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

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at https://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on 8 January 2022.

Copyright Notice

Copyright (c) 2021 IETF Trust and the persons identified as the document authors. All rights reserved.
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).
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>
        Editor: Sergio Belotti
        <mailto:Sergio.Belotti@nokia.com>
        Editor: Italo Busi
        <mailto:Italo.Busi@huawei.com>
        Editor: Haomian Zheng
        <mailto:zhenghaomian@huawei.com>

    // Additional contacts TBA (contributors)

    description
        "Description to be added!!!"

    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
/* 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 {

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 "0.01dbm";
    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";
}
*/

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

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";
                }
            }
        }
    }
}
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()]/
                        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.";
                }
            }
        }
    }
}
+ "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 Q-factor 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;
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 parameter represents the minimum 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 10-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.

5. Contributors

   Gabriele Galimberti
   Cisco
   Email: ggalimbe@cisco.com

   Enrico Griseri
   Nokia
   Email: Enrico.Griseri@nokia.com

   Aihua Guo
   Futurewei
   Email: aihuaguoyfurewei.com

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.

8. References

8.1. Normative References
8.2. Informative References

[I-D.ietf-ccamp-dwdm-if-param-yang]
Galimberti, G., Kunze, R., Burk, A., Hiremagalur, D., and G. Grammel, "A YANG model to manage the optical interface


Authors’ Addresses

Dieter Beller (editor)
Nokia
Email: Dieter.Beller@nokia.com

Sergio Belotti (editor)
Nokia
Email: Sergio.Belotti@nokia.com

Haomian Zheng
Huawei
Email: ZhengHaomian@huawei.com

Italo Busi
Huawei
Email: Italo.Busi@huawei.com
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).

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at https://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on August 26, 2021.
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
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.
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.

- 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.

- 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.

- 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]
      +--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
```yang
++-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
```

Lopez de Vergara, et al. Expires August 26, 2021
| +--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 |
| | | | +--:(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 |
| | | +--:(technology)? |
| | | | +--:(generic) |
| | | | | +--rw generic? |
| | | | | rt-types:generalized-label |
| | +--rw direction?  te-label-direction |
| +--rw label-end |
| | +--rw te-label |
| | | +--:(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
```yang
++-rw node-id
  |  te-node-id
++-rw hop-type?
  |  te-hop-type
++-rw direction?
  te-link-direction
++-:(as-number)
  +++-rw as-number-hop
    +++-rw as-number
      |  inet:as-number
    +++-rw hop-type?
      te-hop-type
++-:(label)
  +++-rw label-hop
    +++-rw te-label
      +++-rw (technology)?
        ++-:(generic)
          +++-rw generic?
            rt-types:generalized
++-rw direction?
  te-label-direction
++-:(srlg)
  +++-rw srlg
    +++-rw srlg?  uint32
    +++-rw explicit-route-include-objects
      ++-rw route-object-include-object*
        [index]
          +++-rw index
            uint32
          +++-rw (type)?
            ++-:(numbered-node-hop)
              +++-rw numbered-node-hop
                +++-rw node-id
                  |  te-node-id
                +++-rw hop-type?
                  te-hop-type
            ++-:(numbered-link-hop)
              +++-rw numbered-link-hop
                +++-rw link-tp-id
                  |  te-tp-id
                +++-rw hop-type?
                  te-hop-type
                +++-rw direction?
                  te-link-direction
            ++-:(unnumbered-link-hop)
              +++-rw unnumbered-link-hop
                +++-rw link-tp-id
                  |  te-tp-id
```

Lopez de Vergara, et al. Expires August 26, 2021
---rw node-id
  |  |     | te-node-id
---rw hop-type?
  |  |     | te-hop-type
---rw direction?
  |     | te-link-direction
++-:(as-number)
   ++-rw as-number-hop
      ++-rw as-number
         | inet:as-number
         ++-rw hop-type?
            te-hop-type
++-:(label)
   ++-rw label-hop
      ++-rw te-label
         ++-rw (technology)?
            +-:(generic)
               ++-rw generic?
                  rt-types:generalized
   ++-rw direction?
      te-label-direction
   ++-rw tiebreakers
      ++-rw tiebreaker* [tiebreaker-type]
         ++-rw tiebreaker-type identityref
      +-:(objective-function)
         {path-optimization-objective-function}?
         ++-rw objective-function
            ++-rw objective-function-type?
               identityref
   ++-rw preference?          uint8
   ++-rw k-requested-paths?   uint8
   ++-rw named-path-constraint? leafref
      {te-types:named-path-constraints}?
   ++-rw te-bandwidth
      ++-rw (technology)?
         +-:(generic)
            ++-rw generic? te-bandwidth
   ++-rw link-protection?     identityref
   ++-rw setup-priority?      uint8
   ++-rw hold-priority?       uint8
   ++-rw signaling-type?      identityref
   ++-rw path-metric-bounds
      ++-rw path-metric-bound* [metric-type]
         ++-rw metric-type identityref
         ++-rw upper-bound? uint64
   ++-rw path-affinities-values
      ++-rw path-affinities-value* [usage]
         ++-rw usage identityref
+++rw 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
        +--:(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
          +--:(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
    ++-- (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-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-label
          +-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)?
 |       |  ++-ro 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
Internet-Draft       Flexi-Grid YANG       February 2021

node-id
    te-node-id
hop-type?
    te-hop-type
direction?
    te-link-direction

: (as-number)
    as-number-hop
    as-number
        inet:as-number
    hop-type?
        te-hop-type

: (label)
    label-hop
    te-label
        (technology)?
            : (generic)
                generic?
                    rt-types:generic

: (objective-function)
    objective-function
        objective-function-type?
            identityref

named-path-constraint?
    leafref
        (te-types:named-path-constraints)?

bandwidth
    (technology)?
        : (generic)
            generic?
                bandwidth

link-protection?
    identityref

setup-priority?
    uint8
hold-priority?
    uint8
signaling-type?
    identityref

path-metric-bounds
    path-metric-bound*
        metric-type?
            identityref
        upper-bound?
            uint64
path-affinities-values
    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 direction?
   rt-types:generalized-label
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
te-tp-id
  +--ro node-id
  |    te-node-id
  +--ro hop-type?
  |    te-hop-type
  +--ro direction?
    te-link-direction
  (as-number)
    +--ro as-number-hop
      +--ro as-number
        |    inet:as-number
      +--ro hop-type?
        te-hop-type
  (label)
    +--ro label-hop
      +--ro te-label
        +--ro (technology)?
          +--:(generic)
            +--ro generic?
              rt-types:generalized
    +--ro direction?
      te-label-direction
  shared-resources-tunnels
    +--ro lsp-shared-resources-tunnel*
      tunnel-ref
  +--ro lsps
    +--ro lsp*
      [source destination tunnel-id lsp-id extended-tunn...]

source
types:te-node-id
+--ro destination
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 flags*
                        path-attribute-flags
            +-:(label)
                ++-ro label-hop
                    ++-ro te-label
                        +-:(technology)?
                            +-:(generic)
                                ++-ro generic?
                                    rt-types:generalized-label
            +-:(te-label-direction)
                ++-ro flags*
                    path-attribute-flags
            ++-ro path-properties
                ++-ro path-metric* [metric-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


Lopez de Vergara, et al. Expires August 26, 2021
---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
              :-(technology)?
                :-(generic)
                  ---rw generic?
                    rt-types:generalized
            ---rw direction?
              te-label-direction
        :-(srlg)
          ---rw srlg
            ---rw srlg?
              uint32
---rw explicit-route-inlude-objects
  ---rw route-object-inlude-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
            ---rw hop-type? inet:as-number
          ---rw hop-type? te-hop-type
      ---:(label)
        ---rw label-hop
          ---rw te-label
            ---rw (technology)?
              ---:(generic)
                ---rw generic? rt-types:generalized
        ---rw 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)
<pre>+++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
      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
</pre>
+--ro affinity-name* [name]
   +--ro name string

---ro path-srlbs-lists
   +--ro path-srlbs-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 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
      +--ro 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
        +--w input
          +--w action-type? identityref
          +--ro output
---ro action-result? identityref

---x protection-external-commands

---w input

---w protection-external-command?

---w protection-group-ingress-node-id?

---w protection-group-egress-node-id?

---w path-ref? path-ref

---w traffic-type?

---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

---ro destination

---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?

---ro protection-group-egress-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
5.2. YANG Code

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

Lopez de Vergara, et al. Expires August 26, 2021
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:10-tunnel-attributes;
}

/* Augment TE label. */

/* Augment label hop of route-object-exclude-always of named-path-constraints */
  description "Flex-grid label.";
  case flexi-grid {
    uses 10-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 10-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 10-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 10-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 10-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 10-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 10-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 10-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 10-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 10-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 10-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 10-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 10-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 10-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 10-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 10-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 10-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 10-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 10-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 10-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 10-types:flexi-grid-label-hop;
    }
  }
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-exclude/
   + "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;
   }
}
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 10-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 10-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 10-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 10-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 10-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 10-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 10-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 10-types:flexi-grid-label-hop;
  }
}

/* Augment label hop of record-route of reverse primary LSP */
augment "\lte:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/
  + "te:p2p-primary-reverse-path/
  + "te:lsp/te:lsp/te:lsp-record-route-information/
  + "te:lsp-record-route-information/te:type/te:label/
  + "te:label-hop/te:te-label/te:technology" {
  description "Flex-grid label.";
  case flexi-grid {
    uses 10-types:flexi-grid-label-hop;
  }
}

/* Augment label hop of path-route of reverse primary LSP */
augment "\lte:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/
  + "te:p2p-primary-reverse-path/
  + "te:lsp/te:lsp/te:path-properties/
  + "te:path-route-objects/te:path-computed-route-object/
  + "te:type/te:label/
  + "te:label-hop/te:te-label/te:technology" {
  description "Flex-grid label.";
  case flexi-grid {
    uses 10-types:flexi-grid-label-hop;
  }
}

/* Augment label hop of route-exclude of secondary path */
augment "\lte: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 10-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 10-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 10-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 10-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.";
}

Lopez de Vergara, et al. Expires August 26, 2021
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 10-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 10-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 10-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 10-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 10-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 10-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 10-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/"
/* Augment label hop of record-route of LSP */
augment "/te:te/te:lsp-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 10-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 10-types-ext:10-tunnel-attributes;
      uses 10-types-ext:10-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:

Zafar Ali
Cisco
Email: zali@cisco.com
9. Acknowledgments

This work is also partially funded by the Spanish State Research Agency under the project AgileMon (AEI PID2019-104451RB-C21) and by the Spanish Ministry of Science, Innovation and Universities under the program for the training of university lecturers (Grant number: FPU19/05678).

10. References

10.1. Normative References

[I-D.ietf-ccamp-flexigrid-yang]
Madrid, U., Perdices, D., King, D., Lee, Y., and H. Zheng,
"A YANG Data Model for Flexi-Grid Optical Networks",
draft-ietf-ccamp-flexigrid-yang-08 (work in progress),
November 2020.

[I-D.ietf-teas-yang-te]
Saad, T., Gandhi, R., Liu, X., Beeram, V., and I. Bryskin,
"A YANG Data Model for Traffic Engineering Tunnels, Label
Switched Paths and Interfaces", draft-ietf-teas-yang-te-25
(work in progress), July 2020.

and A. Bierman, Ed., "Network Configuration Protocol
(NETCONF)", RFC 6241, DOI 10.17487/RFC6241, June 2011,

[RFC7699] Farrel, A., King, D., Li, Y., and F. Zhang, "Generalized
Labels for the Flexi-Grid in Lambda Switch Capable (LSC)
Label Switching Routers", RFC 7699, DOI 10.17487/RFC7699,

RFC 7950, DOI 10.17487/RFC7950, August 2016,

10.2. Informative References
"Routing and Wavelength Assignment Information Model for
Wavelength Switched Optical Networks", RFC 7446,
DOI 10.17487/RFC7446, February 2015,

Fu, X., Ceccarelli, D., and I. Hussain, "Framework and
Requirements for GMPLS-Based Control of Flexi-Grid Dense
Wavelength Division Multiplexing (DWDM) Networks",
RFC 7698, DOI 10.17487/RFC7698, November 2015,

Authors’ Addresses

Jorge E. Lopez de Vergara Mendez
Naudit HPCN
Email: jorge.lopez_vergara@uam.es

Daniel Perdices Burrero
Universidad Autonoma de Madrid
Email: daniel.perdices@uam.es

Daniel King
Old Dog Consulting
Email: daniel@olddog.co.uk

Victor Lopez
Telefonica I+D/GCTO
Email: victor.lopezalvarez@telefonica.com

Italo Busi
Huawei Technologies
Email: Italo.Busi@huawei.com
A YANG Data Model for Flexi-Grid Optical Networks
draft-ietf-ccamp-flexigrid-yang-11

Abstract

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

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

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at https://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on 15 May 2022.

Copyright Notice

Copyright (c) 2021 IETF Trust and the persons identified as the document authors. All rights reserved.
1. Introduction

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

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

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

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

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

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

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

2. Terminology

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

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

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

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

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

3. Tree Diagram

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

3.1. Prefixes in Data Node Names

In this document, names of data nodes and other data model objects are prefixed using the standard prefix associated with the corresponding YANG imported modules, as shown in Figure 1. It uses prefixes from [RFC9093], [RFC8345], and [RFC8795].

+-------------+-------------------------+-----------------+
<table>
<thead>
<tr>
<th>Prefix</th>
<th>YANG module</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>l0-types</td>
<td>RFC9093</td>
<td>[RFCXXXX]</td>
</tr>
<tr>
<td>flexgt</td>
<td>ietf-flexi-grid-topology</td>
<td>[RFCYYYY]</td>
</tr>
<tr>
<td>nw</td>
<td>ietf-network</td>
<td>[RFC8345]</td>
</tr>
<tr>
<td>nt</td>
<td>ietf-network-topology</td>
<td>[RFC8345]</td>
</tr>
<tr>
<td>tet</td>
<td>ietf-te-topology</td>
<td>[RFC8795]</td>
</tr>
</tbody>
</table>
+-------------+-------------------------+-----------------+

Figure 1: Prefixes and Corresponding YANG modules

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

4. Example of Use

In order to explain how this model is used, we provide the following example. An optical network usually has multiple transponders, switches (nodes) and links. Figure 1 shows a simple topology.
In order to configure a network media channel to interconnect transponders A and E, first of all we have to populate the flexi-grid topology YANG model with all elements in the network:

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

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

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

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

5. YANG Data Model for Flexi-Grid Topology
5.1. Flexi-Grid Topology Data Model Overview

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

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

The figure below shows the augmentation relationship between YANG models.

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

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

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

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

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

5.2. Attributes Augmentation

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

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

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

Figure 4: Flexi-Grid Topology Augmentation

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

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

Figure 5: Flex-Grid Node Augmentation

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

5.3. Bandwidth Augmentation

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

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

5.4. Label Augmentation

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

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

module: ietf-flexi-grid-topology
  augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
    +--rw flexi-grid-topology!
  augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes:
      +--rw flexi-grid-node!
  augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
      /tet:label-restrictions/tet:label-restriction:
        +--rw grid-type?    identityref
        +--rw priority?     uint8
        +--rw flexi-grid
          +--rw slot-width-granularity?    identityref
          +--rw min-slot-width-factor?    uint16
          +--rw max-slot-width-factor?    uint16
  augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
      /tet:connectivity-matrix/tet:from/tet:label-restrictions
        /tet:label-restriction:
          +--rw grid-type?    identityref
          +--rw priority?     uint8
          +--rw flexi-grid
            +--rw slot-width-granularity?    identityref
            +--rw min-slot-width-factor?    uint16
            +--rw max-slot-width-factor?    uint16
  augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
      /tet:connectivity-matrix/tet:to/tet:label-restrictions
        /tet:label-restriction:
          +--rw grid-type?    identityref
          +--rw priority?     uint8
          +--rw flexi-grid
            +--rw slot-width-granularity?    identityref
            +--rw min-slot-width-factor?    uint16
            +--rw max-slot-width-factor?    uint16
  augment /nw:networks/nw:network/nw:node/tet:te
    /tet:information-source-entry/tet:connectivity-matrices
      /tet:label-restrictions/tet:label-restriction:
        +--ro grid-type?    identityref
        +--ro priority?     uint8
---ro flexi-grid
  ---ro slot-width-granularity? identityref
  ---ro min-slot-width-factor? uint16
  ---ro max-slot-width-factor? uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:from/tet:label-restrictions
  /tet:label-restriction:
  ---ro grid-type? identityref
  ---ro priority? uint8
++ro flexi-grid
  ---ro slot-width-granularity? identityref
  ---ro min-slot-width-factor? uint16
  ---ro max-slot-width-factor? uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:to/tet:label-restrictions
  /tet:label-restriction:
  ---ro grid-type? identityref
  ---ro priority? uint8
---ro flexi-grid
  ---ro slot-width-granularity? identityref
  ---ro min-slot-width-factor? uint16
  ---ro max-slot-width-factor? uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point
  /tet:local-link-connectivities/tet:label-restrictions
  /tet:label-restriction:
  ---rw grid-type? identityref
  ---rw priority? uint8
++rw flexi-grid
  ---rw slot-width-granularity? identityref
  ---rw min-slot-width-factor? uint16
  ---rw max-slot-width-factor? uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point
  /tet:local-link-connectivities
  /tet:local-link-connectivity/tet:label-restrictions
  /tet:label-restriction:
  ---rw grid-type? identityref
  ---rw priority? uint8
++rw flexi-grid
  ---rw slot-width-granularity? identityref
  ---rw min-slot-width-factor? uint16
  ---rw max-slot-width-factor? uint16
augment /nw:networks/nw:network/nt:link/tet:te
  /tet:te-link-attributes/tet:label-restrictions
  /tet:label-restriction:
+++rw grid-type? identityref
+++rw priority? uint8
+++rw flexi-grid
    +++rw slot-width-granularity? identityref
    +++rw min-slot-width-factor? uint16
    +++rw max-slot-width-factor? uint16
augment /nw:networks/nw:network/nt:link/tet:te
    /tet:information-source-entry/tet:label-restrictions
    /tet:label-restriction:
    +++ro grid-type? identityref
    +++ro priority? uint8
    +++ro flexi-grid
    +++ro slot-width-granularity? identityref
    +++ro min-slot-width-factor? uint16
    +++ro max-slot-width-factor? uint16
    /tet:te-link-attributes/tet:label-restrictions
    /tet:label-restriction:
    +++rw grid-type? identityref
    +++rw priority? uint8
    +++rw flexi-grid
    +++rw slot-width-granularity? identityref
    +++rw min-slot-width-factor? uint16
    +++rw max-slot-width-factor? uint16
augment /nw:networks/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
    /tet:label-restrictions/tet:label-restriction
    /tet:label-start/tet:te-label/tet:technology:
    +++:(flexi-grid)
        +++rw flexi-n? 10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
    /tet:label-restrictions/tet:label-restriction
    /tet:label-end/tet:te-label/tet:technology:
    +++:(flexi-grid)
        +++rw flexi-n? 10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
    /tet:label-restrictions/tet:label-restriction
    /tet:label-step/tet:technology:
    +++:(flexi-grid)
        +++rw flexi-grid-channel-spacing? identityref
        +++rw flexi-n-step? uint8
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
    /tet:label/tet:label-hop/tet:te-label/tet:technology:
    +++:(flexi-grid)
+-rw (single-or-super-channel)?
  +--:(single)
    |  +-rw flexi-n?  10-types:flexi-n
    |  +-rw flexi-m?  10-types:flexi-m
  +--:(super)
    |  +-rw subcarrier-flexi-n* [flexi-n]
      |     +-rw flexi-n  10-types:flexi-n
      |     +-rw flexi-m? 10-types:flexi-m
    augment /nw:networks/nw:network/nw:node/tet:te
      /tet:te-node-attributes/tet:connectivity-matrices
      /tet:label/tet:label-hop/tet:te-label/tet:technology:
  +--:(flexi-grid)
    +-rw (single-or-super-channel)?
      +--:(single)
        |  +-rw flexi-n?  10-types:flexi-n
        |  +-rw flexi-m?  10-types:flexi-m
      +--:(super)
        |  +-rw subcarrier-flexi-n* [flexi-n]
          |     +-rw flexi-n  10-types:flexi-n
          |     +-rw flexi-m? 10-types:flexi-m
      augment /nw:networks/nw:network/nw:node/tet:te
        /tet:te-node-attributes/tet:connectivity-matrices
        /tet:optimizations/tet:algorithm/tet:metric
        /tet:optimization-metric
        /tet:explicit-route-exclude-objects
        /tet:route-object-exclude-object/tet:type/tet:label
        /tet:label-hop/tet:te-label/tet:technology:
    +--:(flexi-grid)
      +-rw (single-or-super-channel)?
        +--:(single)
          |  +-rw flexi-n?  10-types:flexi-n
          |  +-rw flexi-m?  10-types:flexi-m
        +--:(super)
          |  +-rw subcarrier-flexi-n* [flexi-n]
            |     +-rw flexi-n  10-types:flexi-n
            |     +-rw flexi-m? 10-types:flexi-m
        augment /nw:networks/nw:network/nw:node/tet:te
          /tet:te-node-attributes/tet:connectivity-matrices
          /tet:optimizations/tet:algorithm/tet:metric
          /tet:optimization-metric
          /tet:explicit-route-include-objects
          /tet:route-object-include-object/tet:type/tet:label
          /tet:label-hop/tet:te-label/tet:technology:
| | +--rw flexi-m? 10-types:flexi-m
++--:(super)
  +--rw subcarrier-flexi-n* [flexi-n]
    +--rw flexi-n 10-types:flexi-n
    +--rw flexi-m? 10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:te-node-attributes/tet:connectivity-matrices
  /tet:path-properties/tet:path-route-objects
  /tet:te-label/tet:technology:
++--:(flexi-grid)
  +--ro (single-or-super-channel)?
    +--:(single)
      |  +--ro flexi-n? 10-types:flexi-n
      |  +--ro flexi-m? 10-types:flexi-m
    +--:(super)
      +--ro subcarrier-flexi-n* [flexi-n]
        +--ro flexi-n 10-types:flexi-n
        +--ro flexi-m? 10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:te-node-attributes/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:from/tet:label-restrictions
  /tet:label-restriction/tet:label-start/tet:te-label
  /tet:technology:
++--:(flexi-grid)
  +--rw flexi-n? 10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:te-node-attributes/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:from/tet:label-restrictions
  /tet:label-restriction/tet:label-end/tet:te-label
  /tet:technology:
++--:(flexi-grid)
  +--rw flexi-n? 10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:te-node-attributes/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:from/tet:label-restrictions
  /tet:label-restriction/tet:label-step/tet:technology:
++--:(flexi-grid)
  +--rw flexi-grid-channel-spacing? identityref
  +--rw flexi-n-step? uint8
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:te-node-attributes/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:to/tet:label-restrictions
  /tet:label-restriction/tet:label-start/tet:te-label
  /tet:technology:
++--:(flexi-grid)
  +--rw flexi-n? 10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
/tet:te-node-attributes/tet:connectivity-matrices
/tet:connectivity-matrix/tet:to/tet:label-restrictions
/tet:label-restriction/tet:label-end/tet:te-label
/tet:technology:
  +--:(flexi-grid)
    +--rw flexi-n? 10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:te-node-attributes/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:to/tet:label-restrictions
  /tet:label-restriction/tet:label-step/tet:technology:
  +--:(flexi-grid)
    +--rw flexi-grid-channel-spacing? identityref
    +--rw flexi-n-step? uint8
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:te-node-attributes/tet:connectivity-matrices
  /tet:path-element/tet:type/tet:label/tet:label-hop
  /tet:te-label/tet:technology:
  +--:(flexi-grid)
    +--rw (single-or-super-channel)?
      +--:(single)
        |  +--rw flexi-n? 10-types:flexi-n
        |  +--rw flexi-m? 10-types:flexi-m
      +--:(super)
        +--rw subcarrier-flexi-n* [flexi-n]
          +--rw flexi-n 10-types:flexi-n
          +--rw flexi-m? 10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:te-node-attributes/tet:connectivity-matrices
  /tet:path-element/tet:type/tet:label/tet:label-hop
  /tet:te-label/tet:technology:
  +--:(flexi-grid)
    +--rw (single-or-super-channel)?
      +--:(single)
        |  +--rw flexi-n? 10-types:flexi-n
        |  +--rw flexi-m? 10-types:flexi-m
      +--:(super)
        +--rw subcarrier-flexi-n* [flexi-n]
          +--rw flexi-n 10-types:flexi-n
          +--rw flexi-m? 10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:te-node-attributes/tet:connectivity-matrices
  /tet: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:
augment /nw:networks/nw:network/nw:node/tet:te
/tet:label-hop/tet:te-label/tet:technology:

