfp-n-k)
                |  +--rw gfp-n                    uint8
                |  +--rw gfp-k?                   gfp-k
                +--:(flexe-client)
                |  +--rw flexe-client             flexe-client-rate
                +--:(flexe-aware)
                |  +--rw flexe-aware-n            uint16
                +--:(packet)
                   +--rw opuflex-payload-rate    union
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:primary-reverse-path
               /te:computed-paths-properties/te:computed-path-properties
               /te:path-properties/te:te-bandwidth/te:technology:
       +--:(otn)
          +--ro otn-bandwidth
             +--ro odu-type?                      identityref
             +--ro (oduflex-type)?
                +--:(generic)
                |  +--ro nominal-bit-rate         union
                +--:(cbr)
                |  +--ro client-type              identityref
                +--:(gfp-n-k)
                |  +--ro gfp-n                    uint8
                |  +--ro gfp-k?                   gfp-k
                +--:(flexe-client)
                |  +--ro flexe-client             flexe-client-rate
```

```
                +--:(flexe-aware)
                |  +--ro flexe-aware-n           uint16
                +--:(packet)
                   +--ro opuflex-payload-rate    union
     augment /te:te/te:tunnels/te:tunnel/te:secondary-paths
               /te:secondary-path/te:te-bandwidth/te:technology:
       +--:(otn)
          +--rw otn-bandwidth
             +--rw odu-type?                     identityref
             +--rw (oduflex-type)?
                +--:(generic)
                |  +--rw nominal-bit-rate        union
                +--:(cbr)
                |  +--rw client-type             identityref
                +--:(gfp-n-k)
                |  +--rw gfp-n                   uint8
                |  +--rw gfp-k?                  gfp-k
                +--:(flexe-client)
                |  +--rw flexe-client            flexe-client-rate
                +--:(flexe-aware)
                |  +--rw flexe-aware-n           uint16
                +--:(packet)
                   +--rw opuflex-payload-rate    union
     augment /te:te/te:tunnels/te:tunnel/te:secondary-paths
               /te:secondary-path/te:computed-paths-properties
               /te:computed-path-properties/te:path-properties
               /te:te-bandwidth/te:technology:
       +--:(otn)
          +--ro otn-bandwidth
             +--ro odu-type?                     identityref
             +--ro (oduflex-type)?
                +--:(generic)
                |  +--ro nominal-bit-rate        union
                +--:(cbr)
                |  +--ro client-type             identityref
                +--:(gfp-n-k)
                |  +--ro gfp-n                   uint8
                |  +--ro gfp-k?                  gfp-k
                +--:(flexe-client)
                |  +--ro flexe-client            flexe-client-rate
                +--:(flexe-aware)
                |  +--ro flexe-aware-n           uint16
                +--:(packet)
                   +--ro opuflex-payload-rate    union
     augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
               /te:secondary-reverse-path/te:te-bandwidth/te:technology:
       +--:(otn)
          +--rw otn-bandwidth
```

```
           +--rw odu-type?                    identityref
           +--rw (oduflex-type)?
              +--:(generic)
              |  +--rw nominal-bit-rate       union
              +--:(cbr)
              |  +--rw client-type            identityref
              +--:(gfp-n-k)
              |  +--rw gfp-n                  uint8
              |  +--rw gfp-k?                 gfp-k
              +--:(flexe-client)
              |  +--rw flexe-client           flexe-client-rate
              +--:(flexe-aware)
              |  +--rw flexe-aware-n          uint16
              +--:(packet)
                 +--rw opuflex-payload-rate   union
   augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
             /te:secondary-reverse-path/te:computed-paths-properties
             /te:computed-path-properties/te:path-properties
             /te:te-bandwidth/te:technology:
     +--:(otn)
        +--ro otn-bandwidth
           +--ro odu-type?                    identityref
           +--ro (oduflex-type)?
              +--:(generic)
              |  +--ro nominal-bit-rate       union
              +--:(cbr)
              |  +--ro client-type            identityref
              +--:(gfp-n-k)
              |  +--ro gfp-n                  uint8
              |  +--ro gfp-k?                 gfp-k
              +--:(flexe-client)
              |  +--ro flexe-client           flexe-client-rate
              +--:(flexe-aware)
              |  +--ro flexe-aware-n          uint16
              +--:(packet)
                 +--ro opuflex-payload-rate   union
   augment /te:te/te:globals/te:named-path-constraints
             /te:named-path-constraint/te:path-in-segment
             /te:label-restrictions/te:label-restriction:
     +--rw otn-label-range
        +--rw range-type?      otn-label-range-type
        +--rw tsg?             identityref
        +--rw odu-type-list*   identityref
        +--rw priority?        uint8
   augment /te:te/te:globals/te:named-path-constraints
             /te:named-path-constraint/te:path-out-segment
             /te:label-restrictions/te:label-restriction:
     +--rw otn-label-range
```

```
          +--rw range-type?      otn-label-range-type
          +--rw tsg?             identityref
          +--rw odu-type-list*   identityref
          +--rw priority?        uint8
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:path-in-segment/te:label-restrictions
               /te:label-restriction:
       +--rw otn-label-range
          +--rw range-type?      otn-label-range-type
          +--rw tsg?             identityref
          +--rw odu-type-list*   identityref
          +--rw priority?        uint8
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:path-out-segment
               /te:label-restrictions/te:label-restriction:
       +--rw otn-label-range
          +--rw range-type?      otn-label-range-type
          +--rw tsg?             identityref
          +--rw odu-type-list*   identityref
          +--rw priority?        uint8
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:primary-reverse-path
               /te:path-in-segment/te:label-restrictions
               /te:label-restriction:
       +--rw otn-label-range
          +--rw range-type?      otn-label-range-type
          +--rw tsg?             identityref
          +--rw odu-type-list*   identityref
          +--rw priority?        uint8
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:primary-reverse-path
               /te:path-out-segment/te:label-restrictions
               /te:label-restriction:
       +--rw otn-label-range
          +--rw range-type?      otn-label-range-type
          +--rw tsg?             identityref
          +--rw odu-type-list*   identityref
          +--rw priority?        uint8
     augment /te:te/te:tunnels/te:tunnel/te:secondary-paths
               /te:secondary-path/te:path-in-segment
               /te:label-restrictions/te:label-restriction:
       +--rw otn-label-range
          +--rw range-type?      otn-label-range-type
          +--rw tsg?             identityref
          +--rw odu-type-list*   identityref
          +--rw priority?        uint8
     augment /te:te/te:tunnels/te:tunnel/te:secondary-paths
               /te:secondary-path/te:path-out-segment
```

```
                /te:label-restrictions/te:label-restriction:
        +--rw otn-label-range
           +--rw range-type?      otn-label-range-type
           +--rw tsg?             identityref
           +--rw odu-type-list*   identityref
           +--rw priority?        uint8
      augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
                /te:secondary-reverse-path/te:path-in-segment
                /te:label-restrictions/te:label-restriction:
        +--rw otn-label-range
           +--rw range-type?      otn-label-range-type
           +--rw tsg?             identityref
           +--rw odu-type-list*   identityref
           +--rw priority?        uint8
      augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
                /te:secondary-reverse-path/te:path-out-segment
                /te:label-restrictions/te:label-restriction:
        +--rw otn-label-range
           +--rw range-type?      otn-label-range-type
           +--rw tsg?             identityref
           +--rw odu-type-list*   identityref
           +--rw priority?        uint8
      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:
        +--:(otn)
           +--rw otn-label
              +--rw tpn?       otn-tpn
              +--rw tsg?       identityref
              +--rw ts-list?   string
      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:
        +--:(otn)
           +--rw otn-label
              +--rw tpn?       otn-tpn
              +--rw tsg?       identityref
              +--rw ts-list?   string
      augment /te:te/te:globals/te:named-path-constraints
                /te:named-path-constraint/te:path-in-segment
                /te:label-restrictions/te:label-restriction
                /te:label-start/te:te-label/te:technology:
        +--:(otn)
           +--rw otn-label
              +--rw tpn?   otn-tpn
              +--rw ts?    otn-ts
```