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

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

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

augment /nw:networks/nw:network/nw:node/tet:te
    /tet:information-source-entry/tet:connectivity-matrices
    /tet:connectivity-matrix/tet:path-properties
    /tet:path-route-objects/tet:path-route-object/tet:type
    /tet:label-hop/tet:te-label/tet:technology:
+--:(flexi-grid)
   +--ro (single-or-super-channel)?
      +--:(single)
++--:(single)
  |++--rw flexi-n? 10-types:flexi-n
  |++--rw flexi-m? 10-types:flexi-m
++--:(super)
  ++--rw subcarrier-flexi-n* [flexi-n]
  |++--rw flexi-n 10-types:flexi-n
  |++--rw flexi-m? 10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point
  /tet:local-link-connectivities/tet:optimizations
  /tet:algorithm/tet:metric/tet:optimization-metric
  /tet:explicit-route-exclude-objects
  /tet:route-object-exclude-object/tet:type/tet:label
  /tet:label-hop/tet:te-label/tet:technology:
++--:(flexi-grid)
  ++--rw (single-or-super-channel)?
  ++--:(single)
    |++--rw flexi-n? 10-types:flexi-n
    |++--rw flexi-m? 10-types:flexi-m
  ++--:(super)
    ++--rw subcarrier-flexi-n* [flexi-n]
    |++--rw flexi-n 10-types:flexi-n
    |++--rw flexi-m? 10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point
  /tet:local-link-connectivities/tet:optimizations
  /tet:algorithm/tet:metric/tet:optimization-metric
  /tet:explicit-route-exclude-objects
  /tet:route-object-exclude-object/tet:type/tet:label
  /tet:label-hop/tet:te-label/tet:technology:
++--:(flexi-grid)
  ++--rw (single-or-super-channel)?
  ++--:(single)
    |++--rw flexi-n? 10-types:flexi-n
    |++--rw flexi-m? 10-types:flexi-m
  ++--:(super)
    ++--rw subcarrier-flexi-n* [flexi-n]
    |++--rw flexi-n 10-types:flexi-n
    |++--rw flexi-m? 10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point
  /tet:local-link-connectivities/tet:path-properties
  /tet:path-route-objects/tet:path-route-object/tet:type
  /tet:label-tet:label-hop/tet:te-label/tet:technology:
++--:(flexi-grid)
  ++--ro (single-or-super-channel)?
  ++--:(single)
    |++--ro flexi-n? 10-types:flexi-n
|  +--ro flexi-m?  10-types:flexi-m
++--:(super)
  +--ro subcarrier-flexi-n* [flexi-n]
    +--ro flexi-n  10-types:flexi-n
    +--ro flexi-m?  10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
/tet:tunnel-termination-point
/tet:local-link-connectivities
/tet:local-link-connectivity/tet:label-restrictions
/tet:label-restriction/tet:label-start/tet:te-label
/tet:technology:
++--:(flexi-grid)
  +--rw flexi-n?  10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
/tet:tunnel-termination-point
/tet:local-link-connectivities
/tet:local-link-connectivity/tet:label-restrictions
/tet:label-restriction/tet:label-end/tet:te-label
/tet:technology:
++--:(flexi-grid)
  +--rw flexi-n?  10-types:flexi-n
augment /nw:networks/nw:network/nw:node/tet:te
/tet:tunnel-termination-point
/tet:local-link-connectivities
/tet:local-link-connectivity/tet:label-restrictions
/tet:label-restriction/tet:label-step/tet:technology:
++--:(flexi-grid)
  +--rw flexi-grid-channel-spacing? identityref
  +--rw flexi-n-step?  uint8
augment /nw:networks/nw:network/nw:node/tet:te
/tet:tunnel-termination-point
/tet:local-link-connectivities
/tet:local-link-connectivity/tet:underlay
/tet:primary-path/tet:path-element/tet:type/tet:label
/tet:label-hop/tet:te-label/tet:technology:
++--:(flexi-grid)
  +--rw (single-or-super-channel)?
    ++--:(single)
      +--rw flexi-n?  10-types:flexi-n
      +--rw flexi-m?  10-types:flexi-m
    ++--:(super)
      +--rw subcarrier-flexi-n* [flexi-n]
        +--rw flexi-n  10-types:flexi-n
        +--rw flexi-m?  10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
/tet:tunnel-termination-point
/tet:local-link-connectivities
/tet:local-link-connectivity/tet:underlay/tet:backup-path
/tet:path-element/tet:type/tet:label/tet:label-hop
/tet:te-label/tet:technology:
  +++:(flexi-grid)
  +++-rw (single-or-super-channel)?
    +++: (single)
      +++-rw flexi-n? 10-types:flexi-n
      +++-rw flexi-m? 10-types:flexi-m
    +++: (super)
    +++-rw subcarrier-flexi-n* [flexi-n]
      +++-rw flexi-n 10-types:flexi-n
      +++-rw flexi-m? 10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
/tet:tunnel-termination-point
/tet:local-link-connectivities
/tet:local-link-connectivity/tet:optimizations
/tet:algorithm/tet:metric/tet:optimization-metric
/tet:explicit-route-exclude-objects
/tet:route-object-exclude-object/tet:type/tet:label
/tet:label-hop/tet:te-label/tet:technology:
  +++:(flexi-grid)
  +++-rw (single-or-super-channel)?
    +++: (single)
      +++-rw flexi-n? 10-types:flexi-n
      +++-rw flexi-m? 10-types:flexi-m
    +++: (super)
    +++-rw subcarrier-flexi-n* [flexi-n]
      +++-rw flexi-n 10-types:flexi-n
      +++-rw flexi-m? 10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
/tet:tunnel-termination-point
/tet:local-link-connectivities
/tet:local-link-connectivity/tet:optimizations
/tet:algorithm/tet:metric/tet:optimization-metric
/tet:explicit-route-include-objects
/tet:route-object-include-object/tet:type/tet:label
/tet:label-hop/tet:te-label/tet:technology:
  +++:(flexi-grid)
  +++-rw (single-or-super-channel)?
    +++: (single)
      +++-rw flexi-n? 10-types:flexi-n
      +++-rw flexi-m? 10-types:flexi-m
    +++: (super)
    +++-rw subcarrier-flexi-n* [flexi-n]
      +++-rw flexi-n 10-types:flexi-n
      +++-rw flexi-m? 10-types:flexi-m
augment /nw:networks/nw:network/nw:node/tet:te
/tet:tunnel-termination-point
/tet:local-link-connectivities
/tet:local-link-connectivity/tet:path-properties
/tet:path-route-objects/tet:path-route-object/tet:type
/tet:label/tet:label-hop/tet:te-label/tet:technology:
++-(flexi-grid)
  ++-ro (single-or-super-channel)?
    ++-:(single)
      ++-ro flexi-n? 10-types:flexi-n
      ++-ro flexi-m? 10-types:flexi-m
    ++-:(super)
      ++-ro subcarrier-flexi-n* [flexi-n]
        ++-ro flexi-n 10-types:flexi-n
        ++-ro flexi-m? 10-types:flexi-m
    augment /nw:networks/nw:network/nt:link/tet:te
      /tet:te-link-attributes/tet:underlay/tet:primary-path
      /tet:path-element/tet:type/tet:label/tet:label-hop
      /tet:te-label/tet:technology:
  ++-:(flexi-grid)
    ++-rw (single-or-super-channel)?
      ++-:(single)
        ++-rw flexi-n? 10-types:flexi-n
        ++-rw flexi-m? 10-types:flexi-m
      ++-:(super)
        ++-rw subcarrier-flexi-n* [flexi-n]
          ++-rw flexi-n 10-types:flexi-n
          ++-rw flexi-m? 10-types:flexi-m
    augment /nw:networks/nw:network/nt:link/tet:te
      /tet:te-link-attributes/tet:underlay/tet:backup-path
      /tet:path-element/tet:type/tet:label/tet:label-hop
      /tet:te-label/tet:technology:
  ++-:(flexi-grid)
    ++-rw (single-or-super-channel)?
      ++-:(single)
        ++-rw flexi-n? 10-types:flexi-n
        ++-rw flexi-m? 10-types:flexi-m
      ++-:(super)
        ++-rw subcarrier-flexi-n* [flexi-n]
          ++-rw flexi-n 10-types:flexi-n
          ++-rw flexi-m? 10-types:flexi-m
    augment /nw:networks/nw:network/nt:link/tet:te
      /tet:te-link-attributes/tet:label-restrictions
      /tet:label-restriction/tet:label-start/tet:te-label
      /tet:technology:
++-:(flexi-grid)
  ++-rw flexi-n? 10-types:flexi-n
  augment /nw:networks/nw:network/nt:link/tet:te
    /tet:te-link-attributes/tet:label-restrictions
    /tet:label-restriction/tet:label-end/tet:te-label
    /tet:technology:
+--:(flexi-grid)
  +--rw flexi-n? 10-types:flexi-n
augment /nw:networks/nw:network/nt:link/tet:te
  /tet:te-link-attributes/tet:label-restrictions
  /tet:label-restriction/tet:label-step/tet:technology:
+--:(flexi-grid)
  +--rw flexi-grid-channel-spacing? identityref
  +--rw flexi-n-step? uint8
augment /nw:networks/nw:network/nt:link/tet:te
  /tet:information-source-entry/tet:label-restrictions
  /tet:label-restriction/tet:label-start/tet:te-label
  /tet:technology:
+--:(flexi-grid)
  +--ro flexi-n? 10-types:flexi-n
augment /nw:networks/nw:network/nt:link/tet:te
  /tet:information-source-entry/tet:label-restrictions
  /tet:label-restriction/tet:label-step/tet:technology:
+--:(flexi-grid)
  +--ro flexi-grid-channel-spacing? identityref
  +--ro flexi-n-step? uint8
  /tet:te-link-attributes/tet:underlay/tet:primary-path
  /tet:path-element/tet:type/tet:label/tet:label-hop
  /tet:te-label/tet:technology:
+--:(flexi-grid)
  +--rw (single-or-super-channel)?
    +--:(single)
      |  +--rw flexi-n? 10-types:flexi-n
      |  +--rw flexi-m? 10-types:flexi-m
    +--:(super)
      +--rw subcarrier-flexi-n* [flexi-n]
        +--rw flexi-n 10-types:flexi-n
        +--rw flexi-m? 10-types:flexi-m
  /tet:te-link-attributes/tet:underlay/tet:backup-path
  /tet:path-element/tet:type/tet:label/tet:label-hop
  /tet:te-label/tet:technology:
+--:(flexi-grid)
  +--rw (single-or-super-channel)?
    +--:(single)
      |  +--rw flexi-n? 10-types:flexi-n
      |  +--rw flexi-m? 10-types:flexi-m
7. The YANG Code for Flexi-grid topology

```<CODE BEGINS> file "ietf-flexi-grid-topology@2021-10-25.yang"
module ietf-flexi-grid-topology {
    yang-version 1.1;
    prefix "flexgt";

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

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

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

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

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

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

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

    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."
  }
}

  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 10-types:flexi-grid-label-range-info;
  }

  + "tet:te-node-attributes/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/tet:from/"
  + "tet:label-restrictions/tet:label-restriction" {
  when "./././././././././.
  + "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 10-types:flexi-grid-label-range-info;
  }

  + "tet:te-node-attributes/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/tet:to/"
  + "tet:label-restrictions/tet:label-restriction" {
  when "././././././././.
  + "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 10-types:flexi-grid-label-range-info;
  }

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

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

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

    + "tet:tunnel-termination-point/
    + "tet:local-link-connectivities/
    + "tet:label-restrictions/tet:label-restriction" {
when "../../../../nw:network-types/tet:te-topology/
    + "flexgt:flexi-grid-topology" {
    description
        "Augmentation parameters apply only for networks with
        flexi-grid topology type.";
    }
}
description
   "Augment TE label range information for the Tunnel Termination Point (TTP) Local Link Connectivities."
uses l0-types:flexi-grid-label-range-info;
}
   + "tet:tunnel-termination-point/"
   + "tet:local-link-connectivities/"
   + "tet:local-link-connectivity/"
   + "tet:label-restrictions/tet:label-restriction" {
   when "./././././.nw:network-types/tet:te-topology/"
   + "flexgt:flexi-grid-topology" {
      description
         "Augmentation parameters apply only for networks with flexi-grid topology type.";
   }
}
description
   "Augment TE label range information for the TTP Local Link Connectivity entry.";
uses l0-types:flexi-grid-label-range-info;
}
   + "tet:te-link-attributes/"
   + "tet:label-restrictions/tet:label-restriction" {
   when "./././././.nw:network-types/tet:te-topology/"
   + "flexgt:flexi-grid-topology" {
      description
         "Augmentation parameters apply only for networks with flexi-grid topology type.";
   }
}
description
   "Augment TE label range information for the TE link.";
uses l0-types:flexi-grid-label-range-info;
}
   + "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 10-types:flexi-grid-label-range-info;
}

augment "//nw:networks/tet:te/tet:templates/
  + "tet:link-template/tet:te-link-attributes/
  + "tet:label-restrictions/tet:label-restriction" {
  description
  "Augment TE label range information for the TE link template.";
  uses 10-types:flexi-grid-label-range-info;
}

/ *
  * Augment TE label
  */

augment "//nw:networks/nw:network/nw:node/tet:te/
  + "tet:te-node-attributes/tet:connectivity-matrices/
  + "tet:label-restrictions/tet:label-restriction/
  + "tet:label-start/
  + "tet:te-label/tet:technology" {
  when ".../.../.../.../.../nw:network-types/tet:te-topology/
  + "flexgt:flexi-grid-topology" {
    description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
  }
  description
  "Augment TE label range start for the TE node
  connectivity matrices.";
  case flexi-grid {
    uses 10-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 10-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/"
        + "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 10-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/"
        + "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 10-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 10-types:flexi-grid-label-hop;
}
"

+ "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 10-types:flexi-grid-label-hop;
}
"

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "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 10-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 10-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 10-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 10-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 10-types:flexi-grid-label-start-end;
}
}

augment "*/nw:networks/nw:network/nw:node/tet:te/
+ "tet:te-node-attributes/tet:connectivity-matrices/"
Internet-Draft               Flexi-Grid YANG               November 2021

+ "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 10-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 10-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 10-types:flexi-grid-label-hop;
}
}

+ "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 10-types:flexi-grid-label-hop;
}
}
description
"Augment TE label hop for the computed path route objects of the connectivity matrix entry.";
case flexi-grid {
  uses 10-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: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: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" {
      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 10-types:flexi-grid-label-start-end;
}
+ "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;
}
}

+ "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;
}
}

+ "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 10-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 10-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 10-types:flexi-grid-label-hop;
}

+ "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 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 10-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 10-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/"
Internet-Draft               Flexi-Grid YANG               November 2021

+ "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 10-types:flexi-grid-label-step;
}
}

+ "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 10-types:flexi-grid-label-start-end;
}
}

+ "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.";
flexi-grid topology type.
}
}

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: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: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: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" {

+ "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;
  }
}

+ "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 connectivity matrix entry
information source."
  case flexi-grid {
    uses l0-types:flexi-grid-label-hop;
  }
}

+ "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 10-types:flexi-grid-label-hop;
 }
}

+ "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 10-types:flexi-grid-label-hop;
 }
}

+ "tet:tunnel-termination-point/
+ "tet:local-link-connectivities/
+ "tet:label-restrictions/tet:label-restriction/
+ "tet:label-start/
+ "tet:te-label/tet:technology" {
    when "/nw:networks/nw:network/nw:node/tet:te/"
    + "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 10-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:networks/nw:network/nw:node/tet:te/"
    + "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 10-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:networks/nw:network/nw:node/tet:te/"
    + "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 10-types:flexi-grid-label-start-end;
    }
}
flexi-grid topology type."

}\}
description
"Augment TE label range step for the TTP
Local Link Connectivities."

case flexi-grid {
    uses 10-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 10-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 10-types:flexi-grid-label-hop;
}
 + "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 10-types:flexi-grid-label-hop;
 }
}

 + "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 10-types:flexi-grid-label-hop;
 }
}
  + "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.";

  case flexi-grid {
    uses 10-types:flexi-grid-label-hop;
  }
}

  + "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.";

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

  + "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 10-types:flexi-grid-label-start-end;
}
}

  + "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 10-types:flexi-grid-label-step;
}
}

  + "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;
}


    + "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;
}


    + "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 10-types:flexi-grid-label-hop;
}

  + "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 10-types:flexi-grid-label-hop;
}

  + "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 10-types:flexi-grid-label-hop;
}

+ "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:networks/nw:network/nt:link/tet:te/
+ "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 10-types:flexi-grid-label-hop;
}

+ "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:networks/nw:network/nt:link/tet:te/
+ "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 10-types:flexi-grid-label-hop;
}

+ "tet:te-link-attributes/
+ "tet:label-restrictions/tet:label-restriction/"


```yang
+ "tet:label-start/tet:te-label/tet:technology" {
  when "/nw:networks/nw:network/nt:link/tet:te/
      + "tet:te-link-attributes/
      + "tet:label-restrictions/tet:label-restriction/
      + "tet:te-label/tet:technology" {
    description
      "Augmentation parameters apply only for networks with
      flexi-grid topology type.";
  }
}

describe
  "Augment TE label range start for the TE link.";
  case flexi-grid {
    uses 10-types:flexi-grid-label-start-end;
  }
}

  + "tet:te-link-attributes/
  + "tet:label-restrictions/tet:label-restriction/
  + "tet:te-label/tet:technology" {
  when "/nw:networks/nw:network/nt:link/tet:te/
      + "tet:te-link-attributes/
      + "tet:label-restrictions/tet:label-restriction/
      + "tet:te-label/tet:technology" {
    description
      "Augmentation parameters apply only for networks with
      flexi-grid topology type.";
  }
}

describe
  "Augment TE label range end for the TE link.";
  case flexi-grid {
    uses 10-types:flexi-grid-label-start-end;
  }
}

  + "tet:te-link-attributes/
  + "tet:label-restrictions/tet:label-restriction/
  + "tet:label-step/tet:technology" {
  when "/nw:networks/nw:network/nt:link/tet:te/
      + "tet:te-link-attributes/
      + "tet:label-restrictions/tet:label-restriction/
      + "tet:label-step/tet:technology" {
    description
      "Augmentation parameters apply only for networks with
      flexi-grid topology type.";
  }
}

describe
  "Augment TE label range step for the TE link.";
  case flexi-grid {
    uses 10-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 10-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 10-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 10-types:flexi-grid-label-start-end;
 }
)
information source.
  
  case flexi-grid {
    uses 10-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 10-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 10-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 10-types:flexi-grid-label-start-end;
  }
}

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

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:
9. IANA Considerations

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

   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
   Prefix: flexi-grid-topology
   Reference: [This.I-D]

10. Contributors

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

Oscar Gonzalez de Dios Telefonica I+D/GCTO Email: oscar.gonzalezdedios@telefonica.com

Gabriele Galimberti Cisco Email: ggalimbe@cisco.com

Zafar Ali Cisco Email: zali@cisco.com

Daniel Michaud Vallinoto Universidad Autonoma de Madrid Email: daniel.michaud@estudiante.uam.es

Steven Hill, MTN Group Technology Email: Steven.Hill@mtn.com
11. Acknowledgments

The work presented in this document has been partially funded by the European Commission under the project H2020 METRO-HAUL (Metro High bandwidth, 5G Application-aware optical network, with edge storage, compute and low Latency), Grant Agreement number: 761727.

This work is also partially funded by the Spanish State Research Agency under the project AgileMon (AEI PID2019-104451RB-C21) and by the Spanish Ministry of Science, Innovation and Universities under the program for the training of university lecturers (Grant number: FPU19/05678).

Thanks to Adrian Farrel for reviewing this document and assisting with conversion to XML.

12. References

12.1. Normative References


12.2. Informative References


[I-D.ietf-ccamp-flexigrid-tunnel-yang]

[I-D.ietf-ccamp-optical-impairment-topology-yang]


Authors’ Addresses

Jorge E. Lopez de Vergara Mendez
Naudit HPCN
Email: jorge.lopez_vergara@uam.es

Daniel Perdices Burrero
Universidad Autónoma de Madrid
Email: daniel.perdices@uam.es

Daniel King
Old Dog Consulting
Email: daniel@olddog.co.uk
Young Lee
Samsung

Email: younglee.tx@gmail.co

Haomian Zheng
Huawei Technologies

Email: zhenghaomian@huawei.com
A YANG Data Model for L1 Connectivity Service Model (L1CSM)
draft-ietf-ccamp-l1csm-yang-15

Abstract

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

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at https://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on March 12, 2022.

Copyright Notice

Copyright (c) 2021 IETF Trust and the persons identified as the document authors. All rights reserved.
This document provides a YANG data model for L1VPN Connectivity Service Model (L1CSM) which can be classified as Network Service YANG module per [RFC8199]. The intent of this document is to provide a transport service model exploiting YANG data model, which can be utilized by a client network controller to initiate a service request connectivity request as well as retrieving service states toward a transport network controller communicating with the client controller via a NETCONF [RFC8341] or a RESTCONF [RFC8040] interface.

[RFC4847] provides a framework and service level requirements for Layer 1 Virtual Private Networks (L1VPNs). It classifies service models as management-based service model, signaling-based service model (Basic Mode) and signaling and routing service model (Enhanced Mode).
In the management-based service model, customer management systems and provider management systems communicate with each other. Customer management systems access provider management systems to request layer 1 connection setup/deletion between a pair of CEs. Customer management systems may obtain additional information, such as resource availability information and monitoring information, from provider management systems. There is no control message exchange between a CE and PE.

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

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

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

1.1. Deployment Scenarios

Figure 1 depicts a deployment scenario of the L1VPN SDN control-based service model for an external customer instantiating L1 point-to-point connectivity to the provider.
Figure 1: L1VPN SDN Controller/EMS/NMS-Based Service Model: External Customer

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

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

![Diagram of network architecture]

**Figure 2: L1VPN SDN Controller/EMS/NMS-Based Service Model: Internal Customer**
The benefit is that the same layer 1 transport network resources are shared by multiple services. A large capacity backbone network (data plane) can be built economically by having the resources shared by multiple services usually with flexibility to modify topologies, while separating the control functions for each service department. Thus, each customer can select a specific set of features that are needed to provide their own service [RFC4847].

1.2. Terminology

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

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

- client
- server
- 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 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] and ietf-yang-types specified in [RFC6991] are imported in this module.

<table>
<thead>
<tr>
<th>Prefix</th>
<th>YANG module</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>l1csm</td>
<td>ietf-l1csm</td>
<td>[RFC XXXX]</td>
</tr>
<tr>
<td>l1-types</td>
<td>ietf-layer1-types</td>
<td>[I-D.ietf-ccamp-layer1-types]</td>
</tr>
<tr>
<td>yang</td>
<td>ietf-yang-types</td>
<td>[RFC6991]</td>
</tr>
</tbody>
</table>

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

2. Definitions

  L1VC Layer 1 Virtual Connection
  SLS Service Level Specification
  UNI User Network Interface
  PE Provider Edge
  CE Customer Edge
  EP End Point
  P Protocol
  C Coding
  O Optical Interface

3. L1CSM YANG Model (Tree Structure)
module: ietf-l1csm
  +--rw l1-connectivity
    +--rw access
      +--rw unis
        +--rw uni* [id]
          +--rw 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 endpoint-1
            +--rw id string
            +--rw uni /l1-connectivity/access/unis/uni/id
          +--rw endpoint-2
            +--rw id string
            +--rw uni /l1-connectivity/access/unis/uni/id
        +--rw start-time? yang:date-and-time
        +--rw time-interval? int32
        +--rw performance-metric* identityref

4. L1CSM YANG Code

<CODE BEGINS>file "ietf-l1csm@2021-02-19.yang"
module ietf-l1csm {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-l1csm";
  prefix "l1csm";

  import ietf-yang-types {
    prefix "yang";
    reference
      "RFC6991: Common YANG Data Types";
  }

  import ietf-layer1-types {
    prefix "l1-types";
    reference
      "RFCYYYY: A YANG Data Model for Layer 1 Types";
  }
}

Lee, et al. Expires March 12, 2022
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) 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 (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 "2021-02-19" {  
  description  
    "Initial revision.";
  reference  
    "RFC XXXX: A Yang Data Model for L1 Connectivity Service Model (L1CSM)";
  // Note: The RFC Editor will replace XXXX with the number assigned to the RFC once this draft becomes an RFC.
identity service-performance-metric {
  description
    "Base identity of service-specific performance metric";
  reference
    "MEF63: Subscriber Layer 1 Service Attributes";
}

identity one-way-delay {
  base service-performance-metric;
  description
    "One way delay.";
  reference
    "MEF63: Subscriber Layer 1 Service Attributes";
}

identity one-way-errored-second {
  base service-performance-metric;
  description
    "One way errored second";
  reference
    "MEF63: Subscriber Layer 1 Service Attributes";
}

identity one-way-severely-errored-second {
  base service-performance-metric;
  description
    "One way severely errored second";
  reference
    "MEF63: Subscriber Layer 1 Service Attributes";
}

identity one-way-unavailable-second {
  base service-performance-metric;
  description
    "One way unavailable second";
  reference
    "MEF63: Subscriber Layer 1 Service Attributes";
}

identity one-way-availability {
  base service-performance-metric;
  description
    "One way availability";
  reference
    "MEF63: Subscriber Layer 1 Service Attributes";
}
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-sls-service-attributes {
  description
  "The value of the Subscriber L1VC SLS (Service Level
  
leaf start-time {
  type yang:date-and-time;
  description
    "A time that represent the date and time for the start of
    the SLS";
}
leaf time-interval {
  type int32;
  units seconds;
  description
    "A time interval (e.g., 2,419,200 seconds which is 28 days)
    that is used in conjunction with time-start to specify a
    contiguous sequence of time intervals T for determining
    when performance objectives are met.";
}
leaf-list performance-metric {
  type identityref {
    base service-performance-metric;
  }
  description
    "List of service performance metric.";
}

grouping subscriber-l1vc-endpoint-attributes {
  description
    "Subscriber layer 1 connection endpoint attributes";
  reference
    "MEF63: Subscriber Layer 1 Service Attributes";
  container endpoint-1 {
    description
      "One end of UNI id’s - string and id";
    leaf id {
      type string;
      mandatory true;
      description
        "Subscriber end point ID of one end";
    }
    leaf uni {
      type leafref {
        path "/l1-connectivity/access/unis/un1/id";
      }
      mandatory true;
description
   "This is one end of subscriber L1VC end point ID value = UNI-1";
}
}
container endpoint-2 {
    description
        "One end of UNI id’s - string and id";
    leaf id {
        type string;
        must ' != ../../endpoint-1/id' {
            error-message
                "The two end points must not be equal to each other.";
        }
        mandatory true;
        description
            "Subscriber end point ID of the other end";
    }
    leaf uni {
        type leafref {
            path "/l1-connectivity/access/unis/uni/id";
        }
        mandatory true;
        description
            "This is one other end of subscriber L1VC end point ID value = UNI-2";
    }
}
}

/*
 * 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 UNI’s to be configured";
}

list uni {
key "id";

description
"UNI identifier";
leaf 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";
        }
    }
}

container services {
    description
"L1VC services";
    list service {
        key "service-id";
        description
"A unique identifier of a subscriber L1VC service";
        leaf service-id {
            type string;
            mandatory true;
            description
"A unique service identifier for subscriber L1VC.";
        }
        uses subscriber-l1vc-endpoint-attributes;
        uses subscriber-l1vc-sls-service-attributes;
    }
}
5. Security Considerations

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

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

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

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

unis:
- id

Service:
- service-id
- endpoint-1
- endpoint-2
- start-time
- time-interval
- performance-metric
The security considerations spelled out in the YANG 1.1 specification [RFC7950] apply for this document as well.

6. IANA Considerations

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

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-l1csm
prefix:       l1csm
reference:    RFC XXXX

7. Acknowledgements

The authors would like to thank Tom Petch for his helpful comments and valuable contributions and Robert Wilton for his review that improved the model significantly.

8. Contributors

Italo Busi
Huawei Technologies
Email: Italo.Busi@huawei.com

Giuseppe Fioccola
Huawei Technologies
Email: giuseppe.fioccola@huawei.com

Dhruv Dhody
Huawei Technologies
Email: dhruv.ietf@gmail.com
9. References

9.1. Normative References

[I-D.ietf-ccamp-layer1-types]


9.2. Informative References


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 UNI endpoints. The service is configured with the starting time to be 06:06:09 on 2018-09-13 for the service life time of 2419200 seconds (which is corresponds to 28 days). In addition, the service is configured to collect one performance metric, One-way-Delay.
{
  "ll-connectivity": {
    "access": {
      "unis": {
        "uni": [
          {
            "id": "MTL-HQ-Node3-Slot2-Port1",
            "protocol": "ETH-10GigE_LAN",
            "coding": "ETH-10GR-PCS-49",
            "optical_interface": "LR-PMD-clause-52"
          },
          {
            "id": "MTL-STL-Node5-Slot4-Port3",
            "protocol": "ETH-10GigE_LAN",
            "coding": "ETH-10GR-PCS-49",
            "optical_interface": "ER-PMD-clause-52"
          }
        ],
        "services": {
          "service": [
            {
              "service-id": "Sub-L1VC-1867-LT-MEGAMART",
              "endpoint-1": {
                "id": "MTL-HQ_1867-MEGAMART",
                "uni": "MTL-HQ-Node3-Slot2-Port1"
              },
              "endpoint-2": {
                "id": "MTL-STL_1867-MEGAMART",
                "uni": "MTL-STL-Node5-Slot4-Port3"
              },
              "start-time": "2018-09-13T06:06:09Z",
              "time-interval": 2419200,
              "performance-metric": "One-way-Delay"
            }
          ]
        }
      }
    }
  }
}
Authors' Addresses

Young Lee
Samsung
Samsung
Seoul
South Korea

Email: younglee.tx@gmail.com

KwangKoog Lee
Korea Telecom
South Korea

Email: kwangkoog.lee@kt.com

Haomian Zheng
Huawei Technologies
H1, Huawei Xiliu Beipo Village, Songshan Lake
Dongguan, Guangdong 523808
China

Email: zhenghaomian@huawei.com

Oscar Gonzalez de Dios
Telefonica

Email: oscar.gonzalezdedios@telefonica.com

Daniele Ceccarelli
Ericsson

Email: daniele.ceccarelli@ericsson.com
Abstract

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

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at https://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on March 12, 2022.

Copyright Notice

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

This document is subject to BCP 78 and the IETF Trust’s Legal Provisions Relating to IETF Documents (https://trustee.ietf.org/license-info) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.
1. Introduction

This document specifies common data types for use in YANG [RFC7950] data models of Layer 1 networks. The derived types and groupings are types applicable to modeling Traffic Engineering (TE) for Layer 1 networks.

The Optical Transport Networking, a typical Layer 1 network, is specified in [RFC7062]. The corresponding routing and signaling protocol are specified in [RFC7138] and [RFC7139]. The types and groupings defined in this document are consistent to 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 data model in this draft only defines groupings, typedef and identities. There is no configuration or state data as specified in the Network Management Datastore Architecture [RFC8342]. The document is consistent with other specifications, including [MEF63] for Layer 1 service attributes, [ITU-Tg709] and [ITU-Tgsup43] for OTN data plane definitions.
2. Terminology and Notations

Refer to [RFC7062] for the 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, names of data nodes and other data model objects are prefixed using the standard prefix associated with the corresponding YANG imported modules.

+----------------+-----------------+-----------------+
| Prefix          | YANG module     | Reference       |
+----------------+-----------------+-----------------+
| l1-types        | ietf-layer1-types | This Document   |
+----------------+-----------------+-----------------+

4. Layer 1 Types Overview

4.1. Relationship with other Modules

This document defines one YANG module for common Layer 1 types. 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 OTN, in its technology-specific modules, such as topology and tunnels. It is worth noting that the generic traffic-engineering (TE) types module is specified in [RFC8776] as ietf-te-types, 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, are specified in ietf-te-types in [RFC8776], while the OTN-specific attributes, such as odu-type, are specified in ietf-layer1-types in this document.

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 of the server layer ODU Link (HO ODUk or ODUCn) supporting a client layer ODU LSP (LO ODUj or ODUk, respectively). Three granularities, 1.25G/2.5G/5G, have been specified.
odu-type:

This specifies the type of ODUk LSP, including the types specified in [RFC7139] and [RFC7963].

client-signal:

This specifies the client signal types of OTN networks. The initial input was the G-PID specified in [RFC7139]. Identities for some of the categories of client signal types, including ETH, STM-n, OC [ANSI] and Fiber Channel, have been specified.

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 and could be used in OTN topology model for link bandwidth representation. All the bandwidth related sections in generic module, [RFC8776], need to be augmented with this grouping for the usage of Layer 1. The link bandwidth is represented by the number of ODUs that can be supported by the link for each ODU type as follow.

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

For example, an OTN link with 100G bandwidth can support either 1xODU4, 10xODU2 or 80xODU0.

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

otn-path-bandwidth:

This grouping defines the path bandwidth information and could be used in OTN topology model for path bandwidth representation. All the bandwidth related sections in generic module, [RFC8776], need to be augmented with this grouping for the usage of Layer 1. This grouping is also applicable when setting up the OTN tunnel. The path
bandwidth is usually represented by the type of ODU (e.g., ODU0, ODU2, ODU4) being setup along the path as follow.

```
+---:(otn)
   +--rw odu-type? identityref
```

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

**otn-label-range-info:**

This grouping is used to augment the label-restriction list, defined in [RFC8776], with OTN technology-specific attributes, as defined in section Section 4.3.

```
+--rw range-type? otn-label-range-type
+-rw tsg? identityref
+--rw odu-type-list* identityref
+-rw priority? uint8
```

**otn-label-start-end:**

This grouping is used to augment the label-start and label-end containers within the label-restriction list, defined in [RFC8776], with OTN technology-specific attributes, as defined in section Section 4.3.

```
+---:(otn)
   +--rw (range-type)?
      +---:(trib-port)
         |   +--rw otn-tpn? otn-tpn
         +---:(trib-slot)
            +--rw otn-ts? otn-ts
```

**otn-label-step:**

This grouping is used to augment the label-step container within the label-restriction list, defined in [RFC8776], with OTN technology-specific attributes, as defined in section Section 4.3.
otn-label-hop:

This grouping is used to augment the label-hop container, defined in [RFC8776], with OTN technology-specific attributes, as defined in section 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 time slots (numbered from 1 to 80) and the TPN values can be any number from 1 to 80.

The OTN Label Range represents the values for the TPN and TS that are available for ODUk LSPs to be setup over a given OTN Link.
The OTN Label Range is defined by the label-restriction list, defined in [RFC8776], 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 entry of the list.

Each entry of the label-restriction list, as defined in [RFC8776], 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 [RFC8776].

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. Different entries in the label-restriction list will report different TPN ranges for 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 which has a flexible bit rate which is configured when setting up an ODUflex LSP.
[ITU-Tg709], defines six types of ODUflex: ODUflex(CBR), ODUflex(GFP), ODUflex(GFP,n,k), ODUflex(IMC), ODUflex(IMC,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-Tg709]. A YANG choice has been defined to describe these cases:

```
+--rw (oduflex-type)?
    +--):(generic)
    |   +--rw nominal-bit-rate        uint64
    +--):(cbr)
    |   +--rw client-type             identityref
    +--):(gfp-n-k)
    |   +--rw gfp-n                   uint8
    |   +--rw gfp-k?                  l1-types:gfp-k
    +--):(flexe-client)
    |   +--rwflexe-client
    |       l1-types:flexe-client-rate
    +--):(flexe-aware)
    |   +--rw flexe-aware-n           uint16
    +--):(packet)
    +--rw opuflex-payload-rate       uint64
```

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

In order to simplify interoperability the ‘generic’ case should be used only when it is 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-Tg709].