```
     augment /te:te/te:globals/te:named-path-constraints
               /te:named-path-constraint/te:path-in-segment
               /te:label-restrictions/te:label-restriction/te:label-end
               /te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:globals/te:named-path-constraints
               /te:named-path-constraint/te:path-in-segment
               /te:label-restrictions/te:label-restriction/te:label-step
               /te:technology:
       +--:(otn)
          +--rw otn-label-step
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:globals/te:named-path-constraints
               /te:named-path-constraint/te:path-out-segment
               /te:label-restrictions/te:label-restriction
               /te:label-start/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:globals/te:named-path-constraints
               /te:named-path-constraint/te:path-out-segment
               /te:label-restrictions/te:label-restriction/te:label-end
               /te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:globals/te:named-path-constraints
               /te:named-path-constraint/te:path-out-segment
               /te:label-restrictions/te:label-restriction/te:label-step
               /te:technology:
       +--:(otn)
          +--rw otn-label-step
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:optimizations/te:algorithm/te:metric
               /te:optimization-metric/te:explicit-route-exclude-objects
               /te:route-object-exclude-object/te:type/te:label
               /te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
```

```
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:optimizations/te:algorithm/te:metric
               /te:optimization-metric/te:explicit-route-include-objects
               /te:route-object-include-object/te:type/te:label
               /te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:explicit-route-objects
               /te:route-object-exclude-always/te:type/te:label
               /te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:explicit-route-objects
               /te:route-object-include-exclude/te:type/te:label
               /te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:path-in-segment/te:label-restrictions
               /te:label-restriction/te:label-start/te:te-label
               /te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:path-in-segment/te:label-restrictions
               /te:label-restriction/te:label-end/te:te-label
               /te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:path-in-segment/te:label-restrictions
```

```
              /te:label-restriction/te:label-step/te:technology:
       +--:(otn)
          +--rw otn-label-step
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
              /te:primary-path/te:path-out-segment
              /te:label-restrictions/te:label-restriction
              /te:label-start/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
              /te:primary-path/te:path-out-segment
              /te:label-restrictions/te:label-restriction/te:label-end
              /te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
              /te:primary-path/te:path-out-segment
              /te:label-restrictions/te:label-restriction/te:label-step
              /te:technology:
       +--:(otn)
          +--rw otn-label-step
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
              /te:primary-path/te:computed-paths-properties
              /te:computed-path-properties/te:path-properties
              /te:path-route-objects/te:path-route-object/te:type
              /te:label/te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--ro otn-label
             +--ro tpn?       otn-tpn
             +--ro tsg?       identityref
             +--ro ts-list?   string
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
              /te:primary-path/te:primary-reverse-path/te:optimizations
              /te:algorithm/te:metric/te:optimization-metric
              /te:explicit-route-exclude-objects
              /te:route-object-exclude-object/te:type/te:label
              /te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
```

```
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:primary-reverse-path/te:optimizations
               /te:algorithm/te:metric/te:optimization-metric
               /te:explicit-route-include-objects
               /te:route-object-include-object/te:type/te:label
               /te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:primary-reverse-path
               /te:explicit-route-objects/te:route-object-exclude-always
               /te:type/te:label/te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:primary-reverse-path
               /te:explicit-route-objects
               /te:route-object-include-exclude/te:type/te:label
               /te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:primary-reverse-path
               /te:path-in-segment/te:label-restrictions
               /te:label-restriction/te:label-start/te:te-label
               /te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:primary-reverse-path
               /te:path-in-segment/te:label-restrictions
               /te:label-restriction/te:label-end/te:te-label
               /te:technology:
       +--:(otn)
          +--rw otn-label
```

```
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:primary-reverse-path
               /te:path-in-segment/te:label-restrictions
               /te:label-restriction/te:label-step/te:technology:
       +--:(otn)
          +--rw otn-label-step
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:primary-reverse-path
               /te:path-out-segment/te:label-restrictions
               /te:label-restriction/te:label-start/te:te-label
               /te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:primary-reverse-path
               /te:path-out-segment/te:label-restrictions
               /te:label-restriction/te:label-end/te:te-label
               /te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:primary-reverse-path
               /te:path-out-segment/te:label-restrictions
               /te:label-restriction/te:label-step/te:technology:
       +--:(otn)
          +--rw otn-label-step
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:primary-paths
               /te:primary-path/te:primary-reverse-path
               /te:computed-paths-properties/te:computed-path-properties
               /te:path-properties/te:path-route-objects
               /te:path-route-object/te:type/te:label/te:label-hop
               /te:te-label/te:technology:
       +--:(otn)
          +--ro otn-label
             +--ro tpn?       otn-tpn
             +--ro tsg?       identityref
             +--ro ts-list?   string
     augment /te:te/te:tunnels/te:tunnel/te:secondary-paths
```

```
               /te:secondary-path/te:optimizations/te:algorithm
               /te:metric/te:optimization-metric
               /te:explicit-route-exclude-objects
               /te:route-object-exclude-object/te:type/te:label
               /te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /te:te/te:tunnels/te:tunnel/te:secondary-paths
               /te:secondary-path/te:optimizations/te:algorithm
               /te:metric/te:optimization-metric
               /te:explicit-route-include-objects
               /te:route-object-include-object/te:type/te:label
               /te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /te:te/te:tunnels/te:tunnel/te:secondary-paths
               /te:secondary-path/te:explicit-route-objects
               /te:route-object-exclude-always/te:type/te:label
               /te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /te:te/te:tunnels/te:tunnel/te:secondary-paths
               /te:secondary-path/te:explicit-route-objects
               /te:route-object-include-exclude/te:type/te:label
               /te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /te:te/te:tunnels/te:tunnel/te:secondary-paths
               /te:secondary-path/te:path-in-segment
               /te:label-restrictions/te:label-restriction
               /te:label-start/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:secondary-paths
```

```
               /te:secondary-path/te:path-in-segment
               /te:label-restrictions/te:label-restriction/te:label-end
               /te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:secondary-paths
               /te:secondary-path/te:path-in-segment
               /te:label-restrictions/te:label-restriction/te:label-step
               /te:technology:
       +--:(otn)
          +--rw otn-label-step
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:secondary-paths
               /te:secondary-path/te:path-out-segment
               /te:label-restrictions/te:label-restriction
               /te:label-start/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:secondary-paths
               /te:secondary-path/te:path-out-segment
               /te:label-restrictions/te:label-restriction/te:label-end
               /te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:secondary-paths
               /te:secondary-path/te:path-out-segment
               /te:label-restrictions/te:label-restriction/te:label-step
               /te:technology:
       +--:(otn)
          +--rw otn-label-step
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:secondary-paths
               /te:secondary-path/te:computed-paths-properties
               /te:computed-path-properties/te:path-properties
               /te:path-route-objects/te:path-route-object/te:type
               /te:label/te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--ro otn-label
             +--ro tpn?       otn-tpn
             +--ro tsg?       identityref
```

```
             +--ro ts-list?   string
     augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
               /te:secondary-reverse-path/te:optimizations/te:algorithm
               /te:metric/te:optimization-metric
               /te:explicit-route-exclude-objects
               /te:route-object-exclude-object/te:type/te:label
               /te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
               /te:secondary-reverse-path/te:optimizations/te:algorithm
               /te:metric/te:optimization-metric
               /te:explicit-route-include-objects
               /te:route-object-include-object/te:type/te:label
               /te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
               /te:secondary-reverse-path/te:explicit-route-objects
               /te:route-object-exclude-always/te:type/te:label
               /te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
               /te:secondary-reverse-path/te:explicit-route-objects
               /te:route-object-include-exclude/te:type/te:label
               /te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?       otn-tpn
             +--rw tsg?       identityref
             +--rw ts-list?   string
     augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
               /te:secondary-reverse-path/te:path-in-segment
               /te:label-restrictions/te:label-restriction
               /te:label-start/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
```

```
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
               /te:secondary-reverse-path/te:path-in-segment
               /te:label-restrictions/te:label-restriction/te:label-end
               /te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
               /te:secondary-reverse-path/te:path-in-segment
               /te:label-restrictions/te:label-restriction/te:label-step
               /te:technology:
       +--:(otn)
          +--rw otn-label-step
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
               /te:secondary-reverse-path/te:path-out-segment
               /te:label-restrictions/te:label-restriction
               /te:label-start/te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
               /te:secondary-reverse-path/te:path-out-segment
               /te:label-restrictions/te:label-restriction/te:label-end
               /te:te-label/te:technology:
       +--:(otn)
          +--rw otn-label
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
               /te:secondary-reverse-path/te:path-out-segment
               /te:label-restrictions/te:label-restriction/te:label-step
               /te:technology:
       +--:(otn)
          +--rw otn-label-step
             +--rw tpn?   otn-tpn
             +--rw ts?    otn-ts
     augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
               /te:secondary-reverse-path/te:computed-paths-properties
               /te:computed-path-properties/te:path-properties
               /te:path-route-objects/te:path-route-object/te:type
               /te:label/te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--ro otn-label
```