The ‘gfp-n’ 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-Tg709]. With a few exceptions, shown in Table L-7 of [ITU-Tg709], the nominal bit-rate of the
ODUk.ts could be inferred from the value of ‘n’, as shown in Table 7-8 of [ITU-Tg709] 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-Tg709]. 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 defines 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-Tg709].

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-Tg709], and the calculation of ODUflex(IMP) nominal bit rate is defined in section 12.2.6 of [ITU-Tg709]. The same formula is used in both cases.

Section 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-Tg709], 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-Tg709] defines the rules for computing the number of tributary slots to be allocated to ODUflex LSPs when carried over an ODUCn link.

Following the [ITU-Tg709] 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 any other ODUflex type are used.

The number of available ODUs, defined for each ODUk type, including ODUflex, together with the number of available time-slots, reported as part of the OTN label range, provide sufficient information to infer the OTN link bandwidth availability for ODUflex LSPs. This information is independent of the ODUflex type.
4.4.1. Resizable ODUflex

Resizable ODUflex is a special type of ODUflex that supports the procedures defined in [ITU-Tg7044] 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-Tg709].
- 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 support the [ITU-Tg7044] hitless resizing procedures. They also identify whether an OTN link only supports the setup of non-resizable ODUflex LSPs or also supports the setup of resizable ODUflex(GFP,n,k) LSP but with different capabilities (e.g., a lower number of LSPs).

5. YANG Code for Layer1 Types

```yampl
<CODE BEGINS>file "ietf-layer1-types@2021-02-19.yang"
module ietf-layer1-types {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-layer1-types";
  prefix "l1-types";

  organization "IETF CCAMP Working Group";
  contact
    "WG Web: <http://tools.ietf.org/wg/ccamp/>
    WG List: <mailto:ccamp@ietf.org>
    Editor: Haomian Zheng
    <mailto:zhenghaomian@huawei.com>
    Editor: Italo Busi
    <mailto:Italo.Busi@huawei.com>"

  description "This module defines Layer 1 types. 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.
```
typedef otn-tpn {
    type uint16 {
        range "1..4095";
    }
    description
        "Tributary Port Number 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 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
                "Tributary Slot for OTN. ";
            reference
                "RFC7139: GMPLS Signaling Extensions for Control of Evolving G.709 Optical Transport Networks.";
        }
    }
}
"Defines a range of OTN tributary slots. ";
}
enum trib-port {
  description
  "Defines a range of OTN tributary ports. ";
}

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

typedef gfp-k {
  typedef 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 {
  typedef 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)";
      }
    }
  }
}
The FlexE Client signal rate \((s \times 5,156,250.000 \text{ kbit/s})\) used to compute the rate of an ODUflex(IMP, s).
Valid values for \(s\) are \(s=2\) (10G), \(s=4\) (40G) and \(s=5 \times n\) (\(n \times 25\)G).
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)";

identity tributary-slot-granularity {
    description
        "Tributary slot granularity";
    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 ODU protocol is derived.";
identity ODU0 {
  base odu-type;
  description
    "ODU0 protocol (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 protocol (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 ODU1e {
  base odu-type;
  description
    "ODU1e protocol (10.35Gb/s).";
  reference
    "RFC7963: RSVP-TE Extension for Additional Signal Types in G.709 Optical Transport Networks (OTNs)
    ITU-T G.sup43 v5.0 (02/2011): Transport of IEEE 10GBASE-R in optical transport networks (OTN)";
}

identity ODU2 {
  base odu-type;
  description
    "ODU2 protocol (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 protocol (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 protocol (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 ODU3e1 {
    base odu-type;
    description
        "ODU3e1 protocol (41.77Gb/s).";
    reference
        "RFC7963: RSVP-TE Extension for Additional Signal Types in
         G.709 Optical Transport Networks (OTNs)
         ITU-T G.sup43 v5.0 (02/2011): Transport of IEEE 10GBASE-R
         in optical transport networks (OTN)";
}

identity ODU3e2 {
    base odu-type;
    description
        "ODU3e2 protocol (41.78Gb/s).";
    reference
        "RFC7963: RSVP-TE Extension for Additional Signal Types in
         G.709 Optical Transport Networks (OTNs)
         ITU-T G.sup43 v5.0 (02/2011): Transport of IEEE 10GBASE-R
         in optical transport networks (OTN)";
identity ODU4 {
    base odu-type;
    description 
        "ODU4 protocol (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 protocol (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

Zheng & Busi Expires March 12, 2022 [Page 16]
"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 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
        "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
        "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)
         IEEE 802.3-2018, Clause 49: IEEE Standard for Ethernet";
}

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

identity ETH-40Gb {
    base client-signal;
    description
        "Client signal type of 40GbE";
    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 STM-16 {
    base client-signal;
    base coding-func;
    description "Client signal type of STM-16;
    STM-16 G.707 (N=16) coding function.";
    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)
    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 "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 "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 T1.105-1995: 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 T1.105-1995: 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 T1.105-1995: 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.";
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 T1.105-1995: 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
        "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
        "RFC7139: GMPLS Signaling Extensions for Control of Evolving
         G.709 Optical Transport Networks
         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
    "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
    "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
    "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 "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 "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 FICON-4G {
  base client-signal;
  description "Client signal type of Fibre Connection 4G";
  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 FICON-8G {
    base client-signal;
    description
        "Client signal type of Fibre Connection 8G";
    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 ETH-1000X {
    base coding-func;
    description
        "1000BASE-X PCS clause 36 coding function.";
    reference
        "MEF63: Subscriber Layer 1 Service Attributes";
}

identity ETH-10GW {
    base coding-func;
    description
        "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
        "MEF63: Subscriber Layer 1 Service Attributes";
}

identity ETH-40GR {
    base coding-func;
    description
        "40GBASE-R PCS clause 82 coding function.";
    reference
        "MEF63: Subscriber Layer 1 Service Attributes";
}

identity ETH-100GR {

base coding-func;
description
"100GBASE-R PCS clause 82 coding function."
reference
"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
  "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
  "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
  "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
"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
        "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
        "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
        "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
        "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
        "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 "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 "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 "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 "MEF63: Subscriber Layer 1 Service Attributes";
}

grouping otn-link-bandwidth {
    description "Bandwidth attributes for OTN links";
    list odulist {
        key "odu-type";
        description "OTN bandwidth definition";
        leaf odu-type {

Zheng & Busi Expires March 12, 2022 [Page 28]
type identityref {
    base odu-type;
    }
    description "ODU type";
    }
leaf number {
    type uint16;
    description "Number of ODUs";
    }
}

grouping otn-path-bandwidth {
    description "Bandwidth attributes for OTN paths.";
    container otn {
        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 uint64;
                units "bps";
                mandatory true;
                description "Nominal ODUflex bit rate.";
            }
        }
        case cbr {
    leaf client-type {
            }
type identityref {
  base client-signal;
}
mandatory true;
description
  "The CBR client signal for 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 uint64;
    units "Kbps";
    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(IM).";
  }
}

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.";

  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 shall be present when the range-type is TS.

    This leaf can 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;
  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.";
  choice range-type {
    description
      "OTN label range type, either TPN range or TS range";
      case trib-port {
        leaf otn-tpn {
          when "../..../range-type = 'trib-port'" {
            description
              "Valid only when range-type represented by trib-port";
          }
          type otn-tpn;
          description
            "Tributary Port Number.";
          reference
            "RFC7139: GMPLS Signaling Extensions for Control of
             Evolving G.709 Optical Transport Networks.";
      }
  }
case trib-slot {
  leaf otn-ts {
    when "../../../range-type = 'trib-slot'" {
      description
      "Valid only when range-type represented by trib-slot";
    }
    type otn-ts;
    description
    "Tributary Slot 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";
  leaf otn-tpn {
    type otn-tpn;
    description
    "Tributary Port Number.";
    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.";
    reference
    "ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical Transport Network (OTN)";
  }
  leaf ts-list {
    type string {
      pattern "([-9][0-9]*(-[9][0-9])*?)*"
      + "([-9][0-9]*(-[9][0-9])*)?"*";
    }
    description
    "A list of available tributary slots 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.";

  choice range-type {
    description
    "OTN label range type, either TPN range or TS range";
    case trib-port {
      leaf otn-tpn {
        when "./../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.";
      reference
      "RFC7139: GMPLS Signaling Extensions for Control of Evolving G.709 Optical Transport Networks.";
    }
    case trib-slot {
      leaf otn-ts {
        when "./../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 Number.";
      reference
      "RFC7139: GMPLS Signaling Extensions for Control of Evolving G.709 Optical Transport Networks.";
    }
  }
}
6. Security Considerations

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

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

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

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

7. IANA Considerations

It is proposed that IANA should assign new URIs from the "IETF XML Registry" [RFC3688] as follows:
This document registers following YANG modules in the YANG Module Names registry [RFC7950].

name: ietf-layer1-types
prefix: l1-types
reference: RFC XXXX

8. Acknowledgements

The authors and the working group give their sincere thanks for Robert Wilton for the YANG doctor review, and Tom Petch for his comments during the model and document development.

9. Contributors

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

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

Yanlei Zheng
China Unicom
Email: zhengyanlei@chinaunicom.cn

Aihua Guo
Futurewei Technologies
Email: aihuaguo@futurewei.com

Young Lee
Samsung
Email: younglee.tx@gmail.com

Lei Wang
China Mobile
Email: wangleiyj@chinamobile.com

Oscar Gonzalez de Dios
10. References

10.1. Normative References


[ITU-Tg7044] International Telecommunication Union, "Hitless adjustment of ODUflex(GFP)", ITU-T G.7044, October 2011.

[ITU-Tg sup43]


10.2. Informative References

[I-D.ietf-ccamp-client-signal-yang]

[I-D.ietf-ccamp-l1csm-yang]

[I-D.ietf-ccamp-otn-topo-yang]

[I-D.ietf-ccamp-otn-tunnel-model]
[I-D.ietf-ccamp-transport-nbi-app-statement]


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 BCP XXX (RFC XXXX) =========

{

  "examples of label-restrictions for different OTN Links": [

    "//": "HO-ODU1 or OTU1 Link",
    "label-restrictions": {
      "label-restriction": {

        "index": 1,
        "// __DEFAULT__ restriction": "inclusive",

Zheng & Busi Expires March 12, 2022 [Page 40]
Internet-Draft

A YANG Data Model for Layer 1 Types

September 2021

"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 n\
\eeded and 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",
"range-type": "label-range-trib-slot",
"tsg": "tsg-1.25G",
"odu-type-list": "[ ODU0 ]",
"// ts-range": "1-2",
"// ___ COMMENT ___": "Since no TPN range is reportd for\
\ ODU0 with 1.25G TSG, the TPN allocation rule is fixed (TPN = TS#) \
\for mapping LO-ODU0 over HO-ODU1 with 1.25G TSG. See Table 4 of [RF\
\C7139]."
}
]
}
},
{
"// ": "HO-ODU2 or OTU2 Link",
"label-restrictions": {
"label-restriction": [
{
"index ": 1,
"// ___DEFAULT___ restriction": "inclusive",
"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 n\
\eeded and 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",
"range-type": "label-range-trib-slot",
"tsg": "tsg-1.25G",
"odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, ODU1\

Zheng & Busi

Expires March 12, 2022

[Page 41]


"// ___ DEFAULT ___ priority": 7,
"// ts-range": "1-8"
},
{
  "index ": 3,
  "// ___DEFAULT___ restriction": "inclusive",
  "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 \nfor ODUFlex and ODU0 with 1.25G TSG, the TPN assignment rule is flexible within 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",
  "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 \nfor ODU1 with 1.25G TSG, the TPN assignment rule is flexible within a common range for mapping LO-ODU1 over HO-ODU2 with 1.25G TSG. See Table 4 of [RFC7139]."
},
{
  "index ": 5,
  "// ___DEFAULT___ restriction": "inclusive",
  "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 with 2.5G TSG, the TPN allocation rule is fixed (TPN = TS#) for mapping LO-ODU1 over HO-ODU2 with 2.5G TSG. See Table 3 of [RFC7139]."
}
]"},
{
  "// ": "HO-ODU3 or OTU3 Link",
}
}
"label-restrictions": {
  "label-restriction": [
  {
    "index ": 1,
    "// ___DEFAULT___ restriction": "inclusive",
    "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 \nreported for ODU3, the link is an OTU3 Link. TS allocation is not n\needed and TPN shall be set to '1' for mapping ODU3 over OTU3. This \nentry is not present if the OTN Link is an HO-ODU3 Link."
  },
  {
    "index ": 2,
    "// ___DEFAULT___ restriction": "inclusive",
    "range-type": "label-range-trib-slot",
    "tsg": "tsg-1.25G",
    "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, ODU1, ODU2, ODU2e ]",
    "// ___ DEFAULT ___ priority": 7,
    "// ts-range": "1-32"
  },
  {
    "index ": 3,
    "// ___DEFAULT___ restriction": "inclusive",
    "range-type": "label-range-trib-port",
    "tsg": "tsg-1.25G",
    "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, ODU2, ODU2e ]",
    "// ___ DEFAULT ___ priority": 7,
    "// tpn-range": "1-32",
    "// ___ COMMENT ___": "Since this TPN range is reported \nfor ODUFlex, ODU0 and ODU2e with 1.25G TSG, the TPN assignment rule\nis flexible within a common range for mapping LO-ODUFlex, LO-ODU0 \nand LO-ODU2e over HO-ODU3 with 1.25G TSG. See Table 4 of [RFC7139]."
  },
  {
    "index ": 4,
    "// ___DEFAULT___ restriction": "inclusive",
    "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 \n
for ODU1 with 1.25G TSG, the TPN assignment rule is flexible within a common range for mapping LO-ODU1 over HO-ODU3 with 1.25G TSG. See Table 4 of [RFC7139].

},
{
  "index ": 6,
  "// ___DEFAULT___ restriction": "inclusive",
  "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",
  "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 reported 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]."
}

}
{  
  "index": 1,  
  "// DEFAULT restriction": "inclusive",  
  "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 and 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",  
  "range-type": "label-range-trib-slot",  
  "tsg": "tsg-1.25G",  
  "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, ODU1 OdU2, ODU2e, ODU3 ]",  
  "// DEFAULT priority": 7,  
  "// ts-range": "1-80"  
},  
{  
  "index": 3,  
  "// DEFAULT restriction": "inclusive",  
  "range-type": "label-range-trib-port",  
  "tsg": "tsg-1.25G",  
  "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, ODU1 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]."  
}  
},  
{  
  "//": "ODUC1 Link",  
  "label-restrictions": {  
    "label-restriction": [  
      {  
        "index": 1,  
        "// DEFAULT restriction": "inclusive",  
        "range-type": "label-range-trib-slot",  
        "// COMMENT": "Since 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]."
      }  
    ]  
  }  
}
"tsg": "tsg-5G",
"odu-type-list": ": [ ODUFlex-cbr, ODUFlex-gfp, ODU0, ODU1, ODU2, ODU2e, ODU3, ODU4 ]",
"// ___ DEFAULT ___ priority": 7,
"// ts-range": "1-20",
"// ___ COMMENT ___": "Since the TS range is specified for any ODUk, the OTN Link is an ODUCn Link."
},
{
"index": 2,
"// ___DEFAULT___ restriction": "inclusive",
"range-type": "label-range-trib-port",
"tsg": "tsg-5G",
"odu-type-list": ": [ ODUFlex-cbr, ODUFlex-gfp, ODU0, ODU1, 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 common range for mapping any ODUk over ODUCn with 5G TSG."
}]

Authors’ Addresses

Haomian Zheng
Huawei Technologies
H1, Huawei Xiliu Beipo Village, Songshan Lake
Dongguan, Guangdong  523808
China

Email: zhenghaomian@huawei.com

Italo Busi
Huawei Technologies
Milan
Italy

Email: Italo.Busi@huawei.com
A YANG Data Model for Optical Impairment-aware Topology
draft-ietf-ccamp-optical-impairment-topology-yang-08

Abstract

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

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

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at https://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on 28 April 2022.
Copyright Notice

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

This document is subject to BCP 78 and the IETF Trust’s Legal Provisions Relating to IETF Documents (https://trustee.ietf.org/license-info) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

1. Introduction .................................................. 3
   1.1. Terminology ............................................... 4
   1.2. Tree Diagram .............................................. 4
   1.3. Prefixes in Data Node Names ........................... 4
2. Reference Architecture ........................................ 5
   2.1. Control Plane Architecture ............................ 5
   2.2. Transport Data Plane ................................... 6
   2.3. OMS Media Links ......................................... 7
   2.3.1. Optical Tributary Signal (OTS\textsubscript{i}) ........ 8
   2.3.2. Optical Tributary Signal Group (OTS\textsubscript{i}G) .... 9
   2.3.3. Media Channel (MC) .................................. 10
   2.3.4. Media Channel Group (MCG) ......................... 11
   2.4. Amplifiers .................................................. 12
   2.5. Transponders .............................................. 12
   2.5.1. Standard Modes ....................................... 13
   2.5.2. Organizational Modes ................................ 14
   2.5.3. Explicit Modes ....................................... 16
   2.5.4. Transponder Capabilities and Current Configuration . 16
   2.6. 3R Regenerators ......................................... 18
   2.7. WSS/Filter ................................................ 21
   2.8. Optical Fiber ............................................. 21
   2.9. ROADM Node Architectures .............................. 21
   2.9.1. Integrated ROADM Architecture with Integrated Optical Transponders ...................................... 22
   2.9.2. Integrated ROADMs with Integrated Optical Transponders and Single Channel Add/Drop Interfaces for Remote Optical Transponders ...................................... 23
   2.9.3. Disaggregated ROADMs Subdivided into Degree, Add/Drop, and Optical Transponder Subsystems .......... 24
   2.9.4. Optical Impairments Imposed by ROADM Nodes .... 25
3. YANG Model (Tree Structure) ................................ 27
4. Optical Impairment Topology YANG Model .................... 33
5. Security Considerations .......................... 61
6. IANA Considerations ............................... 61
7. Acknowledgments .................................... 61
8. References ......................................... 61
   8.1. Normative References .............................. 61
   8.2. Informative References ............................. 62
Appendix A. Contributors ................................. 65
Appendix B. Additional Authors ............................ 65
Authors' Addresses ..................................... 66

1. Introduction

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

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

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

It is worth noting that optical data plane interoperability is a complex topic especially in a multi vendor environment and usually requires joint engineering, which is independent from control plane and management plane capabilities. The YANG data model defined in this draft is providing sufficient information to enable optical impairment aware path computation. Optical data plane interoperability is outside the scope of this draft.

This document augments the generic TE topology draft [RFC8795] where possible.

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

1.1. Terminology

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

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

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

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

* configuration data
* state data

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

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.
### Table 1: Prefixes and corresponding YANG modules

<table>
<thead>
<tr>
<th>Prefix</th>
<th>YANG module</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>optical-imp-topo</td>
<td>ietf-optical-impairment-topology</td>
<td>[RFCXXXX]</td>
</tr>
<tr>
<td>layer0-types</td>
<td>ietf-layer0-types</td>
<td>[RFC9093]</td>
</tr>
<tr>
<td>10-types-ext</td>
<td>ietf-layer0-types-ext</td>
<td>[I-D.ietf-ccamp-layer0-types-ext]</td>
</tr>
<tr>
<td>nw</td>
<td>ietf-network</td>
<td>[RFC8345]</td>
</tr>
<tr>
<td>nt</td>
<td>ietf-network-topology</td>
<td>[RFC8345]</td>
</tr>
<tr>
<td>tet</td>
<td>ietf-te-topology</td>
<td>[RFC8795]</td>
</tr>
</tbody>
</table>

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

2. Reference Architecture

2.1. Control Plane Architecture

Figure 1 shows the control plane architecture.
The models developed in this document is an abstracted YANG model that may be used in the interfaces between the MDSC and the Optical Domain Controller (aka MPI) and between the Optical Domain Controller and the Optical Device (aka SBI) in Figure 1. It is not intended to support a detailed low-level DWDM interface model. DWDM interface model is supported by the models presented in [I-D.ietf-ccamp-dwdm-if-param-yang].

2.2. Transport Data Plane

This section provides the description of the reference optical network architecture and its relevant components to support optical impairment-aware path computation.

Figure 2 shows the reference architecture.
2.3. OMS Media Links

According to [G.872], OMS Media Link represents a media link between two ROADMs. Specifically, it originates at the ROADM’s Filter in the source ROADM and terminates at the ROADM’s Filter in the destination ROADM.

OMS Media link can be decomposed in a sequence of OTS links type (i), (ii), and (iii) as discussed above. OMS Media link would give an abstracted view of impairment data (e.g., power, OSNR, etc.) to the network controller.

For the sake of optical impairment evaluation OMS Media link can be also decomposed in a sequence of elements such as BA, fiber section, ILA, concentrated loss and PA.
An OMS Media link is terminated on both ends by a link termination point (LTP) as defined in [RFC8345]. Links in optical transport networks are typically bidirectional but have to be modeled as a pair of two unidirectional links following the [RFC8345] modeling approach. Unlike TE links, which are unidirectional, the LTPs on either end of the TE link pair forming the bidirectional link, are bidirectional as described in [I-D.ietf-teas-te-topo-and-tunnel-modeling] and the pair of unidirectional links are connected to the same bidirectional LTP on either end of the link pair.

[Editor’s note: text below related to [G.807] needs to be revised! [G.807] is now in publication process.]

2.3.1. Optical Tributary Signal (OTSi)

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

Path computation needs to know the existing OTSi signals for each OMS link in the topology to determine the optical impairment impact of the existing OTSi signals on the optical feasibility of a new OTSi signal and vice versa, i.e., the impact of the new OTSi on the existing OTSi signals. For determining the optical feasibility of the new OTSi, it is necessary to know the OTSi properties like carrier frequency, baud rate, and signal power for all existing OTSi signals on each OMS link.

Additionally, it is necessary for each ROADM node in the network to know the OTSi signals that are added to or dropped from an OMS link as well as the optical power of these OTSi signals to check whether the ROADM’s optical power constraints are met.

The optical impairment-aware topology YANG model below defines the OTSi properties needed for optical impairment-aware path computation including the spectrum occupied by each OTSi signal. The model also defines a pointer (leafref) from the OTSi to the transceiver module terminating the OTSi signal.
2.3.2. Optical Tributary Signal Group (OTSiG)

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

```
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 |
| K1 K2 K3 K4
```

Figure 3: MC Example containing all 4 OTSi signals of an OTSiG
2.3.3. Media Channel (MC)

The definition of the MC is currently being moved from ITU-T Recommendation G.872 [G.872] to the new draft Recommendation G.807 (still work in progress) [G.807]. Section 3.2.2 defines the term MC and section 7.1.2 provides a more detailed description with some examples. The definition of the MC is very generic (see ITU-T draft Recommendation G.807, Figure 7-1). In the YANG model below, the MC is used with the following semantics:

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

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

Figure 4: Figure Caption TBA

2.3.4. Media Channel Group (MCG)

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

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

\[
\text{MCG1} = \{\text{M1.1, M1.2}\}
\]

![Diagram of MCG and OTSi](image)

Figure 5: Figure Caption TBA

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

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

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

ILAs are placed at locations where the optical amplification of the WDM signal is required on the OMS link between two ROADM nodes. Geolocation information is already defined for TE nodes in [RFC8795] and is also beneficial for ILAs. Therefore, the same geolocation container has been added to the amplifier element on an OMS link containing altitude, latitude, and longitude as optional attributes.

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

2.5. Transponders

[Editor’s note: The relationship between the transponder and the OTSi in the YANG model described in Section 3 needs further clarification and refinement.]
A Transponder is the element that sends and receives the optical signal from a DWDM network. A transponder can comprise one or more transceiver modules. A transceiver represents a transmitter/receiver (Tx/Rx) pair as defined in ITU-T Recommendation G.698.2 [G.698.2]. In addition to the transceiver, which is terminating an OTSi signal, a transponder typically provides additional layer 1 functionality like for example aggregation (multiplexing) of client layer signals, which is outside the scope of this document addressing layer 0 aspects of transponders.

The termination of an OTSi signal by a transceiver is modeled as a function of the tunnel termination point (TTP) as defined in [RFC8795]. Due to the fact that optical transport services (TE tunnels) are typically bidirectional, a TTP is also modeled as a bidirectional entity like the LTP described above. Moreover, a TTP can terminate one or several OTSiG signals (tunnels) as described in [I-D.ietf-teas-te-topo-and-tunnel-modeling] and each OTSiG consists of one or multiple OTSi signals as described in Section 2.3.2. Therefore, a TTP may be associated with multiple transceiver modules.

A transponder is typically characterized by its data/symbol rate and the maximum distance the signal can travel. Other transponder properties are: carrier frequency for the optical channels, output power per channel, measured input power, modulation scheme, FEC, etc.

From a path computation perspective, the selection of the compatible configuration of the source and the destination transceivers is an important factor for optical signals to traverse through the DWDM network.

The YANG model defines three different approaches to describe the transceiver capabilities (called "modes") that are needed to determine optical signal compatibility:

* Standard Modes
* Organizational Modes
* Explicit Modes

2.5.1. Standard Modes

A standard mode is related to an optical specification developed by an SDO organization. Currently, the "Standard Modes" can only be referred to ITU-T G.698.2 [G.698.2] since G.698.2 is the only specification defining "Standard Modes" today. Nothing is precluding, however, to consider other specifications provided by any other SDO in the Standard Mode context as soon as such specifications...
An application code as defined in ITU-T G.698.2 [G.698.2] is representing a standard ITU-T G.698.2 optical interface specification towards the realization of transversely compatible DWDM systems. Two transceivers supporting the same application code and a line system matching the constraints, defined in ITU-T G.698.2, for that application code will interoperate. As the characteristics are encoded in the application code, the YANG model in this document only defines a string, which represents that application code.

2.5.2. Organizational Modes

Organizations like operator groups, industry fora, or equipment vendors can define their own optical interface specifications and make use of transceiver capabilities going beyond existing standards.

An organizational mode is identified by the organization-identifier attribute defining the scope and an operational-mode that is meaningful within the scope of the organization. Hence, the two attributes must always be considered together. It is the responsibility of the organization to assign operational modes and to ensure that operational modes are unique and unambiguous within the scope of the organization.

Two transceivers can be interconnected, if they have at least one (organization-identifier, operational-mode) pair in common and if the supported carrier frequency and power attributes have a matching range. This is a necessary condition for path computation in the context of organizational modes.

An operational mode is a transceiver preset (a configuration with well-defined parameter values) subsuming several transceiver properties defined by the optical interface specification - these properties are not provided for an operational mode and are therefore not defined in the YANG model. Examples of these properties are:

* FEC type
* Modulation scheme
* Encoding (mapping of bit patterns (code words) to symbols in the constellation diagram)
* Baud rate (symbol rate)
* Carrier bandwidth (typically measured in GHz)
The major reason for these transceiver presets is the fact that the attribute values typically cannot be configured independently and are therefore advertised as supported operational mode capabilities. It is the responsibility of the organization to assign operational modes and to ensure that operational modes are unique and not ambiguous within the scope of the organization.

In addition to the transceiver properties subsumed by the operational mode, optical power and carrier frequency related properties are modeled separately, i.e., outside of the operational mode. This modeling approach allows transponders using different transceiver variants (e.g., optical modules) with slightly different power and/or frequency range properties to interoperate without defining separate operational modes. Different optical modules (pluggables) from different suppliers typically have slightly different input and output power ranges or may have slightly different carrier frequency tuning ranges.

The received channel power and the received total power are two parameters that can be measured by the receiver and can be provided by the transceiver in order to allow a controller to determine the expected performance of the end-to-end service taking into account the optical impairments along the path.

An organization may define the operational modes to include the optical power and carrier frequency related properties following the application code approach as defined in ITU-T Recommendation G.698.2 [G.698.2]. In such a case, the explicit optical power and carrier frequency related optional attributes shall be omitted in order to avoid redundant information in the description of the transceiver capabilities. If these attributes are provided in addition to the operational modes including these attribute values implicitly, the parameter values provided explicitly replace the implicit values and take precedence. This shall, however, only be an done in exceptional cases and shall be avoided whenever possible. In case an implicitly given range is extended utilizing the explicit optional attributes, a path computation policy rule may be applied to select a value preferably from the range defined implicitly and to only select a value from the extended range if no path can be found for values in the implicitly defined range. Path computation policy is outside the scope of this topology YANG model.

In summary, the optical power and carrier frequency related attributes shall either be described implicitly by the operational mode following the definition provided by that organization or shall be described explicitly when the optical power and carrier frequency related properties are not included in the operational mode definition.
2.5.3. Explicit Modes

The explicit mode allows to encode, explicitly, any subset of parameters e.g., FEC type, Modulation type, etc, to enable a controller entity to check for interoperability by means outside of this draft. It shall be noted that using the explicit encoding does not guarantee interoperability between two transceivers even in case of identical parameter definitions. The explicit mode shall therefore be used with care, but it could be useful when no common Application Codes or Organizational Modes exist or the constraints of common Application Codes or Organizational Modes cannot be met by the line system.

2.5.4. Transponder Capabilities and Current Configuration

The YANG model described in Section 3 defines the optical transceiver properties. They are divided between:

a. Optical transceiver capabilities, describing how it can be configured

b. Current transceiver setting, indicating how it is currently configured

The transceiver capabilities are described by the set of modes the transceiver is supporting. Each mode MUST follow only one of the three mode options defined above (choice in the YANG model). The YANG model allows to describe the transceiver capabilities by mixing different modes. A transceiver may support some ITU-T application codes and in addition some organizational or explicit modes.

A transceiver mode description comprises the following properties:

* Supported transmitter tuning range with min/max nominal carrier frequency [f_{tx_min}, f_{tx_max}]

* Supported transmitter tunability grid, the distance between two adjacent carrier frequencies (in GHz)

* Supported transmitter power range [p_{tx-min}, p_{tx-max}]

* Supported receiver channel power range [p_{rx-min}, p_{rx-max}]

* Supported maximum total power, rx power for all channels fed into the receiver
These optical transceiver properties are explicitly defined in the model for explicit and organizational modes, while they are implicitly defined for the application codes (see ITU-T G698.2 [G.698.2]).

The set of optical impairment limits, e.g., min OSNR, max PMD, max CD, max PDL, Q-factor limit, are explicitly defined for the explicit modes while they are defined implicitly for the application codes and organizational modes.

It is possible that the set of parameter values defined for an explicit mode may also be represented in form of an organizational mode or one or more application codes. The "supported-mode" container may provide two different lists with pointers to application codes and organizational modes, respectively.

The current transponder configuration describes the properties of the OTSi transmitted or received by the transceiver attached to a specific transponder port.

Each OTSi has the following three pointer attributes modeled as leafrefs:

* Pointer to the transponder instance containing the transceiver terminating the OTSi
* Pointer to the transceiver instance terminating the OTSi
* Pointer to the currently configured transceiver mode

Additionally, the OTSi is described by the following frequency and optical power related attributes:

* current carrier-frequency
* currently transmitted channel power
* currently received channel power
* currently received total power
2.6. 3R Regenerators

Optical transponders are usually used to terminate a layer 0 tunnel (layer 0 service) in the WDM layer. If, however, no optical path can be found from the source transponder to the destination transponder that is optically feasible due to the optical impairments, one or more 3R regenerators are needed for regenerating the optical signal in intermediate nodes. The term "3R" regenerator means: reamplification, reshaping, retiming. As described in [G.807], Appendix IV, a 3R regenerator terminates the OTSi and generates a new OTSi. Depending on the 3R regenerator capabilities, it can provide functions such as carrier frequency translation (carrier-frequency), changes in the modulation scheme (modulation-type) and FEC (FEC-type) while passing through the digital signal except the FEC (the FEC is processed and errors are corrected).

The 3R regenerarion compound function is illustrated in section 10.1 of [G.798.1], and sections 10.3 and 10.4 provide examples of a ROADM architecture and a photonic cross-connect architecture including 3R regenerators. Based on the provided functionality, 3R regenerators are considered as topological layer 0 entities because they are needed for layer 0 path computation in case the optical impairments make it impossible to find an optically feasible end-to-end path from the source transponder to the destination transponder without 3R regeneration. When an end-to-end path includes one or more 3R regenerators, the corresponding layer 0 tunnel is subdivided into 2 or more segments between the source transponder and the destination transponder terminating the layer 0 tunnel.

3R regenerators are usually realized by a pair of optical transponders, which are described in Section 2.5 above. If a pair of optical transponders is used to perform a 3R regeneratorator 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.
* 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 an unidirectional mode.
Due to the fact that 3R regenerators are composed of an optical transponder pair, the capability whether an optical transponder can be used as a 3R regenerator is added to the transponder capabilities. Hence, no additional entity is required for describing 3R regenerators in the TE-topology YANG model. The optical transponder capabilities regarding the 3R regenerator function are described by the following two YANG model attributes:

* supported-termination-type
* supported-3r-mode

The supported-termination-type attribute describes whether the optical transponder can be used as tunnel terminating transponder only, as 3R regenerator only, or whether it can support both functions. The supported-3r-mode attribute describes the configuration of the transponder pair forming the 3R regenerator as described above.
More text to be added here!

2.7. WSS/Filter

WSS separates the incoming light input spectrally as well as spatially, then chooses the wavelength that is of interest by deflecting it from the original optical path and then couple it to another optical fibre port. WSS/Filter is internal to ROADM. So this document does not model the inside of ROADM.

2.8. Optical Fiber

There are various optical fiber types defined by ITU-T. There are several fiber-level parameters that need to be factored in, such as, fiber-type, length, loss coefficient, pmd, connectors (in/out).

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

2.9. ROADM Node Architectures

The ROADM node architectures in today’s dense wavelength division multiplexing (DWDM) networks can be categorized as follows:

* Integrated ROADM architecture with integrated optical transponders

* Integrated ROADM architecture with integrated optical transponders and single channel add/drop ports for remote optical transponders

* Disaggregated ROADM architecture where the ROADM is subdivided into degree, add/drop, and optical transponder subsystems handled as separate network elements

The TE topology YANG model augmentations including optical impairments for DWDM networks defined below intend to cover all the 3 categories of ROADM architectures listed above. In the case of a disaggregated ROADM architecture, it is assumed that optical domain controller already performs some form of abstraction and presents the TE-node representing the disaggregated ROADM in the same way as an integrated ROADM with integrated optical transponders if the optical transponder subsystems and the add/drop subsystems are collocated (short fiber links not imposing significant optical impairments).

The different ROADM architectures are briefly described and illustrated in the following subsections.
[Editor’s note: The modeling of remote optical transponders located for example in the client device with a single channel link between the OT and the add/drop port of the ROADM requires further investigations and will be addressed in a future revision of this document.]

2.9.1. Integrated ROADM Architecture with Integrated Optical Transponders

Figure 2 and Figure 8 below show the typical architecture of an integrated ROADM node, which contains the optical transponders as an integral part of the ROADM node. Such an integrated ROADM node provides DWDM interfaces as external interfaces for interconnecting the device with its neighboring ROADMs (see OTS link above). The number of these interfaces denote also the degree of the ROADM. A degree 3 ROADM for example has 3 DWDM links that interconnect the ROADM node with 3 neighboring ROADMs. Additionally, the ROADM provides client interfaces for interconnecting the ROADM with client devices such as IP routers or Ethernet switches. These client interfaces are the client interfaces of the integrated optical transponders.

Figure 8: ROADM Architecture with Integrated Transponders
2.9.2. Integrated ROADMs 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 ROADM but are separate devices that are interconnected with add/drop ports of the ROADM. If the optical transponders and the ROADM are collocated and if short single channel fiber links are used to interconnect the optical transponders with an add/drop port of the ROADM, the optical domain controller may present these optical transponders in the same way as integrated optical transponders. If, however, the optical impairments of the single channel fiber link between the optical transponder and the add/drop port of the ROADM cannot be neglected, it is necessary to represent the fiber link with its optical impairments in the topology model. This also implies that the optical transponders belong to a separate TE node.

[Editor’s note: this requires further study].

Figure 9: ROADM Architecture with Remote Transponders
2.9.3. Disaggregated ROADMs Subdivided into Degree, Add/Drop, and Optical Transponder Subsystems

Recently, some DWDM network operators started demanding ROADM subsystems from their vendors. An example is the OpenROADM project where multiple operators and vendors are developing related YANG models. The subsystems of a disaggregated ROADM are: single degree subsystems, add/drop subsystems and optical transponder subsystems. These subsystems 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 ROADM node. This disaggregated ROADM architecture is depicted in Figure 10 below.

As this document defines TE topology YANG model augmentations [RFC8795] for the TE topology YANG model provided at the north-bound interface of the optical domain controller, it is a valid assumption that the optical domain controller abstracts the subsystems of a disaggregated ROADM and presents the disaggregated ROADM in the same way as an integrated ROADM hiding all the interconnects that are not relevant from an external TE topology view.
2.9.4. Optical Impairments Imposed by ROADM 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)
A ROADM node contains a wavelength selective photonic switching function (WSS) that is capable of switching media channels (MCs) described in Section 2.3.4. These MCs can be established between two line ports of the ROADM or between a line port and an Add/Drop port of the ROADM. The Add/Drop ports of a ROADM are those ports to which optical transponders are connected. Typically, this is a single channel signal (single OTSi), but principally this could also be a group of OTSi signals. The optical impairments associated with these MCs are different and the paths of the MCs inside the ROADM node can be categorized as follows:

* Express path: MC path between two line ports of the ROADM (unidirectional)
* Add Path: MC path from an Add port to a line port of the ROADM
* Drop path: MC path from a line port to a Drop port of the ROADM

Due to the symmetrical architecture of the ROADM node, the optical impairments associated with the express path are typically the same between any two line ports of the ROADM whereas the optical impairments for the add and drop paths are different and therefore have to be modeled separately.

The optical impairments associated with each of the three types of ROADM-node-internal paths described above are modeled as optical impairment parameter sets. These parameter sets are modeled as an augmentation of the te-node-attributes defined in [RFC8795]. The te-node-attributes are augmented with a list of roadm-path-impairments for the three ROADM path types distinguished by the impairment-type. Each roadm-path-impairments list entry contains the set of optical impairment parameters for one of the three path types indicated by the impairment-type. For the optical feasibility calculation based on the optical impairments, it is necessary to know whether the optical power of the OTSi stays within a certain power window. This is reflected by some optical power related parameters such as loss parameters or power parameters, which are included in the optical impairment parameter sets (see tree view in Section 3).
[RFC8795] defines a connectivity matrix and a local link connectivity list for the TE node. The connectivity matrix describes the connectivity for the express paths between the different lines of the ROADM and the local link connectivity list describes the connectivity for the Add and Drop paths of the ROADM. These matrices are augmented with a new roadm-path-impairment matrix element, an add-path-impairment, and drop-path-impairment matrix element, respectively, which are defined as a pointer to the corresponding entry in the roadm-path-impairments list (leaf-ref).