```
             +--ro tpn?       otn-tpn
             +--ro tsg?       identityref
             +--ro ts-list?   string
     augment /te:te/te:lsps/te:lsp/te:lsp-actual-route-information
               /te:lsp-actual-route-information/te:type/te:label
               /te:label-hop/te:te-label/te:technology:
       +--:(otn)
          +--ro otn-label
             +--ro tpn?       otn-tpn
             +--ro tsg?       identityref
             +--ro ts-list?   string
```

Figure 2

4. OTN Tunnel YANG Code

```
<CODE BEGINS> file "ietf-otn-tunnel@2024-03-21.yang"
module ietf-otn-tunnel {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-otn-tunnel";
  prefix "otn-tnl";

  import ietf-te {
    prefix "te";
    reference
      "RFC ZZZZ: A YANG Data Model for Traffic Engineering Tunnels
      and Interfaces.";
  }
  /* Note: The RFC Editor will replace ZZZZ with the number assigned
     to the RFC once draft-ietf-teas-yang-te becomes an RFC.*/

  import ietf-layer1-types {
    prefix "l1-types";
    reference
      "RFC YYYY: Common YANG Data Types for Layer 1 Networks.";
  }
  /* Note: The RFC Editor will replace YYYY with the number assigned
     to the RFC once draft-ietf-ccamp-layer1-types becomes an RFC.*/

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

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

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

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

        Editor:   Victor Lopez
                  <mailto:victor.lopez@nokia.com>

        Editor:   Yunbin Xu
                  <mailto:xuyunbin@caict.ac.cn>";

     description
       "This module defines a model for OTN Tunnel Services.

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

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       identified as authors of the code.  All rights reserved.

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       without modification, is permitted pursuant to, and subject
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       Relating to IETF Documents
       (https://trustee.ietf.org/license-info).

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

     revision "2024-03-21" {
       description
         "Initial version";
       reference
         "RFC XXXX: A YANG Data Model for Optical Transport Network
         (OTN) Tunnels and Label Switched Paths";
       // RFC Ed.: replace XXXX with actual RFC number, update date
       // information and remove this note
     }

    /*
     * Data nodes
     */

     /*
      * Augment TE bandwidth
      */
```

```
     augment "/te:te/te:globals/te:named-path-constraints/"
           + "te:named-path-constraint/"
           + "te:te-bandwidth/te:technology" {
       description
         "Augment TE bandwidth of the named path constraint.";
       case otn {
         uses l1-types:otn-path-bandwidth;
       }
     }

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

     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:primary-paths/te:primary-path/"
           + "te:te-bandwidth/te:technology" {
       description
         "Augment TE bandwidth of the primary path.";
       case otn {
         uses l1-types:otn-path-bandwidth;
       }
     }

     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:primary-paths/te:primary-path/"
           + "te:computed-paths-properties/"
           + "te:computed-path-properties/te:path-properties/"
           + "te:te-bandwidth/te:technology" {
       description
         "Augment TE bandwidth of primary path's computed path
         properties.";
       case otn {
         uses l1-types:otn-path-bandwidth;
       }
     }

     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:primary-paths/te:primary-path/"
           + "te:primary-reverse-path/"
           + "te:te-bandwidth/te:technology" {
       description
         "Augment TE bandwidth of the primary reverse path.";
```

```
      case otn {
        uses l1-types:otn-path-bandwidth;
      }
    }

    augment "/te:te/te:tunnels/te:tunnel/"
          + "te:primary-paths/te:primary-path/"
          + "te:primary-reverse-path/"
          + "te:computed-paths-properties/"
          + "te:computed-path-properties/te:path-properties/"
          + "te:te-bandwidth/te:technology" {
      description
        "Augment TE bandwidth of the primary reverse path's computed
        path properties.";
      case otn {
        uses l1-types:otn-path-bandwidth;
      }
    }

    augment "/te:te/te:tunnels/te:tunnel/"
          + "te:secondary-paths/te:secondary-path/"
          + "te:te-bandwidth/te:technology" {
      description
        "Augment TE bandwidth of the secondary path.";
      case otn {
        uses l1-types:otn-path-bandwidth;
      }
    }

    augment "/te:te/te:tunnels/te:tunnel/"
          + "te:secondary-paths/te:secondary-path/"
          + "te:computed-paths-properties/"
          + "te:computed-path-properties/te:path-properties/"
          + "te:te-bandwidth/te:technology" {
      description
        "Augment TE bandwidth of the secondary path's computed path
        properties.";
      case otn {
        uses l1-types:otn-path-bandwidth;
      }
    }

    augment "/te:te/te:tunnels/te:tunnel/"
          + "te:secondary-reverse-paths/"
          + "te:secondary-reverse-path/"
          + "te:te-bandwidth/te:technology" {
      description
        "Augment TE bandwidth of the secondary reverse path.";
```

```
        case otn {
          uses l1-types:otn-path-bandwidth;
        }
      }

      augment "/te:te/te:tunnels/te:tunnel/"
            + "te:secondary-reverse-paths/"
            + "te:secondary-reverse-path/"
            + "te:computed-paths-properties/"
            + "te:computed-path-properties/te:path-properties/"
            + "te:te-bandwidth/te:technology" {
        description
          "Augment TE bandwidth of the secondary reverse path's computed
          path properties.";
        case otn {
          uses l1-types:otn-path-bandwidth;
        }
      }

      /*
       * Augment TE label range information
       */

      augment "/te:te/te:globals/te:named-path-constraints/"
            + "te:named-path-constraint/te:path-in-segment/"
            + "te:label-restrictions/te:label-restriction" {
        description
          "Augment TE label range information for the ingress segment
          of the named path constraint.";
        uses l1-types:otn-label-range-info;
      }

      augment "/te:te/te:globals/te:named-path-constraints/"
            + "te:named-path-constraint/te:path-out-segment/"
            + "te:label-restrictions/"
            + "te:label-restriction" {
        description
          "Augment TE label range information for the egress segment
          of the named path constraint.";
        uses l1-types:otn-label-range-info;
      }

      augment "/te:te/te:tunnels/te:tunnel/"
            + "te:primary-paths/te:primary-path/"
            + "te:path-in-segment/te:label-restrictions/"
            + "te:label-restriction" {
        description
          "Augment TE label range information for the ingress segment
```

```
           of the primay path.";
         uses l1-types:otn-label-range-info;
       }

       augment "/te:te/te:tunnels/te:tunnel/"
             + "te:primary-paths/te:primary-path/"
             + "te:path-out-segment/te:label-restrictions/"
             + "te:label-restriction" {
         description
           "Augment TE label range information for the egress segment
           of the primay path.";
         uses l1-types:otn-label-range-info;
       }

       augment "/te:te/te:tunnels/te:tunnel/"
             + "te:primary-paths/te:primary-path/"
             + "te:primary-reverse-path/"
             + "te:path-in-segment/te:label-restrictions/"
             + "te:label-restriction" {
         description
           "Augment TE label range information for the ingress segment
           of the primay reverse path.";
         uses l1-types:otn-label-range-info;
       }

       augment "/te:te/te:tunnels/te:tunnel/"
             + "te:primary-paths/te:primary-path/"
             + "te:primary-reverse-path/"
             + "te:path-out-segment/te:label-restrictions/"
             + "te:label-restriction" {
         description
           "Augment TE label range information for the egress segment
           of the primay reverse path.";
         uses l1-types:otn-label-range-info;
       }

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

       augment "/te:te/te:tunnels/te:tunnel/"
             + "te:secondary-paths/te:secondary-path/"
```

```
           + "te:path-out-segment/te:label-restrictions/"
           + "te:label-restriction" {
       description
         "Augment TE label range information for the egress segment
         of the secondary path.";
       uses l1-types:otn-label-range-info;
     }

     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:secondary-reverse-paths/te:secondary-reverse-path/"
           + "te:path-in-segment/te:label-restrictions/"
           + "te:label-restriction" {
       description
         "Augment TE label range information for the ingress segment
         of the secondary reverse path.";
       uses l1-types:otn-label-range-info;
     }