[Editor’s note: this section is still work in progress]

3. YANG Model (Tree Structure)

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

module: ietf-optical-impairment-topology

augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
  ---rw optical-impairment-topology!

augment /nw:networks/nw:network:
  ---ro otsi-group* [otsi-group-id]
    ++-ro otsi-group-id     string
  ++-ro otsi* [otsi-carrier-id]
    ++-ro otsi-carrier-id   uint16
    ++-ro otsi-carrier-frequency? frequency-thz
    ++-ro tx-channel-power? dbm-t
    ++-ro rx-channel-power? dbm-t
    ++-ro rx-total-power? dbm-t

augment /nw:networks/nw:network/nw:node:
  ---ro transponder* [transponder-id]
    ++-ro transponder-id         uint32
    ++-ro termination-type-capabilities? enumeration
    ++-ro supported-3r-mode? enumeration
  ++-ro transceiver* [transceiver-id]
    ++-ro transceiver-id         uint32
    ++-ro supported-modes
      ++-ro supported-mode* [mode-id]
        ++-ro mode-id         string
        ++-ro (mode)
          +--:(G.698.2)
            ++-ro standard-mode? standard-mode
          +--:(organizational-mode)
            ++-ro organizational-mode
            ++-ro operational-mode?
              operational-mode
            ++-ro organization-identifier?
Internet-Draft    Opt. Impairment-Aware Topo YANG Model     October 2021

    | decimal64
    | +--ro min-carrier-spacing?
    | | frequency-ghz
    | +--ro available-fec-type?
    | | identityref
    | +--ro fec-code-rate?
    | | decimal64
    | +--ro fec-threshold?
    | | decimal64
    | +--ro min-central-frequency?
    | | frequency-thz
    | +--ro max-central-frequency?
    | | frequency-thz
    | +--ro central-frequency-step?
    | | frequency-ghz
    | +--ro tx-channel-power-min?
    | | dbm-t
    | +--ro tx-channel-power-max?
    | | dbm-t
    | +--ro rx-channel-power-min?
    | | dbm-t
    | +--ro rx-channel-power-max?
    | | dbm-t
    | +--ro rx-total-power-max?
    | | dbm-t
    | +--ro configured-mode?
    | | --> ../supported-modes/supported-mode/mode-id
    | +--ro outgoing-otsi
    | | +--ro otsi-group-ref?
    | | | --> ../../../../../otsi-group/otsi-group-id
    | | | +--ro otsi-ref? leafref
    | +--ro incoming-otsi
    | | +--ro otsi-group-ref?
    | | | --> ../../../../../otsi-group/otsi-group-id
    | | | +--ro otsi-ref? leafref
    | +--ro configured-termination-type? enumeration
    +--ro regen-group* [group-id]
    | +--ro group-id uint32
    | +--ro regen-metric? uint32
    +--ro transponder-ref* --> ../../transponder/transponder-id

augment /nw:networks/nw:network/nt:link/tet:te
         /tet:te-link-attributes:
         | +--ro OMS-attributes
         | | +--ro generalized-snr? 10-types-ext:snr
         | | +--ro equalization-mode identityref
         | | +--ro (power-param)?
         | | | +--:(channel-power)
         | | | | +--ro nominal-carrier-power? decimal64
Internet-Draft  Opt. Impairment-Aware Topo YANG Model  October 2021

+-ro nominal-power-spectral-density?  decimal64
+-ro media-channel-group* [i]
  +--ro i  int16
  +--ro media-channels* [flexi-n]
    +--ro flexi-n  10-types:flexi-n
    +--ro flexi-m?  10-types:flexi-m
    +--ro otsi-group-ref?
      |  -> /nw:networks/network/otsi-group/otsi-group-id
    +--ro otsi-ref?  leafref
    +--ro delta-power?  decimal64
  +--ro OMS-elements* [elt-index]
  +--ro elt-index  uint16
  +--ro oms-element-uid?  string
  +--ro reverse-element-ref
    +--ro link-ref?
      |  -> ../../../nt:link/link-id
    +--ro oms-element-ref*  leafref
  +--ro (element)
    +--ro geolocation
      +--ro altitude?  int64
      +--ro latitude?  geographic-coordinate-degree
      +--ro longitude?  geographic-coordinate-degree
    +--ro amplifier
      +--ro type-variety  string
      +--ro operational
        +--ro amplifier-element* []
          +--ro name?  string
          +--ro frequency-range
            +--ro lower-frequency  frequency-thz
            +--ro upper-frequency  frequency-thz
          +--ro actual-gain  decimal64
          +--ro tilt-target  decimal64
          +--ro out-voa  decimal64
          +--ro in-voa  decimal64
          +--ro (power-param)?
            +--ro nominal-carrier-power?  decimal64
            +--ro nominal-power-spectral-density?  decimal64

++-:(fiber)
  +--ro fiber
    +--ro type-variety    string
    +--ro length    decimal64
    +--ro loss-coef    decimal64
    +--ro total-loss    decimal64
    +--ro pmd?    decimal64
    +--ro conn-in?    decimal64
    +--ro conn-out?    decimal64
++-:(concentratedloss)
  +--ro concentratedloss
    +--ro loss    decimal64
augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-point:
  +--ro ttp-transceiver* [transponder-ref transceiver-ref]
    +--ro transponder-ref
      |    -> ../../../transponder/transponder-id
    +--ro transceiver-ref    leafref
augment /nw:networks/nw:network/nw:node/tet:te/tet:tunnel-termination-point:
  +--ro sliceable-transponder-list* [carrier-id]
    +--ro carrier-id    uint32
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes:
  +--ro roadm-path-impairments* [roadm-path-impairments-id]
    +--ro roadm-path-impairments-id    uint32
    +--ro (impairment-type)?
      +--:(roadm-express-path)
        +--ro roadm-express-path* []
          +--ro frequency-range
            |          +--ro lower-frequency    frequency-thz
            |          +--ro upper-frequency    frequency-thz
          +--ro roadm-pmd?    decimal64
          +--ro roadm-cd?    decimal64
          +--ro roadm-pdl?    decimal64
          +--ro roadm-inband-crosstalk?    decimal64
          +--ro roadm-maxloss?    decimal64
      +--:(roadm-add-path)
        +--ro roadm-add-path* []
          +--ro frequency-range
            |          +--ro lower-frequency    frequency-thz
            |          +--ro upper-frequency    frequency-thz
          +--ro roadm-pmd?    decimal64
          +--ro roadm-cd?    decimal64
          +--ro roadm-pdl?    decimal64
          +--ro roadm-inband-crosstalk?    decimal64
          +--ro roadm-maxloss?    decimal64
          +--ro roadm-pmax?    decimal64
++ro roadm-osnr? 10-types-ext:snr
++ro roadm-noise-figure? decimal64
++ro roadm-drop-path* []
    ++ro frequency-range
    | ++ro lower-frequency frequency-thz
    | ++ro upper-frequency frequency-thz
++ro roadm-pmd? decimal64
++ro roadm-cd? decimal64
++ro roadm-pdi? decimal64
++ro roadm-inband-crosstalk? decimal64
++ro roadm-maxloss? decimal64
++ro roadm-minloss? decimal64
++ro roadm-typloss? decimal64
++ro roadm-pmin? decimal64
++ro roadm-pmax? decimal64
++ro roadm-ptyp? decimal64
++ro roadm-osnr? 10-types-ext:snr
++ro roadm-noise-figure? decimal64
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:information-source-entry/tet:connectivity-matrices:
        ++ro roadm-path-impairments? leafref
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:information-source-entry/tet:connectivity-matrices/tet:connectivity-matrix:
        ++ro roadm-path-impairments? leafref
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices:
        ++ro roadm-path-impairments?
            -> ../../roadm-path-impairments/roadm-path-impairments-id
augment /nw:networks/nw:network/nw:node/tet:te
        ++ro roadm-path-impairments? leafref
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point/tet:local-link-connectivities:
        ++ro add-path-impairments? leafref
        ++ro drop-path-impairments? leafref
        ++ro llc-transceiver* [ttp-transponder-ref ttp-transceiver-ref]
            ++ro ttp-transponder-ref
                -> ../../llc-transceiver/transponder-ref
            ++ro ttp-transceiver-ref
                -> ../../llc-transceiver/transceiver-ref
            ++ro is-allowed? boolean
        ++ro add-path-impairments? leafref
        ++ro drop-path-impairments? leafref
augment /nw:networks/nw:network/nw:node/tet:te
4. Optical Impairment Topology YANG Model

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

<CODE BEGINS>
module ietf-optical-impairment-topology {
    yang-version 1.1;

    prefix "optical-imp-topo";

    import ietf-network {
        prefix "nw";
    }

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

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

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

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

    organization "IETF CCAMP Working Group";

    contact
        "Editor: Young Lee <youngelee.tx@gmail.com>
        Editor: Haomian Zheng <zhenghaomin@huawei.com>
        Editor: Nicola Sambo <nicosambo@gmail.com>

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

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

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

revision 2021-10-22 {
  description
    "Initial Version";
  reference
    "RFC XXXX: A Yang Data Model for Impairment-aware Optical Networks";
}

// grouping

grouping sliceable-transponder-attributes {
  description
    "Configuration of a sliceable transponder.";
}

Lee, et al. Expires 28 April 2022 [Page 34]
list sliceable-transponder-list {
  key "carrier-id";
  config false;
  description "List of carriers";
  leaf carrier-id {
    type uint32;
    config false;
    description "Identifier of the carrier";
  }
}

/*
 * Groupings
 */
grouping amplifier-params {
  description "describes parameters for an amplifier";
  container amplifier {
    description "amplifier type, operational parameters are described.";
    leaf type-variety {
      type string;
      mandatory true;
      description "String identifier of amplifier type referencing a specification in a separate equipment catalog";
    }
    container operational {
      description "amplifier operational parameters";
      list amplifier-element {
        description "The list of parallel amplifier elements within an amplifier used to amplify different frequency ranges.";
        leaf name {
          type string;
          description "The name of the amplifier element as specified in the vendor’s specification associated with the type-variety.";
        }
        container frequency-range {
          description "The frequency range amplified by the amplifier element.";
          uses l0-types-ext:frequency-range;
        }
        leaf actual-gain {
          "actual-gain";
        }
      }
    }
  }
}
leaf tilt-target {
    type decimal64 {
        fraction-digits 2;
    }
    units dB;
    mandatory true;
    description "..";
}

leaf out-voa {
    type decimal64 {
        fraction-digits 2;
    }
    units dB;
    mandatory true;
    description "..";
}

leaf in-voa {
    type decimal64 {
        fraction-digits 2;
    }
    units dB;
    mandatory true;
    description "..";
}

uses power-param;
} // list amplifier-element
} // container operational
} // container amplifier
} // grouping amplifier-params

grouping fiber-params {
    description
"String identifier of fiber type referencing a
    specification in a separate equipment catalog";
    container fiber {
        description "fiber characteristics";
        leaf type-variety {
            type string;
            mandatory true;
            description "fiber type";
        }
        leaf length {

type decimal64 {
  fraction-digits 2;
}
units km;
mandatory true;
description "length of fiber";
}
leaf loss-coef {
  type decimal64 {
    fraction-digits 2;
  }
  units dB/km;
  mandatory true;
description "loss coefficient of the fiber";
}
leaf total-loss {
  type decimal64 {
    fraction-digits 2;
  }
  units dB;
  mandatory true;
description "includes all losses: fiber loss and conn-in and conn-out losses";
}
leaf pmd{
  type decimal64 {
    fraction-digits 2;
  }
  units sqrt(ps);
description "pmd of the fiber";
}
leaf conn-in{
  type decimal64 {
    fraction-digits 2;
  }
  units dB;
description "connector-in";
}
leaf conn-out{
  type decimal64 {
    fraction-digits 2;
  }
  units dB;
description "connector-out";
}
grouping roadm-express-path {
    description "The optical impairments of a ROADM express path."
    leaf roadm-pmd {
        type decimal64 {
            fraction-digits 8;
            range "0..max";
        }
        units "ps/(km)^0.5";
        description "Polarization Mode Dispersion";
    }
    leaf roadm-cd {
        type decimal64 {
            fraction-digits 5;
        }
        units "ps/nm";
        description "Chromatic Dispersion";
    }
    leaf roadm-pdl {
        type decimal64 {
            fraction-digits 2;
        }
        units dB;
        description "Polarization dependent loss";
    }
    leaf roadm-inband-crosstalk {
        type decimal64 {
            fraction-digits 2;
        }
        units dB;
        description "In-band crosstalk, or coherent crosstalk, can occur in components that can have multiple same wavelength inputs with the inputs either routed to different output ports, or all but 1 blocked";
    }
    leaf roadm-maxloss {
        type decimal64 {
            fraction-digits 2;
        }
        units dB;
        description "This is the maximum expected add path loss from the ROADM ingress to the ROADM egress assuming no additional add path loss is added";
    }
}
grouping roadm-add-path {
    description "The optical impairments of a ROADM add path.";
    leaf roadm-pmd {
        type decimal64 {
            fraction-digits 8;
            range "0..max";
        }
        units "ps";
        description "Polarization Mode Dispersion";
    }
    leaf roadm-cd {
        type decimal64 {
            fraction-digits 5;
        }
        units "ps/nm";
        description "Cromatic Dispersion";
    }
    leaf roadm-pdl {
        type decimal64 {
            fraction-digits 2;
        }
        units dB ;
        description "Polarization dependent loss";
    }
    leaf roadm-inband-crosstalk {
        type decimal64 {
            fraction-digits 2;
        }
        units dB ;
        description "In-band crosstalk, or coherent crosstalk, can occur in components that can have multiple same wavelength inputs, with the inputs either routed to different output ports, or all but 1 blocked. In the case of add path it is the total of the add block + egress WSS crosstalk contributions."
    }
    leaf roadm-maxloss {
        type decimal64 {
            fraction-digits 2;
        }
        units dB ;
        description "This is the maximum expected add path loss from the add/drop port input to the ROADM egress,"
assuming no additional add path loss is added. This is used to establish the minimum required transponder output power required to hit the ROADM egress target power levels and preventing to hit the WSS attenuation limits. If the add path contains an internal amplifier this loss value should be based on worst case expected amplifier gain due to ripple or gain uncertainty;

leaf roadm-pmax {
    type decimal64 {
        fraction-digits 2;
    }
    units dBm;
    description "This is the maximum (per carrier) power level permitted at the add block input ports, that can be handled by the ROADM node. This may reflect either add amplifier power constraints or WSS adjustment limits. Higher power transponders would need to have their launch power reduced to this value or lower";
}

leaf roadm-osnr {
    type 10-types-ext:snr;
    description "Optical Signal-to-Noise Ratio (OSNR). If the add path contains the ability to adjust the carrier power levels into an add path amplifier (if present) to a target value, this reflects the OSNR contribution of the add amplifier assuming this target value is obtained. The worst case OSNR based on the input power and NF calculation method, and this value, should be used (if both are defined).";
}

leaf roadm-noise-figure {
    type decimal64 {
        fraction-digits 5;
    }
    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.

```yang
grouping roadm-drop-path {
    description "roadm drop block path optical impairments";
    leaf roadm-pmd {
        type decimal64 {
            fraction-digits 8;
            range "0..max";
        }
        units "ps/(km)^0.5";
        description "Polarization Mode Dispersion";
    }
    leaf roadm-cd {
        type decimal64 {
            fraction-digits 5;
        }
        units "ps/nm";
        description "Chromatic Dispersion";
    }
    leaf roadm-pdl {
        type decimal64 {
            fraction-digits 2;
        }
        units dB;
        description "Polarization dependent loss";
    }
    leaf roadm-inband-crosstalk {
        type decimal64 {
            fraction-digits 2;
        }
        units dB;
        description "In-band crosstalk, or coherent crosstalk, can occur in components that can have multiple same wavelength inputs,with the inputs either routed to different output ports,or all but 1 blocked. In the case of drop path it is the total of the ingress to drop e.g. WSS and drop block crosstalk contributions.";
    }
    leaf roadm-maxloss {
```
type decimal64 {
    fraction-digits 2;
}
units dB;
description
"The net loss from the ROADM input, to the output of the drop block.
If ROADM ingress to drop path includes an amplifier, the amplifier gain reduces the net loss.
This is before any additional drop path attenuation that may be required due to drop amplifier power constraints.
The max value correspond to worst case expected loss, including amplifier gain ripple or uncertainty.
It is the maximum output power of the drop amplifier."
}
leaf roadm-minloss {
    type decimal64 {
        fraction-digits 2;
    }
    units dB;
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 decimal64 {
        fraction-digits 2;
    }
    units dB;
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 decimal64 {
    fraction-digits 2;
  }
  units dBm;
  description
  "If the drop path has additional loss that is added, for example, to hit target power levels into a drop path amplifier, or simply, to reduce the power of a strong carrier (due to ripple, for example), then the use of the ROADM input power levels and the above drop losses is not appropriate. This parameter corresponds to the min per carrier power levels expected at the output of the drop block. A detail example of the comparison using these parameters is detailed in section xxx of the document yyy.";
}
leaf roadm-pmax {
  type decimal64 {
    fraction-digits 2;
  }
  units dBm;
  description
  "If the drop path has additional loss that is added, for example, to hit target power levels into a drop path amplifier, or simply, to reduce the power of a strong carrier (due to ripple, for example), then the use of the ROADM input power levels and the above drop losses is not appropriate. This parameter corresponds to the best case per carrier power levels expected at the output of the drop block. A detail example of the comparison using these parameters is detailed in section xxx of the document yyy";
}
leaf roadm-ptyp {
  type decimal64 {
    fraction-digits 2;
  }
  units dBm;
}
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-ext:snr;
  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 should be used";
}

leaf roadm-noise-figure {
  type decimal64 {
    fraction-digits 5;
  }
  units "dB";
  description
  "Drop path Noise Figure. If the drop path contains an amplifier, this is the noise figure of that amplifier, inferred to the ROADM ingress port. This permits to determine amplifier OSNR contribution without having to specify the ROADM nodes losses to that amplifier. This applies for the case of no additional drop path loss, before the amplifier, in order to reduce the power of the carriers to a target value";
}
grouping concentratedloss-params{
    description "concentrated loss";
    container concentratedloss{
        description "concentrated loss";
        leaf loss {
            type decimal64 {
                fraction-digits 2;
            }
            units dB ;
            mandatory true;
            description ".";
        }
    }
}

grouping power-param{
    description "optical power or PSD after the ROADM or after the out-voa";
    choice power-param {
        description "select the mode: channel power or power spectral density";
        case channel-power {
            leaf nominal-carrier-power{
                type decimal64 {
                    fraction-digits 2;
                }
                units dBm ;
                description "Reference channel power. Same grouping is used for the OMS power after the ROADM (input of the OMS) or after the out-voa of each amplifier. ";
            }
        }
        case power-spectral-density{
            leaf nominal-power-spectral-density{
                type decimal64 {
                    fraction-digits 16;
                }
                units W/Hz ;
                description
"Reference power spectral density after
the ROADM or after the out-voa.
Typical value : 3.9 E-14, resolution 0.1nW/MHz";

grouping oms-general-optical-params {
    description "OMS link optical parameters";
    leaf generalized-snr {
        type 10-types-ext:snr;
        description "generalized snr";
    }
    leaf equalization-mode{
        type identityref {
            base 10-types-ext:type-power-mode;
        }
        mandatory true;
        description "equalization mode";
    }
    uses power-param;
}

grouping otsi-group {
    description "OTSiG definition, representing client
digital information stream supported by 1 or more OTSi";

    list otsi {
        key "otsi-carrier-id";
        config false;
        description "list of OTSi contained in 1 OTSiG.
The list could also be of only 1 element";
        leaf otsi-carrier-id {
            type uint16;
            description "OTSi carrier-id";
        }
        uses 10-types-ext:common-transceiver-configured-param;
    } // OTSi list
} // OTSiG grouping

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

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

    // this grouping add both n.m values
    uses l0-types:flexi-grid-frequency-slot;

    leaf otsi-group-ref {
        type leafref {
            path "/nw:networks/nw:network/otsi-group/otsi-group-id";
        }
        description
            "Reference to the otsi-group list to get otsi-group
             identifier of the
             OTSiG carried by this media channel
             that reports the transient stat";
    }

    leaf otsi-ref {
        type leafref {
            path "/nw:networks/nw:network/
                + "otsi-group[otsi-group-id=current()]"
                + "/../otsi-group-ref/"
                + "otsi/otsi-carrier-id" ;
        }
        description
            "Reference to the otsi list supporting
             the related OTSiG to get otsi identifier";
    }

    leaf delta-power{
        type decimal64 {
            fraction-digits 2;
        }
        units dB ;
        description
            "Deviation from the reference carrier power defined for
             the OMS.";
    }

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

description "OMS description";
list OMS-elements {
    key "elt-index";
    description
        "defines the spans and the amplifier blocks of
        the amplified lines";
    leaf elt-index {
        type uint16;
        description
            "ordered list of Index of OMS element
            (whether it’s a Fiber, an EDFA or a
            Concentratedloss)";
    }
    leaf oms-element-uid {
        type string;
        description
            "unique id of the element if it exists";
    }
    container reverse-element-ref {
        description
            "It contains references to the elements which are
            associated with this element in the reverse
direction.";
        leaf link-ref {
            type leafref {
                path "../../../../../nt:link/nt:link-id";
            }
            description
                "The reference to the OMS link which the OMS elements
                belongs to.";
        }
        leaf-list oms-element-ref {
            type leafref {
                path "../../../../../nt:link[nt:link-id=" + "current()/../link-ref]/tet:te/
                + "tet:te-link-attributes/OMS-attributes/
                + "OMS-elements/elt-index";
            }
            description
                "The references to the OMS elements.";
        }
    }
}
choice element {
    mandatory true;
    description "OMS element type";
    case amplifier {
        uses tet:geolocation-container;
        uses amplifier-params;
grouping otsi-ref {
  description
  "References to an OTSi.
  This grouping is intended to be reused within the
  transceiver’s list only.";
  leaf otsi-group-ref {
    type leafref {
      path "../../../../../otsi-group/otsi-group-id";
    }
    description
    "The OTSi generated by the transceiver’s transmitter.";
  }
  leaf otsi-ref {
    type leafref {
      path "../../../../../otsi-group[otsi-group-id=" +
        "current()//otsi-group-ref]/otsi/otsi-carrier-id";
    }
    description
    "The OTSi generated by the transceiver’s transmitter.";
  }
}