     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:secondary-reverse-paths/te:secondary-reverse-path/"
           + "te:path-out-segment/te:label-restrictions/"
           + "te:label-restriction" {
       description
         "Augment TE label range information for the egress segment
         of the secondary reverse path.";
       uses l1-types:otn-label-range-info;
     }

     /*
      * Augment TE label.
      */

     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
         "Augment TE label hop for the explicit route objects always
         excluded by the path computation with the named path
         constraint.";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }

     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
          "Augment TE label hop for the explicit route objects included
          or excluded by the path computation with the named path
          constraint.";
        case otn {
          uses l1-types:otn-label-hop;
        }
      }

      augment "/te:te/te:globals/te:named-path-constraints/"
            + "te:named-path-constraint/te:path-in-segment/"
            + "te:label-restrictions/"
            + "te:label-restriction/te:label-start/"
            + "te:te-label/te:technology" {
        description
          "Augment TE label range start for the ingress segment
          of the named path constraint.";
        case otn {
          uses l1-types:otn-label-start-end;
        }
      }

      augment "/te:te/te:globals/te:named-path-constraints/"
            + "te:named-path-constraint/te:path-in-segment/"
            + "te:label-restrictions/"
            + "te:label-restriction/te:label-end/"
            + "te:te-label/te:technology" {
        description
          "Augment TE label range end for the ingress segment
          of the named path constraint.";
        case otn {
          uses l1-types:otn-label-start-end;
        }
      }

      augment "/te:te/te:globals/te:named-path-constraints/"
            + "te:named-path-constraint/te:path-in-segment/"
            + "te:label-restrictions/te:label-restriction/"
            + "te:label-step/te:technology" {
        description
          "Augment TE label range step for the ingress segment
          of the named path constraint.";
        case otn {
          uses l1-types:otn-label-step;
        }
```

```
     }

     augment "/te:te/te:globals/te:named-path-constraints/"
           + "te:named-path-constraint/te:path-out-segment/"
           + "te:label-restrictions/"
           + "te:label-restriction/te:label-start/"
           + "te:te-label/te:technology" {
       description
         "Augment TE label range start for the egress segment
         of the named path constraint.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/te:te/te:globals/te:named-path-constraints/"
           + "te:named-path-constraint/te:path-out-segment/"
           + "te:label-restrictions/"
           + "te:label-restriction/te:label-end/"
           + "te:te-label/te:technology" {
       description
         "Augment TE label range end for the egress segment
         of the named path constraint.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/te:te/te:globals/te:named-path-constraints/"
           + "te:named-path-constraint/te:path-out-segment/"
           + "te:label-restrictions/te:label-restriction/"
           + "te:label-step/te:technology" {
       description
         "Augment TE label range step for the egress segment
         of the named path constraint.";
       case otn {
         uses l1-types:otn-label-step;
       }
     }

     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:primary-paths/te: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
         "Augment TE label hop for the optimization of the explicit
```

```
        route objects excluded by the path computation of the primary
        path.";
      case otn {
        uses l1-types:otn-label-hop;
      }
    }

    augment "/te:te/te:tunnels/te:tunnel/"
          + "te:primary-paths/te: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
        "Augment TE label hop for the optimization of the explicit
        route objects included by the path computation of the primary
        path.";
      case otn {
        uses l1-types:otn-label-hop;
      }
    }

    augment "/te:te/te:tunnels/te:tunnel/"
          + "te:primary-paths/te:primary-path/"
          + "te:explicit-route-objects/"
          + "te:route-object-exclude-always/te:type/te:label/"
          + "te:label-hop/te:te-label/te:technology" {
      description
        "Augment TE label hop for the explicit route objects always
        excluded by the path computation of the primary path.";
      case otn {
        uses l1-types:otn-label-hop;
      }
    }

    augment "/te:te/te:tunnels/te:tunnel/"
          + "te:primary-paths/te:primary-path/"
          + "te:explicit-route-objects/"
          + "te:route-object-include-exclude/te:type/te:label/"
          + "te:label-hop/te:te-label/te:technology" {
      description
        "Augment TE label hop for the explicit route objects included
        or excluded by the path computation of the primary path.";
      case otn {
        uses l1-types:otn-label-hop;
      }
    }
```

```
     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:primary-paths/te:primary-path/"
           + "te:path-in-segment/te:label-restrictions/"
           + "te:label-restriction/te:label-start/"
           + "te:te-label/te:technology" {
       description
         "Augment TE label range start for the ingress segment
         of the primay path.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:primary-paths/te:primary-path/"
           + "te:path-in-segment/te:label-restrictions/"
           + "te:label-restriction/te:label-end/"
           + "te:te-label/te:technology" {
       description
         "Augment TE label range end for the ingress segment
         of the primay path.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:primary-paths/te:primary-path/"
           + "te:path-in-segment/te:label-restrictions/"
           + "te:label-restriction/te:label-step/te:technology" {
       description
         "Augment TE label range step for the ingress segment
         of the primay path.";
       case otn {
         uses l1-types:otn-label-step;
       }
     }

     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:primary-paths/te:primary-path/"
           + "te:path-out-segment/te:label-restrictions/"
           + "te:label-restriction/te:label-start/"
           + "te:te-label/te:technology" {
       description
         "Augment TE label range start for the egress segment
         of the primay path.";
       case otn {
         uses l1-types:otn-label-start-end;
```

```
      }
    }

    augment "/te:te/te:tunnels/te:tunnel/"
          + "te:primary-paths/te:primary-path/"
          + "te:path-out-segment/te:label-restrictions/"
          + "te:label-restriction/te:label-end/"
          + "te:te-label/te:technology" {
      description
        "Augment TE label range end for the egress segment
        of the primay path.";
      case otn {
        uses l1-types:otn-label-start-end;
      }
    }

    augment "/te:te/te:tunnels/te:tunnel/"
          + "te:primary-paths/te:primary-path/"
          + "te:path-out-segment/te:label-restrictions/"
          + "te:label-restriction/te:label-step/te:technology" {
      description
        "Augment TE label range end for the egress segment
        of the primay path.";
      case otn {
        uses l1-types:otn-label-step;
      }
    }

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

    augment "/te:te/te:tunnels/te:tunnel/"
          + "te:primary-paths/te:primary-path/"
          + "te:primary-reverse-path/"
          + "te:optimizations/te:algorithm/te:metric/"
          + "te:optimization-metric/te:explicit-route-exclude-objects/"
```

```
           + "te:route-object-exclude-object/te:type/te:label/"
           + "te:label-hop/te:te-label/te:technology" {
     description
       "Augment TE label hop for the optimization of the explicit
       route objects excluded by the path computation of the primary
       reverse path.";
     case otn {
       uses l1-types:otn-label-hop;
     }
   }

   augment "/te:te/te:tunnels/te:tunnel/"
         + "te:primary-paths/te:primary-path/"
         + "te:primary-reverse-path/"
         + "te:optimizations/te:algorithm/te:metric/"
         + "te:optimization-metric/te:explicit-route-include-objects/"
         + "te:route-object-include-object/te:type/te:label/"
         + "te:label-hop/te:te-label/te:technology" {
     description
       "Augment TE label hop for the optimization of the explicit
       route objects included by the path computation of the primary
       reverse path.";
     case otn {
       uses l1-types:otn-label-hop;
     }
   }

   augment "/te:te/te:tunnels/te:tunnel/"
         + "te:primary-paths/te:primary-path/"
         + "te:primary-reverse-path/"
         + "te:explicit-route-objects/"
         + "te:route-object-exclude-always/"
         + "te:type/te:label/"
         + "te:label-hop/te:te-label/te:technology" {
     description
       "Augment TE label hop for the explicit route objects always
       excluded by the path computation of the primary reverse
       path.";
     case otn {
       uses l1-types:otn-label-hop;
     }
   }

   augment "/te:te/te:tunnels/te:tunnel/"
         + "te:primary-paths/te:primary-path/"
         + "te:primary-reverse-path/"
         + "te:explicit-route-objects/"
         + "te:route-object-include-exclude/"
```