/* Data nodes */

  description "optical-impairment topology augmented";
  container optical-impairment-topology {
    presence "indicates an impairment-aware topology of
    optical networks";
    description
    "Container to identify impairment-aware topology type";
  }
}

augment "/nw:networks/nw:network" {
  when "nw:network-types/tet:te-topology" + 
    "/optical-imp-topo:optical-impairment-topology" {
description
"This augment is only valid for Optical Impairment.";
}
} description
"Network augmentation for optical impairments data.";
list otsi-group {
  key "otsi-group-id";
  config false;
  description
"the list of possible OTSiG representing client digital
stream";
  leaf otsi-group-id {
    type string;
    description
"A network-wide unique identifier of otsi-group element.
It could be structured e.g., as an URI or as a UUID.";
  }
  uses otsi-group;
} // list of OTSiG

augment "/nw:networks/nw:network/nw:node" {
  when "./nw:network-types/tet:te-topology" +
    "/optical-imp-topo:optical-impairment-topology" {
    description
"This augment is only valid for Optical Impairment.";
  }
} description
"Node augmentation for optical impairments data.";
list transponder {
  key "transponder-id";
  config false;
  description "list of transponder";
  leaf transponder-id {
    type uint32;
    description "transponder identifier";
  }
  leaf termination-type-capabilities {
    type enumeration {
      enum tunnel-only {
        description
"The transponder can only be used in an Optical
Tunnel termination configuration.";
      }
      enum 3r-only {
        description
"The transponder can only be used in a 3R
configuration.";
      }
    }
  }
}
enum 3r-or-tunnel {
  description
  "The transponder can be configure to be used either in an Optical Tunnel termination configuration or in a 3R configuration.";
}

description
"Describes whether the transponder can be used in an Optical Tunnel termination configuration or in a 3R configuration (or both)."

leaf supported-3r-mode {
  when '(.../termination-type-capabilities = "3r-only") or (.../termination-type-capabilities = "3r-or-tunnel")'
    description
    "Applies only when the transponder supports 3R configuration.";
}

type enumeration {
  enum unidir {
    description
    "Unidirectional 3R configuration.";
  }
  enum bidir {
    description
    "Bidirectional 3R configuration.";
  }
}

description
"Describes the supported 3R configuration type.";

list transceiver {
  key "transceiver-id";
  config false;
  description "list of transceiver related to a transponder";
  leaf transceiver-id {
    type uint32;
    description "transceiver identifier";
  }
}

uses 10-types-ext:transceiver-capabilities;
leaf configured-mode {
  type leafref {
    path "../supported-modes/supported-mode/mode-id";
  }
  description
"Reference to the configured mode for transceiver compatibility approach."
}

container outgoing-otsi {
    description
        "The OTSi generated by the transceiver’s transmitter.";
    uses otsi-ref;
}

container incoming-otsi {
    description
        "The OTSi generated by the transceiver’s transmitter.";
    uses otsi-ref;
}

leaf configured-termination-type {
    type enumeration {
        enum tunnel-termination {
            description
                "The transceiver is currently used in an Optical Tunnel termination configuration.";
        }
        enum 3r-regeneration {
            description
                "The transceiver is currently used in a 3R configuration.";
        }
    }
    description
        "Describes whether the current configuration of the transceiver is used in an Optical Tunnel termination configuration or in a 3R configuration.

        If empty, it means that the transceiver is not used.";
}

} // end of list of transceiver
} // end list of transponder

list regen-group {
    key "group-id";
    config false;
    description
        "List of 3R groups. Any 3R group represent a group of transponder in which an a
an electrical connectivity is either in place or could be dynamically provided, to associated transponders used for 3R regeneration.";
    leaf group-id {
        type uint32;
        description
            "Group identifier used an index to access elements in the
leaf regen-metric {
  type uint32;
  description
    "The cost permits choice among different group of
    transponders during path computation";
}
leaf-list transponder-ref {
  type leafref {
    path "../../transponder/transponder-id";
  }
  description
    "The list of transponder belonging to this 3R group.";
}
}
} // end 3R-group

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

augment "/nw:networks/nw:network/nw:node/tet:te"
  + "/tet:tunnel-termination-point" {
  when "/nw:networks/nw:network/nw:network-types"
    + "/tet:te-topology/
      + "optical-imp-topo:optical-impairment-topology" {
    description
      "This augment is only valid for Impairment with
      non-sliceable transponder model";
  }
  description
    "Tunnel termination point augmentation for non-sliceable
    transponder model.";
list ttp-transceiver {
    key "transponder-ref transceiver-ref";
    config false;
    description
        "The list of the transceivers used by the TTP.";
    leaf transponder-ref {
        type leafref {
            path "../../../../transponder/transponder-id";
        }
        description
            "The reference to the transponder hosting the transceiver
             of the TTP.";
    }
    leaf transceiver-ref {
        type leafref {
            path "deref(../transponder-ref)/../transceiver" + 
                "/transceiver-id";
        }
        description
            "The reference to the transceiver of the TTP.";
    }
} // list of transceivers
} // end of augment

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

augment "/nw:networks/nw:network/nw:node/tet:te"
    + "/tet:te-node-attributes" {
    when "/nw:networks/nw:network/nw:network-types"
        +="/tet:te-topology/"
        +"/optical-imp-topo:optical-impairment-topology" {
        description
            "This augment is only valid for Optical Impairment
             topology";
    }
list roadm-path-impairments {
  key "roadm-path-impairments-id";
  config false;
  description
    "The set of optical impairments related to a ROADM path.";

  leaf roadm-path-impairments-id {
    type uint32;
    description "index of the ROADM path-impairment list";
  }

  choice impairment-type {
    description "type path impairment";
    case roadm-express-path {
      list roadm-express-path {
        description
          "The list of optical impairments on a ROADM express path for different frequency ranges.

          Two elements in the list must not have the same range or overlapping ranges.";
        container frequency-range {
          description
            "The frequency range for which these optical impairments apply.";
          uses l0-types-ext:frequency-range;
        }
      }
      uses roadm-express-path;
    }
    case roadm-add-path {
      list roadm-add-path {
        description
          "The list of optical impairments on a ROADM add path for different frequency ranges.

          Two elements in the list must not have the same range or overlapping ranges.";
        container frequency-range {
          description
            "The frequency range for which these optical impairments apply.";
          uses l0-types-ext:frequency-range;
        }
      }
    }
  }
}
uses roadm-add-path;
}

} // case roadm-drop-path
}

} // list roadm-drop-path

description
"The list of optical impairments on a ROADM add path for different frequency ranges.

Two elements in the list must not have the same range or overlapping ranges."

container frequency-range {

description
"The frequency range for which these optical impairments apply."

uses 10-types-ext:frequency-range;
}

uses roadm-drop-path;
}

} // list path impairments

} // augmentation for optical-impairment ROADM

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices"{
when "/nw:networks/nw:network/nw:network-types"
  + "/tet:te-topology/
    + "optical-imp-topo:optical-impairment-topology" {

description
"This augment is only valid for Optical Impairment topology."
}

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

leaf roadm-path-impairments {

type leafref {
  path "../../../tet:te-node-attributes/"
   + "roadm-path-impairments/roadm-path-impairments-id";
}

description "pointer to the list set of ROADM optical impairments";
}

} // augmentation connectivity-matrices information-source
augment "/nw:networks/nw:network/nw:node/tet:te/"
   + "tet:information-source-entry/tet:connectivity-matrices/"
   + "tet:connectivity-matrix" {
when "/nw:networks/nw:network/nw:network-types"
   + "/tet:te-topology/
   + "optical-imp-topo:optical-impairment-topology" {
description
   "This augment is only valid for Optical Impairment
topology ";
}
description
   "Augment TE node connectivity matrix entry information
source.";
leaf roadm-path-impairments {
   type leafref {
      path "././././tet:te-node-attributes/
      + "roadm-path-impairments/roadm-path-impairments-id";
   }
description "pointer to the list set of ROADM optical
impairments";
} // augmentation connectivity-matrix information-source

augment "/nw:networks/nw:network/nw:node/tet:te/"
   + "tet:te-node-attributes/tet:connectivity-matrices" {
when "/nw:networks/nw:network/nw:network-types"
   + "/tet:te-topology/
   + "optical-imp-topo:optical-impairment-topology" {
description
   "This augment is only valid for Optical Impairment
topology ";
}
description
   "Augment default TE node connectivity matrix.";
leaf roadm-path-impairments {
   type leafref {
      path "./././roadm-path-impairments/
      + "roadm-path-impairments-id";
   }
cfg false; /*the identifier in the list */
   "roadm-path-impairments" of ROADM optical impairment*/
   /*is read-only as the rest of attributes*/
description "pointer to the list set of ROADM optical
impairments";
}
} // augmentation connectivity-matrices

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

description
  "Augment TE node connectivity matrix entry.";

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

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

description
  "Augment default TTP LLC.";

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

list llc-transceiver {
    key "ttp-transponder-ref ttp-transceiver-ref";
    config false;
    description "The list of transceivers having a LLC different from the default LLC.";
    leaf ttp-transponder-ref {
        type leafref {
            path "../../tte-transceiver/transponder-ref";
        }
        description "The reference to the transponder hosting the transceiver of this LLCL entry.";
    }
    leaf ttp-transceiver-ref {
        type leafref {
            path "../../tte-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 {
        type leafref {
            path "../../tet:te-node-attributes/" + "roadm-path-impairments/roadm-path-impairments-id" ;
        }
        config false;
        description "pointer to the list set of ROADM optical impairments";
    }
    leaf drop-path-impairments {

type leafref {
    path "../../../tet:te-node-attributes/"
        + "roadm-path-impairments/roadm-path-impairments-id" ;
} }  // augmentation local-link-connectivities

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

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

description
    "Augment TTP LLC entry.";
leaf add-path-impairments {
    type leafref {
        path "../../../tet:te-node-attributes/"
            + "roadm-path-impairments/roadm-path-impairments-id" ;
    } }  // augmentation local-link-connectivity
leaf drop-path-impairments {
    type leafref {
        path "../../../tet:te-node-attributes/"
            + "roadm-path-impairments/roadm-path-impairments-id" ;
    } }  // augmentation local-link-connectivity

5. Security Considerations

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

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

6. IANA Considerations

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

```
--------------------------------------------------------------------
Registrant Contact: The IESG.
XML: N/A, the requested URI is an XML namespace.
--------------------------------------------------------------------
```

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

```
--------------------------------------------------------------------
name:      ietf-optical-impairment-topology
prefix:    optical-imp-topo
reference: RFC XXXX (TDB)
--------------------------------------------------------------------
```

7. Acknowledgments

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

8. References

8.1. Normative References


8.2. Informative References


[I-D.ietf-ccamp-layer0-types-ext]

[I-D.ietf-ccamp-dwdm-if-param-yang]

[I-D.ietf-teas-te-topo-and-tunnel-modeling]


Appendix A. Contributors

Aihua Guo Huawei Technologies
Email: aguo@futurewei.com
Jonas Martensson RISE
Email: jonas.martensson@ri.se

Appendix B. Additional Authors

Haomian Zheng Huawei Technologies
Email: zhenghaomian@huawei.com
Italo Busi Huawei Technologies
Email: Italo.Bus@huawei.com
Nicola Sambo Scuola Superiore Sant’Anna
Email: nicosambo@gmail.com
Giovanni Martinelli Cisco
Email: giomarti@cisco.com
Jean-Luc Auge Orange
Email: jeanjl.auge@orange.com
Julien Meuric Orange
Email: julien.meuric@orange.com
Sergio Belotti Nokia
Email: Sergio.belotti@nokia.com
Enrico Grisenti Nokia
Email: Enrico.Grisenti@nokia.com
Gert Grammel Juniper
Email: ggrammel@juniper.net
Authors’ Addresses

Young Lee
Samsung Electronics
Email: younglee.tx@gmail.com

Esther Le Rouzic
Orange
Email: esther.lerouzic@orange.com

Victor Lopez
Nokia
Email: Victor.Lopez@nokia.com

G. Galimberti
Cisco
Email: ggalimbe@cisco.com

Dieter Beller
Nokia
Email: Dieter.Beller@nokia.com
Abstract

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

Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at https://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."
1. Introduction

A transport network is a server-layer network designed to provide connectivity services for a client-layer network to carry the client traffic transparently across the server-layer network resources. A transport network can be constructed of equipments utilizing any of a number of different transport technologies such as the Optical Transport Networks (OTN) or packet transport such as provided by the MPLS-Transport Profile (MPLS-TP).
This document defines a data model of an OTN network topology, using YANG [RFC7950]. The model can be used by an application exposing to a transport controller. Furthermore, it can be used by an application for the following purposes (but not limited to):

- 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 of a network topology with the characteristic 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 an Optical Transport Networks (OTN) electrical layer, as the scope specified by [RFC7062]. Furthermore, it is not a stand-alone model, but augmenting 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].

2. Terminology and Notations

A simplified graphical representation of the data model is used in this document. The meaning of the symbols in the YANG data tree presented later in this document is defined in [RFC8340]. They are provided below for reference.

- Brackets "[" and "]" enclose list keys.
- Abbreviations before data node names: "rw" means configuration (read-write) and "ro" state data (read-only).
- Symbols after data node names: "?" means an optional node, "!" means a presence container, and "*" denotes a list and leaf-list.
- Parentheses enclose choice and case nodes, and case nodes are also marked with a colon (":").
- Ellipsis ("...") stands for contents of subtrees that are not shown.
Some of the key terms used in this document are listed as follow.

- TS: Tributary Slot.
- TSG: Tributary Slot Granularity.
- TPN: Tributary Port Number.

3. YANG Data Model for OTN Topology

3.1. OTN Topology Data Model Overview

This document aims to describe the data model for OTN topology. As a classic Traffic-engineering (TE) technology, OTN provide TDM switching in transport network [ITU-T g709]. 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 network. Common types, identities and groupings defined in [I-D.ietf-ccamp-layer1-types] are reused in this document. [RFC8345] describes a network topology model and provide 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 with 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.
The YANG module ietf-otn-topology defined in this document conforms to the Network Management Datastore Architecture (NMDA) defined in [RFC8342].

3.2. Attributes Augmentation

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

Following the guidelines in [RFC8795], a otn-topology network-type is specified as the indicator of OTN in the topology as follow.

   augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
       ++--rw otn-topology!

Two OTN technology-specific parameters are specified to augment the generic TE link attributes.

   augment /nw:networks/nw:network/nt:link/tet:te
       /tet:te-link-attributes:
       ++--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 allows reporting also the access links which are capable of supporting 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 as well as OTN.

A client-svc container is specified to augment the generic TE link termination point to describe if the point is capable of carrying client signal and what kind of signal can be carried as follow.
The client-facing is an indicator on whether the point is needed to carry client signal. A list of support-client-signal is used to provide the capabilities of client signal specified in [I-D.ietf-ccamp-layer1-types].

3.3. 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].

3.4. 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].