```
           + "te:type/te:label/"
           + "te:label-hop/te:te-label/te:technology" {
     description
       "Augment TE label hop for the explicit route objects included
       or excluded by the path computation of the primary reverse
       path.";
     case otn {
       uses l1-types:otn-label-hop;
     }
   }

   augment "/te:te/te:tunnels/te:tunnel/"
         + "te:primary-paths/te:primary-path/"
         + "te:primary-reverse-path/"
         + "te:path-in-segment/te:label-restrictions/"
         + "te:label-restriction/te:label-start/"
         + "te:te-label/te:technology" {
     description
       "Augment TE label range start for the ingress segment
       of the primay reverse path.";
     case otn {
       uses l1-types:otn-label-start-end;
     }
   }

   augment "/te:te/te:tunnels/te:tunnel/"
         + "te:primary-paths/te:primary-path/"
         + "te:primary-reverse-path/"
         + "te:path-in-segment/te:label-restrictions/"
         + "te:label-restriction/te:label-end/"
         + "te:te-label/te:technology" {
     description
       "Augment TE label range end for the ingress segment
       of the primay reverse path.";
     case otn {
       uses l1-types:otn-label-start-end;
     }
   }

   augment "/te:te/te:tunnels/te:tunnel/"
         + "te:primary-paths/te:primary-path/"
         + "te:primary-reverse-path/"
         + "te:path-in-segment/te:label-restrictions/"
         + "te:label-restriction/te:label-step/te:technology" {
     description
       "Augment TE label range step for the ingress segment
       of the primay reverse path.";
     case otn {
```

```
         uses l1-types:otn-label-step;
       }
     }

     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:primary-paths/te:primary-path/"
           + "te:primary-reverse-path/"
           + "te:path-out-segment/te:label-restrictions/"
           + "te:label-restriction/te:label-start/"
           + "te:te-label/te:technology" {
       description
         "Augment TE label range start for the egress segment
         of the primay reverse path.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:primary-paths/te:primary-path/"
           + "te:primary-reverse-path/"
           + "te:path-out-segment/te:label-restrictions/"
           + "te:label-restriction/te:label-end/"
           + "te:te-label/te:technology" {
       description
         "Augment TE label range end for the egress segment
         of the primay reverse path.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:primary-paths/te:primary-path/"
           + "te:primary-reverse-path/"
           + "te:path-out-segment/te:label-restrictions/"
           + "te:label-restriction/te:label-step/te:technology" {
       description
         "Augment TE label range step for the egress segment
         of the primay reverse path.";
       case otn {
         uses l1-types:otn-label-step;
       }
     }

     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:primary-paths/te:primary-path/"
           + "te:primary-reverse-path/"
```

```
            + "te:computed-paths-properties/te:computed-path-properties/"
            + "te:path-properties/te:path-route-objects/"
            + "te:path-route-object/te:type/te:label/"
            + "te:label-hop/te:te-label/te:technology" {
        description
          "Augment TE label hop for the route object of the computed
          primary reverse path.";
        case otn {
          uses l1-types:otn-label-hop;
        }
      }

      augment "/te:te/te:tunnels/te:tunnel/"
            + "te:secondary-paths/te: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
          "Augment TE label hop for the optimization of the explicit
          route objects excluded by the path computation of the
          secondary path.";
        case otn {
          uses l1-types:otn-label-hop;
        }
      }

      augment "/te:te/te:tunnels/te:tunnel/"
            + "te:secondary-paths/te: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
          "Augment TE label hop for the optimization of the explicit
          route objects included by the path computation of the
          secondary path.";
        case otn {
          uses l1-types:otn-label-hop;
        }
      }

      augment "/te:te/te:tunnels/te:tunnel/"
            + "te:secondary-paths/te:secondary-path/"
            + "te:explicit-route-objects/"
            + "te:route-object-exclude-always/te:type/te:label/"
            + "te:label-hop/te:te-label/te:technology" {
        description
```

```
          "Augment TE label hop for the explicit route objects always
          excluded by the path computation of the secondary path.";
        case otn {
          uses l1-types:otn-label-hop;
        }
      }

      augment "/te:te/te:tunnels/te:tunnel/"
            + "te:secondary-paths/te:secondary-path/"
            + "te:explicit-route-objects/"
            + "te:route-object-include-exclude/te:type/te:label/"
            + "te:label-hop/te:te-label/te:technology" {
        description
          "Augment TE label hop for the explicit route objects included
          or excluded by the path computation of the secondary path.";
        case otn {
          uses l1-types:otn-label-hop;
        }
      }

      augment "/te:te/te:tunnels/te:tunnel/"
            + "te:secondary-paths/te:secondary-path/"
            + "te:path-in-segment/te:label-restrictions/"
            + "te:label-restriction/te:label-start/"
            + "te:te-label/te:technology" {
        description
          "Augment TE label range start for the ingress segment
          of the secondary path.";
        case otn {
          uses l1-types:otn-label-start-end;
        }
      }

      augment "/te:te/te:tunnels/te:tunnel/"
            + "te:secondary-paths/te:secondary-path/"
            + "te:path-in-segment/te:label-restrictions/"
            + "te:label-restriction/te:label-end/"
            + "te:te-label/te:technology" {
        description
          "Augment TE label range end for the ingress segment
          of the secondary path.";
        case otn {
          uses l1-types:otn-label-start-end;
        }
      }
      augment "/te:te/te:tunnels/te:tunnel/"
            + "te:secondary-paths/te:secondary-path/"
            + "te:path-in-segment/te:label-restrictions/"
```

```
            + "te:label-restriction/te:label-step/te:technology" {
        description
          "Augment TE label range step for the ingress segment
          of the secondary path.";
        case otn {
          uses l1-types:otn-label-step;
        }
      }

      augment "/te:te/te:tunnels/te:tunnel/"
            + "te:secondary-paths/te:secondary-path/"
            + "te:path-out-segment/te:label-restrictions/"
            + "te:label-restriction/te:label-start/"
            + "te:te-label/te:technology" {
        description
          "Augment TE label range start for the egress segment
          of the secondary path.";
        case otn {
          uses l1-types:otn-label-start-end;
        }
      }

      augment "/te:te/te:tunnels/te:tunnel/"
            + "te:secondary-paths/te:secondary-path/"
            + "te:path-out-segment/te:label-restrictions/"
            + "te:label-restriction/te:label-end/"
            + "te:te-label/te:technology" {
        description
          "Augment TE label range end for the egress segment
          of the secondary path.";
        case otn {
          uses l1-types:otn-label-start-end;
        }
      }

      augment "/te:te/te:tunnels/te:tunnel/"
            + "te:secondary-paths/te:secondary-path/"
            + "te:path-out-segment/te:label-restrictions/"
            + "te:label-restriction/te:label-step/te:technology" {
        description
          "Augment TE label range step for the egress segment
          of the secondary path.";
        case otn {
          uses l1-types:otn-label-step;
        }
      }

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

```
           + "te:secondary-paths/te:secondary-path/"
           + "te:computed-paths-properties/"
           + "te:computed-path-properties/"
           + "te:path-properties/te:path-route-objects/"
           + "te:path-route-object/te:type/te:label/"
           + "te:label-hop/te:te-label/te:technology" {
       description
         "Augment TE label hop for the route object of the computed
         secondary path.";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }

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

     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:secondary-reverse-paths/te:secondary-reverse-path/"
           + "te:optimizations/te:algorithm/te:metric/"
           + "te:optimization-metric/te:explicit-route-include-objects/"
           + "te:route-object-include-object/te:type/te:label/"
           + "te:label-hop/te:te-label/te:technology" {
       description
         "Augment TE label hop for the optimization of the explicit
         route objects included by the path computation of the
         secondary reverse path.";
       case otn {
         uses l1-types:otn-label-hop;
       }
     }

     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:secondary-reverse-paths/te:secondary-reverse-path/"
           + "te:explicit-route-objects/"
           + "te:route-object-exclude-always/te:type/te:label/"
```

```
             + "te:label-hop/te:te-label/te:technology" {
        description
          "Augment TE label hop for the explicit route objects always
          excluded by the path computation of the secondary reverse
          path.";
        case otn {
          uses l1-types:otn-label-hop;
        }
      }

      augment "/te:te/te:tunnels/te:tunnel/"
            + "te:secondary-reverse-paths/te:secondary-reverse-path/"
            + "te:explicit-route-objects/"
            + "te:route-object-include-exclude/te:type/te:label/"
            + "te:label-hop/te:te-label/te:technology" {
        description
          "Augment TE label hop for the explicit route objects included
          or excluded by the path computation of the secondary reverse
          path.";
        case otn {
          uses l1-types:otn-label-hop;
        }
      }

      augment "/te:te/te:tunnels/te:tunnel/"
            + "te:secondary-reverse-paths/te:secondary-reverse-path/"
            + "te:path-in-segment/te:label-restrictions/"
            + "te:label-restriction/te:label-start/"
            + "te:te-label/te:technology" {
        description
          "Augment TE label range start for the ingress segment
          of the secondary reverse path.";
        case otn {
          uses l1-types:otn-label-start-end;
        }
      }

      augment "/te:te/te:tunnels/te:tunnel/"
            + "te:secondary-reverse-paths/te:secondary-reverse-path/"
            + "te:path-in-segment/te:label-restrictions/"
            + "te:label-restriction/te:label-end/"
            + "te:te-label/te:technology" {
        description
          "Augment TE label range end for the ingress segment
          of the secondary reverse path.";
        case otn {
          uses l1-types:otn-label-start-end;
        }
```

```
     }

     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:secondary-reverse-paths/te:secondary-reverse-path/"
           + "te:path-in-segment/te:label-restrictions/"
           + "te:label-restriction/te:label-step/te:technology" {
       description
         "Augment TE label range step for the ingress segment
         of the secondary reverse path.";
       case otn {
         uses l1-types:otn-label-step;
       }
     }

     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:secondary-reverse-paths/te:secondary-reverse-path/"
           + "te:path-out-segment/te:label-restrictions/"
           + "te:label-restriction/te:label-start/"
           + "te:te-label/te:technology" {
       description
         "Augment TE label range start for the egress segment
         of the secondary reverse path.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:secondary-reverse-paths/te:secondary-reverse-path/"
           + "te:path-out-segment/te:label-restrictions/"
           + "te:label-restriction/te:label-end/"
           + "te:te-label/te:technology" {
       description
         "Augment TE label range end for the egress segment
         of the secondary reverse path.";
       case otn {
         uses l1-types:otn-label-start-end;
       }
     }

     augment "/te:te/te:tunnels/te:tunnel/"
           + "te:secondary-reverse-paths/te:secondary-reverse-path/"
           + "te:path-out-segment/te:label-restrictions/"
           + "te:label-restriction/te:label-step/te:technology" {
       description
         "Augment TE label range step for the egress segment
         of the secondary reverse path.";
       case otn {
```

```
          uses l1-types:otn-label-step;
        }
      }

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

      augment "/te:te/te:lsps/"
            + "te:lsp/te:lsp-actual-route-information/"
            + "te:lsp-actual-route-information/te:type/te:label/"
            + "te:label-hop/te:te-label/te:technology" {
        description
          "Augment TE label hop for the record route of the LSP.";
        case otn {
          uses l1-types:otn-label-hop;
        }
      }
    }
    <CODE ENDS>
```

Figure 3

5. IANA Considerations

IANA is requested to register the following URI in the "ns" subregistry within the "IETF XML Registry" [RFC3688]:

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

IANA is requested to register the following YANG module in the "YANG Module Names" subregistry [RFC6020] within the "YANG Parameters" registry.

```
name:         ietf-otn-tunnel
namespace:    urn:ietf:params:xml:ns:yang:ietf-otn-tunnel
prefix:       otn-tnl
reference:    RFC XXXX
```

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

6. Security Considerations

This section is modeled after the template described in Section 3.7 of [I-D.ietf-netmod-rfc8407bis].

The "ietf-te-types" and the "ietf-te-packet-types" YANG modules define data models that are designed to be accessed via YANG-based management protocols, such as NETCONF [RFC6241] and RESTCONF [RFC8040]. These protocols have to use a secure transport layer (e.g., SSH [RFC4252], TLS [RFC8446], and QUIC [RFC9000]) and have to use mutual authentication.

The Network Configuration Access Control Model (NACM) [RFC8341] provides the means to restrict access for particular NETCONF or RESTCONF users to a preconfigured subset of all available NETCONF or RESTCONF protocol operations and content.

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 can 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. Specifically, the following subtrees and data nodes have particular sensitivities/vulnerabilities:

* "otnt:otn-bandwidth"

  This subtree specifies the configurations of OTN technology-specific information under any occurrence of the tet:te-bandwidth container, as defined in [I-D.ietf-teas-yang-te] (e.g., "/te:te/te:tunnels/te:tunnel/te:te-bandwidth/te:technology/otnt:otn/otnt:otn-bandwidth"). By configuring the OTN bandwidth attributes, an attacker may create an unauthorized OTN traffic path. By removing or modifying it, a malicious attacker may cause OTN traffic to be disabled or misrouted.

* "otnt:otn-label-range"

This subtree specifies the configurations of OTN technology-specific label range information under any occurrence of the tet:label-restriction container, as defined in [I-D.ietf-teas-yang-te] (e.g., "/te:te/te:tunnels/te:tunnel/te:primary-paths/te:primary-path/te:path-in-segment/te:label-restrictions/te:label-restriction/otnt:otn-label-range"). By configuring the OTN label range attributes, an attacker may create an unauthorized OTN traffic path. By removing or modifying, a malicious attacker may cause OTN traffic to be disabled or misrouted.

* "otnt:otn-label"

  This subtree specifies the configurations of OTN technology-specific label information under any occurrence of the tet:te-label container, as defined in [I-D.ietf-teas-yang-te] (e.g., "/te:te/te:tunnels/te:tunnel/te:primary-paths/te:primary-path/te:explicit-route-objects/te:route-object-include-exclude/te:type/te:label/te:label-hop/te:te-label/te:technology/otnt:otn/otnt:otn-label"). By configuring, removing or modifying the OTN label attributes, a malicious attacker may cause OTN traffic to be disabled or misrouted.

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. Specifically, the following subtrees and data nodes have particular sensitivities/vulnerabilities:

* "otnt:otn-bandwidth"

  This subtree specifies the configurations of OTN technology-specific information under any occurrence of the tet:te-bandwidth container, as defined in [I-D.ietf-teas-yang-te] (e.g., "/te:te/te:tunnels/te:tunnel/te:te-bandwidth/te:technology/otnt:otn/otnt:otn-bandwidth"). Unauthorized access to this data node can disclose the OTN bandwidth information of OTN tunnels and LSPs.

* "otnt:otn-label-range"

This subtree specifies the configurations of OTN technology-specific label range information under any occurrence of the tet:label-restriction container, as defined in [I-D.ietf-teas-yang-te] (e.g., "/te:te/te:tunnels/te:tunnel/te:primary-paths/te:primary-path/te:path-in-segment/te:label-restrictions/te:label-restriction/otnt:otn-label-range"). Unauthorized access to this data node can disclose the state information of OTN tunnels and LSPs.

* "otnt:otn-label"

  This subtree specifies the configurations of OTN technology-specific label information under any occurrence of the tet:te-label container, as defined in [I-D.ietf-teas-yang-te] (e.g., "/te:te/te:tunnels/te:tunnel/te:primary-paths/te:primary-path/te:explicit-route-objects/te:route-object-include-exclude/te:type/te:label/te:label-hop/te:te-label/te:technology/otnt:otn/otnt:otn-label"). Unauthorized access to this data node can disclose the state information of OTN tunnels and LSPs.

This YANG module does not define RPC operations.

This YANG module uses groupings from other YANG modules that define nodes that may be considered sensitive or vulnerable in network environments. Refer to the Security Considerations of [I-D.ietf-ccamp-layer1-types] for information as to which nodes may be considered sensitive or vulnerable in network environments.

Finally, the YANG module described in this document augments the "ietf-te" YANG module [I-D.ietf-teas-yang-te] by adding data nodes. The security considerations for the subtrees described in those RFCs apply equally to the new data nodes that this module adds.

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22 October 2021

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

Abstract

The requirement of slicing network resources with desired quality of service is emerging at every network technology, including the Optical Transport Networks (OTN). As a part of the transport network, OTN can provide hard pipes with guaranteed data isolation and deterministic low latency, which are highly demanded in the Service Level Agreement (SLA).

This document describes a framework for OTN network slicing and a YANG data model augmentation of the OTN topology model. Additional YANG data model augmentations will be defined in a future version of this draft.

Status of This Memo

Table of Contents

1. Introduction

The requirement of slicing network resources with desired quality of service is emerging at every network technology, including the Optical Transport Networks (OTN). As a part of the transport network, OTN can provide hard pipes with guaranteed data isolation and deterministic low latency, which are highly demanded in the Service Level Agreement (SLA). This document describes a framework for OTN network slicing and a YANG data model augmentation of the OTN topology model. Additional YANG data model augmentations will be defined in a future version of this draft.

1.1. Definition of OTN Slice

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

An OTN slice is a technology-specific realization of an IETF network slice [I-D.ietf-teas-ietf-network-slices] in the OTN domain, with the capability of configuring slice resources in the term of OTN technologies. Therefore, all the terms and definitions concerning network slicing as defined in [I-D.ietf-teas-ietf-network-slices] apply to OTN slicing.

An OTN slice can span multiple OTN administrative domains, encompassing access links, intra-domain paths, and inter-domain links. An OTN slice may include multiple endpoints, each associated with a set of physical or logical resources, e.g. optical port or time slots, at the termination point (TP) of an access link or inter-domain link at an OTN provider edge (PE) equipment.

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

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

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

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


          +-------------------------+  +-----------------------+
          | +-----+      +-------+  |  | +-------+      +-----+|
   +----+ | | OTN |      | OTN   |  |  | | OTN   |      | OTN ||  +----+
   | CE +-+-o PE  +-...--+ Borde o--+--+-o Borde +-...--+ PE  o+--+ CE |
   +----+ |/|     |      | Node  |\ |  | | Node  |      |     ||  +----+
         |||+-----+      +-------+ |||  | +-------+      +-----+| |
         |||    OTN Domain 1       |||  |      OTN Domain 2     | |
         |++-----------------------++|  +-----------------------+ |
         | |                       | |                           |
         | +-----+    +------------+ |                           |
         |       |    |              |                           |
         V       V    V              V                           V
      Access    OTN Slice       Inter-domain                  Access
      Link      Endpoint        Link                          Link
```

Figure 1: OTN Slice

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

2. Use Cases for OTN Network Slicing

2.1. Leased Line Services with OTN

For end business customers (like OTT or enterprises), leased lines have the advantage of providing high-speed connections with low costs. On the other hand, the traffic control of leased lines is very challenging due to rapid changes in service demands. Carriers are recommended to provide network-level slicing capabilities to meet this demand. Based on such capabilities, private network users have full control over the sliced resources which have been allocated to them and which could be used to support their leased lines, when needed. Users may formulate policies based on the demand for services and time to schedule the resources from the entire network's perspective flexibly. For example, the bandwidth between any two points may be established or released based on the time or monitored traffic characteristics. The routing and bandwidth may be adjusted at a specific time interval to maximize network resource utilization efficiency.

2.2. Co-construction and Sharing

Co-construction and sharing of a network are becoming a popular means among service providers to reduce networking building CAPEX. For Co-construction and sharing case, there are typically multiple co-founders for the same network. For example, one founder may provide optical fibres and another founder may provide OTN equipment, while each occupies a certain percentage of the usage rights of the network resources. In this scenario, the network O&M is performed by a certain founder in each region, where the same founder usually deploys an independent management and control system. The other founders of the network use each other's management and control system to provision services remotely. In this scenario, different founders' network resources need to be automatically (associated) divided, isolated, and visualized. All founders may share or have independent O&M capabilities, and should be able to perform service-level provisioning in their respective slices.

2.3. Wholesale of optical resources

In the optical resource wholesale market, smaller, local carriers and wireless carriers may rent resources from larger carriers, or infrastructure carriers instead of building their networks. Likewise, international carriers may rent resources from respective local carriers and local carriers may lease their owned networks to each other to achieve better network utilization efficiency. From the perspective of a resource provider, it is crucial that a network slice is timely configured to meet traffic matrix requirements requested by its tenants. The support for multi-tenancy within the resource provider's network demands that the network slices are qualitatively isolated from each other to meet the requirements for transparency, non-interference, and security. Typically, a resource purchaser expects to use the leased network resources flexibly, just like they are self-constructed. Therefore, the purchaser is not only provided with a network slice, but also the full set of functionalities for operating and maintaining the network slice. The purchaser also expects to, flexibly and independently, schedule and maintain physical resources to support their own end-to-end automation using both leased and self-constructed network resources.

2.4. Vertical dedicated network with OTN

Vertical industry slicing is an emerging category of network slicing due to the high demand for private high-speed network interconnects for industrial applications. In this scenario, the biggest challenge is to implement differentiated optical network slices based on the requirements from different industries. For example, in the financial industry, to support high-frequency transactions, the slice must ensure to provide the minimum latency along with the mechanism for latency management. For the healthcare industry, online diagnosis network and software capabilities to ensure the delivery of HD video without frame loss. For bulk data migration in data centers, the network needs to support on-demand, large-bandwidth allocation. In each of the aforementioned vertical industry scenarios, the bandwidth shall be adjusted as required to ensure flexible and efficient network resource usage.

2.5. End-to-end network slicing

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

3. Framework for OTN slicing

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

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

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

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

* Link-based slicing, in which a link and its associated link termination points (LTPs) are dedicatedly allocated to a particular OTN slice.

* Tributary-slot based slicing, in which multiple OTN slices share the same link by allocating different OTN tributary slots in different granularities.

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

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

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

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

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

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

Figure 2: Positioning of OTN Slicing Interfaces

OTN-SC functionalities may be recursive such that a higher-level OTN-SC may designate the creation of OTN slices to a lower-level OTN-SC in a recursive manner. This scenario may apply to the creation of

OTN slices in multi-domain OTN networks, where multiple domain-wide OTN slices provisioned by lower-layer OTN-SCs are stitched to support a multi-domain OTN slice provisioned by the higher-level OTN-SC. Alternatively, the OTN-SC may interface with an MDSC, which in turn interfaces with multiple PNCs through the MPI to realize OTN slices in multi-domain OTN networks without OTN-SC recursion. Figure 3 illustrates both options for OTN slicing in multi-domain.

```
+--------------------+                    +--------------------+
|       OTN-SC       |                    |       OTN-SC       |
+---------|----------+                    +---|----------|-----+
          |MPI                                |OTN-SC NBI|
+---------|----------+                    +---|----+ +---|-----+
|       MDSC         |                    | OTN-SC | | OTN-SC  |
+---|----------|-----+                    +---|----+ +---|-----+
    |MPI       |MPI                           |MPI       |MPI
+---|----+ +---|-----+                    +---|----+ +---|-----+
|   PNC  | |   PNC   |                    |   PNC  | |   PNC   |
+--------+ +---------+                    +--------+ +---------+
Multi-domain Option 1                     Multi-domain Option 2
```

Figure 3: OTN-SC for multi-domain

OTN-SC functionalities are logically independent and may be deployed in different combinations to cater to the realization needs. In reference with the ACTN control framework [RFC8453], an OTN-SC may be deployed - as an independent network function; - together with a Physical Network Controller (PNC) for single-domain or with a Multi-Domain Service Orchestrator (MDSC)for multi-domain; - together with a higher-level network slice controller to support end-to-end network slicing;

4. YANG Data Model for OTN Slicing Configuration

4.1. OTN Slicing YANG Model for MPI

4.1.1. MPI YANG Model Overview

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

number of ODU containers. The MDSC or PNC, based on the marked resources by the OTN-SC, will update the underlying TE topology with new TE link for each of the colored links to keep booked the reserved OTN resources e.g. time slots or ODU containers.

4.1.2. MPI YANG Model Tree

```
module: ietf-otn-slice

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

Figure 4: OTN slicing tree diagram

4.1.3. MPI YANG Code

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

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

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

     import ietf-te-topology {
```

```
          prefix "tet";
          reference
            "RFC8795: YANG Data Model for Traffic Engineering
            (TE) Topologies";
        }

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

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

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

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

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

           Editor: Aihua Guo
                   <mailto:aihuaguo.ietf@gmail.com>

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

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

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

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           identified as authors of the code.  All rights reserved.
```

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

        revision "2021-10-22" {
          description
            "Latest revision of MPI YANG model for OTN slicing.";
          reference
            "draft-zheng-ccamp-yang-otn-slicing-03: Framework and Data
             Model for OTN Network Slicing";
        }

        /*
         * Groupings
         */

        grouping otn-link-slice-profile {
          description
            "Profile of an OTN link slice.";
          choice otn-slice-granularity {
            default "link";
            description
              "Link slice granularity.";
            case link {
              leaf slice-id {
                type uint32;
                 description
                   "Slice identifier";
              }
            }
            case link-resource {
              list slices {
                key slice-id;
                description
                  "List of slices.";
                leaf slice-id {
                  type uint32;
                  description
                    "Slice identifier";
                }
                choice technology {
                  description
                    "Data plane technology types.";
```

```
                case otn {
                  choice slice-bandwidth {
                    description
                      "Bandwidth specification for OTN slices.";
                    case containers {
                      uses l1-types:otn-link-bandwidth;
                    }
                    case time-slots {
                      leaf otn-ts-num {
                        type uint32;
                        description
                          "Number of OTN tributary slots allocated for the
                           slice.";
                      }
                    }
                  }
                }
              }
              leaf sliced-link-ref {
                type leafref {
                  path "../../../../../nt:link/nt:link-id";
                }
                config false;
                description
                  "Relative reference to virtual links generated from
                   this TE link.";
              }
            }
          }
        }
      }

      /*
       * Augments
       */
      augment "/nw:networks/nw:network/nt:link/tet:te/"
            + "tet:te-link-attributes" {
        when "../../../nw:network-types/tet:te-topology/"
           + "otntopo:otn-topology" {
          description
            "Augmentation parameters apply only for networks with
             OTN topology type.";
        }
        description
          "Augment OTN TE link attributes with slicing profile.";
        uses otn-link-slice-profile;
      }
    }
```

<CODE ENDS>

Figure 5: OTN slicing YANG model

4.2. OTN Slicing YANG Model for OTN-SC NBI

4.2.1. NBI YANG Model Overview

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

The base model defines a transport network slice (TNS) with the following constructs and attributes: - Common attributes, which include a set of common attributes like slice identifier, name, description and names of customers who use the slice. - Endpoints, which represent conceptual points of connection from a customer device to the TNS. An endpoint is mapped to specific physical or virtual resources of the customer and provider, and such mapping is pre-negotiated and known to both the customer and provider prior to the slice configuration. The mechanism for endpoint negotiation is outside the scope of this draft. - Network topology, which represent set of shared, reserved resources organized as a virtual topology between all of the endpoints. A customer could use such network topology to define detailed connecvitiy path traversing the topology, and allow sharing of resources between its multiple endpoint pairs. - Connectivity matrix, which represent the intended virtual connections between the endpoints within a TNS. A connctivity matrix entry could be associated with an explicit path over the above network topology. - Service-level objectives (SLOs) associated with different objects, including the TNS, node, link, termination point, and explicit path, within a TNS.

4.2.2. NBI YANG Model Tree for Transport Network Slice

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

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

Figure 6: Tree diagram for transport network slice

4.2.3. NBI YANG Code for Transport Network Slice

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

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

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

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

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

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

           Editor: Aihua Guo
                   <mailto:aihuaguo.ietf@gmail.com>

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

        description
          "This module defines a YANG data model to configure an OTN
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```

```
           set forth in Section 4.c of the IETF Trust's Legal Provisions
           Relating to IETF Documents
           (https://trustee.ietf.org/license-info).
           This version of this YANG module is part of RFC XXXX; see
           the RFC itself for full legal notices.";

        revision "2021-10-22" {
          description
            "Latest revision of NBI YANG model for OTN slicing.";
          reference
            "draft-zheng-ccamp-yang-otn-slicing-03: Framework and Data
             Model for OTN Network Slicing";
        }

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

```
            "Process and threads isolation.";
        }
        identity physical-network-isolation {
          base physical-isolation;
          description
            "Process and threads isolation.";
        }
        identity virtual-resource-isolation {
          base logical-isolation;
          description
            "A network slice has access to specific range of resources
             that do not overlap with other network slices
             (e.g. VM isolation).";
        }
        identity network-functions-isolation {
          base logical-isolation;
          description
            "NF (Network Function) is dedicated to the network slice, but
             virtual resources are shared.";
        }
        identity service-isolation {
          base logical-isolation;
          description
            "NSC data are isolated from other NSCs, but virtual
             resources and NFs are shared.";
        }

        /*
         * Groupings
         */

        grouping ns-generic-info {
          description
            "Generic configuration of a network slice";
            leaf ns-name {
              type string;
              description
                "Name of the specific network slice";
            }
            leaf ns-description {
              type string;
              description
                "Description regarding the specific network slice";
            }
            leaf-list customer-name {
              type string;
              description
                "List of customers using the slice";
```

```
            }
        }

        grouping ns-slo {
          description
            "SLO configuration of a network slice";

          container slo {
            description
              "SLO configuration of a network slice";

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

```
        grouping node-slo {
          description
            "Node SLO";
          container slo {
            description
              "SLO configuration of a node";
            leaf isolation-level {
              type identityref {
                base isolation-level;
              }
              description
                "A network slice instance may be fully or partly, logically
                 and/or physically, isolated from another network slice
                 instance. This attribute describes different types of
                 isolation:";
            }
          }
        }

        grouping link-slo {
          description
            "Link SLO";
          container slo {
            description
              "SLO configuration of a link";
            leaf delay-tolerance {
              type boolean;
              description
                "'true' if is not too critical how long it takes to deliver
                 the amount of data.";
              reference
                "GSMA-NS-Template: Generic Network Slice Template,
                 Version 3.0.";
            }
            leaf-list periodicity {
              type uint64;
              units seconds;
              description
                "A list of periodicities supported by the network slice.";
              reference
                "GSMA-NS-Template: Generic Network Slice Template,
                 Version 3.0.";
            }
            leaf isolation-level {
              type identityref {
                base isolation-level;
              }
              description
```

```
                "A network slice instance may be fully or partly, logically
                 and/or physically, isolated from another network slice
                 instance. This attribute describes different types of
                 isolation:";
            }
          }
        }

        grouping connectivity-matrix-slo {
          description
            "SLO configuration of a path within a network slice";

          container slo {
            description
              "Path SLO configuration";
          }
          leaf delay-tolerance {
            type boolean;
            description
              "'true' if is not too critical how long it takes to deliver
               the amount of data.";
            reference
              "GSMA-NS-Template: Generic Network Slice Template,
               Version 3.0.";
          }
          leaf-list periodicity {
            type uint64;
            units seconds;
            description
              "A list of periodicities supported by the network slice.";
            reference
              "GSMA-NS-Template: Generic Network Slice Template,
               Version 3.0.";
          }
          leaf isolation-level {
            type identityref {
              base isolation-level;
            }
            description
              "A network slice instance may be fully or partly, logically
               and/or physically, isolated from another network slice
               instance. This attribute describes different types of
               isolation:";
          }
        }

        grouping connectivity-matrix-entry-slo {
          description
```

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

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

        grouping explicit-path {
          description
            "Explicit path for a connectivity matrix entry";

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

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

```
                type inet:uri;
                description
                  "Termination point identifier.";
              }
              leaf endpoint-id {
                type leafref {
                  path "/network-slices/network-slice[ns-id=current()"+
                       "/../../../../../ns-id]/endpoints/endpoint/"+
                       "endpoint-id";
                }
                description
                  "Relative reference to TP id.";
              }
            }
          }
          list link {
            key "link-id";
            description
              "Link identifier.";
            leaf link-id {
              type inet:uri;
              description
                "Link identifier.";
            }
            uses link-slo;
            container source {
              description
                "Link source node";
              leaf source-node {
                type leafref {
                  path "../../../node/node-id";
                }
                description
                  "Source node identifier, must be in same topology.";
              }
              leaf source-tp {
                type leafref {
                  path "../../../node[node-id=current()/../"+
                       "source-node]/termination-point/tp-id";
                }
                description
                  "Termination point within source node that terminates
                   the link.";
              }
            }
            container destination {
              description
                "Link destination node";
```

```
              leaf dest-node {
                type leafref {
                  path "../../../node/node-id";
                }
                description
                  "Destination node identifier, must be in same topology.";
              }
              leaf dest-tp {
                type leafref {
                  path "../../../node[node-id=current()/../"+
                       "dest-node]/termination-point/tp-id";
                }
                description
                  "Termination point within destination node that terminates
                   the link.";
              }
            }
          }
        }

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

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

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

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

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

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

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

Figure 7: YANG model for transport network slice

4.2.4. NBI YANG Model Tree for OTN slice

TBD.

4.2.5. NBI YANG Code for OTN Slice

TBD.

5. Manageability Considerations

To ensure the security and controllability of physical resource isolation, slice-based independent operation and management are required to achieve management isolation. Each optical slice typically requires dedicated accounts, permissions, and resources for independent access and O&M. This mechanism is to guarantee the information isolation among slice tenants and to avoid resource conflicts. The access to slice management functions will only be permitted after successful security checks.

6. Security Considerations

<Add any security considerations>

7. IANA Considerations

<Add any IANA considerations>

8. References

8.1. Normative References

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