3.5. YANG Tree for OTN topology

module: ietf-otn-topology

augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
  +++rw otn-topology!
augment /nw:networks/nw:network/nt:link/tet:te
    /tet:te-link-attributes:
        +++rw tsg? identityref
        +++rw distance? uint32
augment /nw:networks/nw:network/nw:node/nt:termination-point
    /tet:te:
        +++rw client-svc!
        +++rw client-facing? boolean
        +++rw supported-client-signal* identityref
    /tet:interface-switching-capability/tet:max-lsp-bandwidth
/tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--rw otn
      +--rw odu-type? identityref
      +--rw (oduflex-type)?
        +--:(generic)
          |  +--rw nominal-bit-rate uint64
          +--:(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 uint64
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:node-attributes/tet:connectivity-matrices
  /tet:path-constraints/tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--rw odulist* [odu-type]
      +--rw odu-type identityref
      +--rw number? uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:node-attributes/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:path-constraints
  /tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--rw odulist* [odu-type]
      +--rw odu-type identityref
      +--rw number? uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:path-constraints/tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--ro odulist* [odu-type]
      +--ro odu-type identityref
      +--ro number? uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:path-constraints
  /tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--ro odulist* [odu-type]
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point/tet:client-layer-adaptation
    /tet:switching-capability/tet:te-bandwidth
    /tet:technology:
      +--:(otn)
        +--rw odulist* [odu-type]
          +--rw odu-type identityref
          +--rw number? uint16
        augment /nw:networks/nw:network/nw:node/tet:te
      /tet:tunnel-termination-point
        /tet:local-link-connectivities/tet:path-constraints
        /tet:te-bandwidth/tet:technology:
          +--:(otn)
            +--rw odulist* [odu-type]
              +--rw odu-type identityref
              +--rw number? uint16
            augment /nw:networks/nw:network/nw:node/tet:te
          /tet:tunnel-termination-point
            /tet:local-link-connectivities
            /tet:local-link-connectivity/tet:path-constraints
            /tet:te-bandwidth/tet:technology:
              +--:(otn)
                +--rw odulist* [odu-type]
                  +--rw odu-type identityref
                  +--rw number? uint16
            augment /nw:networks/nw:network/nt:link/tet:te
            /tet:te-link-attributes
              /tet:interface-switching-capability/tet:max-lsp-bandwidth
              /tet:te-bandwidth/tet:technology:
                +--:(otn)
                  +--rw otn
                    +--rw odu-type? identityref
                    +--rw (oduflex-type)?
                      +--:(generic)
                        | +--rw nominal-bit-rate uint64
                      +--:(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 uint64
            augment /nw:networks/nw:network/nt:link/tet:te
            /tet:te-link-attributes/tet:max-link-bandwidth
/tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--rw odulist* [odu-type]
      +--rw odu-type identityref
      +--rw number? uint16
  augment /nw:networks/nw:network/nt:link/tet:te
    /tet:te-link-attributes/tet:max-resv-link-bandwidth
    /tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--rw odulist* [odu-type]
      +--rw odu-type identityref
      +--rw number? uint16
  augment /nw:networks/nw:network/nt:link/tet:te
    /tet:te-link-attributes/tet:unreserved-bandwidth
    /tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--rw odulist* [odu-type]
      +--rw odu-type identityref
      +--rw number? uint16
  augment /nw:networks/nw:network/nt:link/tet:te
    /tet:information-source-entry/tet:max-lsp-bandwidth
    /tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--ro otn
    +--ro odu-type? identityref
    +--ro (oduflex-type)?
      +--:(generic)
        |  +--ro nominal-bit-rate uint64
      +--:(cbr)
        |  +--ro client-type identityref
        +--:(gfp-n-k)
          |  +--ro gfp-n uint8
          |  +--ro gfp-k? gfp-k
          +--:(flexe-client)
            |  +--ro flexe-client flexe-client-rate
          +--:(flexe-aware)
            |  +--ro flexe-aware-n uint16
            +--:(packet)
              +--ro opuflex-payload-rate uint64
  augment /nw:networks/nw:network/nt:link/tet:te
    /tet:information-source-entry/tet:max-link-bandwidth
    /tet:te-bandwidth/tet:technology:
/tet:information-source-entry/tet:max-resv-link-bandwidth
/tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--ro odulist* [odu-type]
      +--ro odu-type identityref
      +--ro number? uint16
  augment /nw:networks/nw:network/nt:link/tet:te
      /tet:information-source-entry/tet:unreserved-bandwidth
      /tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--ro odulist* [odu-type]
      +--ro odu-type identityref
      +--ro number? uint16
      /tet:te-link-attributes
      /tet:interface-switching-capability/tet:max-lsp-bandwidth
      /tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--rw otn
      +--rw odu-type? identityref
      +--rw (oduflex-type)?
        +--:(generic)
          |  +--rw nominal-bit-rate uint64
        +--:(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 uint64
      /tet:te-link-attributes/tet:max-link-bandwidth
      /tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--rw odulist* [odu-type]
      +--rw odu-type identityref
      +--rw number? uint16
      /tet:te-link-attributes/tet:max-resv-link-bandwidth
      /tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--rw odulist* [odu-type]
      +--rw odu-type identityref
      +--rw number? uint16
  /tet:te-link-attributes/tet:unreserved-bandwidth
  /tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--rw odulist* [odu-type]
      +--rw odu-type    identityref
      +--rw number?     uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:te-node-attributes/tet:connectivity-matrices
  /tet:label-restrictions/tet:label-restriction:
  +--rw range-type?      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 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 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 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 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:
/tet:label-restriction:
  +++-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 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 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 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 range-type?        otn-label-range-type
  +++-ro tsg?               identityref
  +++-ro odu-type-list*     identityref
  +++-ro priority?          uint8
          /tet:te-link-attributes/tet:label-restrictions
          /tet:label-restriction:
  +++-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 (range-type)?
  +--:(trib-port)
    |  +--rw otn-tpn?  otn-tpn
  +--:(trib-slot)
    +--rw otn-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 (range-type)?
  +--:(trib-port)
    |  +--rw otn-tpn?  otn-tpn
  +--:(trib-slot)
    +--rw otn-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 (range-type)?
  +--:(trib-port)
    |  +--rw otn-tpn?  otn-tpn
  +--:(trib-slot)
    +--rw otn-ts?  otn-ts
augment /nw:networks/nw:network/nw:node/tet:te
/tet:te-node-attributes/tet:connectivity-matrices
/tet:label/tet:label-hop/tet:te-label/tet:technology:
+--:(otn)
  +--rw otn-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:label-hop/tet:te-label/tet:technology:
+--:(otn)
  +--rw otn-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-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)
   +=--ro otn-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:path-properties/tet:path-route-objects
         /tet:te-label/tet:technology:
++--:(otn)
   +=--rw otn-tscp?  otn-tscp
   +=--rw tscp?     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:from/tet:label-restrictions
         /tet:label-restriction/tet:label-start/tet:te-label
         /tet:te-label/tet:technology:
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 (range-type)?
      +--:(trib-port)
       |   +--rw otn-tpn?   otn-tpn
       +--:(trib-slot)
            +--rw otn-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 (range-type)?
      +--:(trib-port)
       |   +--rw otn-tpn?   otn-tpn
       +--:(trib-slot)
            +--rw otn-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 (range-type)?
      +--:(trib-port)
       |   +--rw otn-tpn?   otn-tpn
       +--:(trib-slot)
            +--rw otn-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 (range-type)?
      +--:(trib-port)
       |   +--rw otn-tpn?   otn-tpn
       +--:(trib-slot)
            +--rw otn-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-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-element/tet:type/tet:label/tet:label-hop
    /tet:te-label/tet:technology:
    +--:(otn)
    ++-rw otn-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: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-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: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-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-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 (range-type)?
    +--:(trib-port)
 | ++-- ro otn-tpn? otn-tpn
++--: (trib-slot)
   ++-- ro otn-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 (range-type)?
   ++--: (trib-port)
    | ++-- ro otn-tpn? otn-tpn
   ++-- ro otn-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-tpn? otn-tpn
   ++-- ro tsg? identityref
   ++-- ts-list? string
augment /nw:networks/nw:network/nw:node/tet:te
 /tet:information-source-entry/tet:connectivity-matrices
 /tet:label/tet:label-hop/tet:te-label/tet:technology:
++--: (otn)
   ++-- ro otn-tpn? otn-tpn
   ++-- ro tsg? identityref
   ++-- ts-list? string
augment /nw:networks/nw:network/nw:node/tet:te
 /tet:information-source-entry/tet:connectivity-matrices
 /tet:label/tet:label-hop/tet:te-label/tet:technology:
++--: (otn)
   ++-- ro otn-tpn? otn-tpn
   ++-- ro tsg? identityref
   ++-- ts-list? string
augment /nw:networks/nw:network/nw:node/tet:te
 /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-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-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:te-label/tet:technology:
+-+:(otn)
  +--ro otn-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 (range-type)?
    +-+:(trib-port)
      |  +--ro otn-tpn? otn-tpn
    +-+:(trib-slot)
      +--ro otn-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 (range-type)?
    +-+:(trib-port)
      |  +--ro otn-tpn? otn-tpn
    +-+:(trib-slot)
      +--ro otn-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)
  ---: (range-type)?
  +--: (trib-port)
    |  ---: ro otn-tpn? otn-tpn
    +--: (trib-slot)
      ---: ro otn-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)
  ---: (range-type)?
  +--: (trib-port)
    |  ---: ro otn-tpn? otn-tpn
    +--: (trib-slot)
      ---: ro otn-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)
  ---: (range-type)?
  +--: (trib-port)
    |  ---: ro otn-tpn? otn-tpn
    +--: (trib-slot)
      ---: ro otn-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)
  ---: (range-type)?
  +--: (trib-port)
    |  ---: ro otn-tpn? otn-tpn
    +--: (trib-slot)
      ---: ro otn-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-tpn? otn-tpn
  ---: ro tsg? identityref
  ---: ro ts-list? string

augment /nw:networks/nw:network/nw:node/tet:te
Internet-Draft  OTN Topology YANG Model  July 2021

/tet:information-source-entry/tet:connectivity-matrices
/tet:path-element/tet:type/tet:label/tet:label-hop
/tet:te-label/tet:technology:
++--:(otn)
  +--ro otn-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: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-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: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-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-hop/tet:te-label/tet:technology:
++--:(otn)
  +--ro otn-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 (range-type)?
    ++--:(trib-port)
      |  +--rw otn-tpn?  otn-tpn

+--+(trib-slot)
  +--rw otn-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:technology:
+--:(otn)
  +-rw (range-type)?
  +--:(trib-port)
    |  +-rw otn-tpn? otn-tpn
    +--:(trib-slot)
  +--rw otn-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 (range-type)?
  +--:(trib-port)
    |  +-rw otn-tpn? otn-tpn
    +--:(trib-slot)
  +--rw otn-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-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-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-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-object-include-object/tet:te-label/tet:technology:
++---(otn)
|   +++-rw otn-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-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 (range-type)?
|   |   +++-:trib-port
|   |       |   +++-rw otn-tpn? otn-tpn
|   |       |   +++-:trib-slot
|   |       |       +++-rw otn-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 (range-type)?
|   |   +++-:trib-port
|   |       |   +++-rw otn-tpn? otn-tpn
|   |       |   +++-:trib-slot
|   |       |       +++-rw otn-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 (range-type)?
    |   +--:(trib-port)
    |       |   +--rw otn-tpn? otn-tpn
    |   +--:(trib-slot)
    |       +--rw otn-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-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-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-tpn? otn-tpn
    ++-rw tsg? identityref
    +--rw ts-list? string
/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-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-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-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-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 (range-type)?
      +--:(trib-port)
        |   +--rw otn-tpn?  otn-tpn
      +--:(trib-slot)
        +--rw otn-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 (range-type)?
   ++--:(trib-port)
      | ++--rw otn-tpn?  otn-tpn
   ++--:(trib-slot)
      ++--rw otn-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 (range-type)?
      ++--:(trib-port)
         | ++--rw otn-tpn?  otn-tpn
      ++--:(trib-slot)
         ++--rw otn-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 (range-type)?
      ++--:(trib-port)
         | ++--ro otn-tpn?  otn-tpn
      ++--:(trib-slot)
         ++--ro otn-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 (range-type)?
      ++--:(trib-port)
         | ++--ro otn-tpn?  otn-tpn
      ++--:(trib-slot)
         ++--ro otn-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 (range-type)?
      ++--:(trib-port)
         | ++--ro otn-tpn?  otn-tpn
      ++--:(trib-slot)
         ++--ro otn-ts?  otn-ts
   /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)
4. The YANG Code

<CODE BEGINS> file "ietf-otn-topology@2021-07-08.yang"
module ietf-otn-topology {

yang-version 1.1;
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 "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: 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) 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
This version of this YANG module is part of RFC XXXX; see
the RFC itself for full legal notices.";

revision 2021-07-08 {
    description
        "Initial Revision";
    reference
        "RFC XXXX: A YANG Data Model for Optical Transport Network
        Topology";
        // RFC Ed.: replace XXXX with actual RFC number, update date
        // information and remove this note
}

/*
 * 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 newtork";
    }

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 network.";
            }
        description "Augment link configuration";
}
leaf tsg {
  type identityref {
    base l1-types:tributary-slot-granularity;
  }
  description "Tributary slot granularity.";
  reference
  "G.709/Y.1331, February 2016: Interfaces for the
  Optical Transport Network (OTN)";
}
leaf distance {
  type uint32;
  description "distance in the unit of kilometers";
}
}

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 network";
  }
  description "OTN TP attributes config in ODU topology.";
}
container client-svc {
  presence "client-facing LTP.";
  description
  "OTN LTP Service attributes.";
  leaf client-facing {
    type boolean;
    default 'false';
    description
      "Indicates whether this LTP is a client-facing LTP.";
  }
  leaf-list supported-client-signal {
    type identityref {
      base 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-path-bandwidth;
 }
 }

 + "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;
 }
 }

 + "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 "/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 "/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 "/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 TE bandwidth path constraints of the
      tunnel termination point information source";
    case otn {
      uses l1-types:otn-link-bandwidth;
    }
  }
}

OTN topology type."
}

description
"Augment client TE bandwidth of the tunnel termination point
(TTP)"

case otn {
  uses l1-types:otn-link-bandwidth;
}

  + "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;
}

  + "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 "/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.";
}
}

+ "tet:te-link-attributes/
+ "tet:max-link-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.";
}
}

+ "tet:te-link-attributes/
+ "tet:max-resv-link-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.";
}
}

+ "tet:te-link-attributes/"
+ "tet:unreserved-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 unreserved TE bandwidth for the TE Link";
  case otn {
    uses l1-types:otn-link-bandwidth;
  }
}

  + "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-path-bandwidth;
  }
}

  + "tet:information-source-entry/"
  + "tet:max-link-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 TE bandwidth for the TE link information source";
case otn {
  uses l1-types:otn-link-bandwidth;
}
}
augment "//nw:networks/nw:network/nt:link/tet:te/
+ "tet:information-source-entry/
+ "tet:max-resv-link-bandwidth/
+ "tet:te-bandwidth/tet:technology" {
when "../../../nw:network-types/tet:te-topology/
+ "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";
case otn {
  uses l1-types:otn-link-bandwidth;
}
}
augment "//nw:networks/nw:network/nt:link/tet:te/
+ "tet:information-source-entry/
+ "tet:unreserved-bandwidth/
+ "tet:te-bandwidth/tet:technology" {
when "../../../nw:network-types/tet:te-topology/
+ "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";
case otn {
  uses l1-types:otn-link-bandwidth;
}
}
augment "//nw:networks/tet:te/tet:templates/
+ "tet:link-template/tet:te-link-attributes/
+ "tet:interface-switching-capability/
+ "tet:max-lsp-bandwidth/"
+ "tet:te-bandwidth/tet:technology" { 
  description
  "Augment maximum LSP TE bandwidth of the TE link template";
  case otn {
    uses l1-types:otn-path-bandwidth;
  }
}

augment "/nw:networks/tet:te/tet:templates/"
  + "tet:link-template/tet:te-link-attributes/"
  + "tet:max-link-bandwidth/"
  + "tet:te-bandwidth/tet:technology" { 
  description
  "Augment maximum TE bandwidth the TE link template";
  case otn {
    uses l1-types:otn-link-bandwidth;
  }
}

augment "/nw:networks/tet:te/tet:templates/"
  + "tet:link-template/tet:te-link-attributes/"
  + "tet:max-resv-link-bandwidth/"
  + "tet:te-bandwidth/tet:technology" { 
  description
  "Augment maximum reservable TE bandwidth for the TE link template.";
  case otn {
    uses l1-types:otn-link-bandwidth;
  }
}

augment "/nw:networks/tet:te/tet:templates/"
  + "tet:link-template/tet:te-link-attributes/"
  + "tet:unreserved-bandwidth/"
  + "tet:te-bandwidth/tet:technology" { 
  description
  "Augment unreserved TE bandwidth the TE link template";
  case otn {
    uses l1-types:otn-link-bandwidth;
  }
}

/ *
  * Augment TE label range information
  */

augment "/nw:networks/nw:network/nw:node/tet:te/"
description
  "Augmentation parameters apply only for networks with OTN topology type.";
}
description
  "Augment TE label range information for the TE node connectivity matrices.";
  uses l1-types:otn-label-range-info;
}
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 l1-types:otn-label-range-info;
}
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 l1-types:otn-label-range-info;
}
+ "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 l1-types:otn-label-range-info;
}

  + "tet:information-source-entry/tet:connectivity-matrices/
  + "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 l1-types:otn-label-range-info;
}

  + "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 l1-types:otn-label-range-info;
}

  + "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 l1-types:otn-label-range-info;
}

+ "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 l1-types:otn-label-range-info;
}

+ "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 l1-types:otn-label-range-info;
}

+ "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 ll-types:otn-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 ll-types:otn-label-range-info;
}

/*
* Augment TE label
*/

+ "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 ll-types:otn-label-start-end;
}
}

+ "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;
}
}

  + "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;
}
}

  + "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;
}

    + "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 "%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/%/
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 li1-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 li1-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;
  }
}

+ "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;
  }
}
"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 11-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 11-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;
}

  + "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: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" {
    description "Augmentation parameters apply only for networks with OTN topology type.";
    case otn {
        uses l1-types:otn-label-step;
    }
  }
}

  + "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-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" {
    description "Augmentation parameters apply only for networks with OTN topology type.";
    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;
}
}
+ "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 hop for the explicit route objects included  
  by the path computation of the connectivity matrix entry.";
  case otn {  
    uses l1-types:otn-label-hop;
  }
}
  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: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;
  }
}
"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;
  }
}

  + "tet:information-source-entry/tet:connectivity-matrices/
  + "tet:optimizations/tet:algorithm/tet:metric/
  + "tet:optimization-metric/
  + "tet:explicit-route-include-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 included
by the path computation of the TE node connectivity matrices
information source.";
  case otn {
    uses l1-types:otn-label-hop;
  }
}

  + "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.";
}
OTN topology type.

"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;
}
  + "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.";
  case otn {
    uses l1-types:otn-label-step;
  }
}

  + "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.";
  case otn {
    uses l1-types:otn-label-start-end;
  }
}

  + "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;
  }
}

+ "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;
  }
}

+ "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;
}
}

  + "tet:information-source-entry/tet:connectivity-matrices/
  + "tet:connection-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;
}
}

  + "tet:information-source-entry/tet:connectivity-matrices/
  + "tet:connection-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;
}
}

 + "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 "./../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../../.../..../ Page 56

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:networks/nw:network/nw:node/tet:te/"
 + "tet:tunnel-termination-point/"
 + "tet:local-link-connectivities/"
 + "tet:label-restrictions/tet:label-restriction/"
 + "tet:technology" {  
when "/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.";
  case otn {  
    uses ll-types:otn-label-start-end;
  }
}
}
}

Percent: 74/74
when "./././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././. ridic

+ "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;
}
}

+ "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 "././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././.}.ridic

+ "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;
}
}

+ "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 "./././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././././.}.ridic

+ "nw:network-types/tet:te-topology/"
+ "otnt:otn-topology" {
  description
  "Augmentation parameters apply only for networks with
  OTN topology type.";
}
description
"Augmentation parameters apply only for networks with
OTN topology type.";
}
"Augment TE label hop for the underlay backup path of the TTP Local Link Connectivities."

case otn {
  uses l1-types:otn-label-hop;
}

+ "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;
  }
}

+ "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;
  }
}

  + '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;
  }
}

  + '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 li-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 li-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;
}
}

+ "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;
}
}

+ "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 ll-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 ll-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 ll-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" {
5. IANA Considerations

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

```
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
prefix:     otnt
reference:  RFC XXXX
```

6. Security Considerations

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

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

There are a number of data nodes defined in this YANG module that are writable/creatable/deletable (i.e., config true, which is the default). These data nodes may be considered sensitive or vulnerable in some network environments. Write operations (e.g., edit-config) to these data nodes without proper protection can have a negative effect on network operations. Considerations in Section 8 of [RFC8795] are also applicable to their subtrees in the module defined in this document.

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. Considerations in Section 8 of [RFC8795] are also applicable to their subtrees in the module defined in this document.

7. Acknowledgements

We would like to thank Igor Bryskin, Zhe Liu, Zheyu Fan and Daniele Ceccarelli for their comments and discussions.

8. Contributors

Aihua Guo
Futurewei
Email: aihuaguo.ietf@gmail.com

Anurag Sharma
Google
Email: ansha@google.com

Yunbin Xu
CAICT
Email: xuyunbin@caict.ac.cn

Lei Wang
China Mobile
Email: wangleiyj@chinamobile.com

9. References

9.1. Normative References

[I-D.ietf-ccamp-layer1-types]

[I-D.ietf-ccamp-otn-tunnel-model]

[ITU-Tg709]


9.2. Informative References

[I-D.ietf-ccamp-transport-nbi-app-statement]

[I-D.ietf-teas-actn-yang]

[RFC7062]

[RFC8340]

Authors’ Addresses

Haomian Zheng
Huawei Technologies
H1, Huawei Industrial Base, Songshan Lake
Dongguan, Guangdong 523808
China

Email: zhenghaomian@huawei.com

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

Email: Italo.Busi@huawei.com

Xufeng Liu
Volta Networks

Email: xufeng.liu.ietf@gmail.com

Sergio Belotti
Nokia

Email: sergio.belotti@nokia.com

Oscar Gonzalez de Dios
Telefonica

Email: oscar.gonzalezdedios@telefonica.com
OTN Tunnel YANG Model
draft-ietf-ccamp-otn-tunnel-model-14

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

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at https://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on January 13, 2022.

Copyright Notice

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

This document is subject to BCP 78 and the IETF Trust’s Legal Provisions Relating to IETF Documents (https://trustee.ietf.org/license-info) in effect on the date of
1. Introduction

OTN transport networks, specified in [ITU-T-g709], 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].

2. Terminology and Notations

A simplified graphical representation of the data model is used in this document. The meaning of the symbols in the YANG data tree presented later in this draft is defined in [RFC8340]. They are provided below for reference.

- Brackets "[" and "]" enclose list keys.
- Abbreviations before data node names: "rw" means configuration (read-write) and "ro" state data (read-only).
3. OTN Tunnel Model Description

3.1. 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     |
+----------------+
              ^
              |
          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].

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

3.2. 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].

3.3. 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].

4. 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
    |   |   +--rw odu-type? identityref
    |   |   +--rw (oduflex-type)?
    |       +--:(generic)
    |       |   |   +--rw nominal-bit-rate uint64
    |       |   |   +--:(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   uint64
augment /te:te/te:tunnels/te:tunnel/te:te-bandwidth/te:technology:
  +--:(otn)
    +--rw otn
      +--rw odu-type?    identityref
    +--rw (oduflex-type)?
      +--:(generic)
        |  +--rw nominal-bit-rate   uint64
      +--:(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   uint64
augment /te:te/te:tunnels/te:tunnel/te:primary-paths
/te:primary-path/te:te-bandwidth/te:technology:
  +--:(otn)
    +--rw otn
      +--rw odu-type?    identityref
    +--rw (oduflex-type)?
      +--:(generic)
        |  +--rw nominal-bit-rate   uint64
      +--:(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   uint64
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
      +--ro odu-type?    identityref
    +--ro (oduflex-type)?
      +--:(generic)
| ++--ro nominal-bit-rate        uint64
| ++--ro client-type             identityref
++--:(gfp-n-k)
  | ++--ro gfp-n                   uint8
  | ++--ro gfp-k?                  gfp-k
++--:(flexe-client)
  | ++--ro flexe-client            flexe-client-rate
++--:(flexe-aware)
  | ++--ro flexe-aware-n           uint16
++--:(packet)
  | ++--ro opuflex-payload-rate    uint64
augment /te:te/te:tunnels/te:tunnel/te:primary-paths
   /te:primary-path/te:primary-reverse-path/te:te-bandwidth
   /te:technology:
++--:(otn)
  ++--rw otn
    ++--rw odu-type?                     identityref
    ++--rw (oduflex-type)?
    ++--:(generic)
      | ++--rw nominal-bit-rate        uint64
      ++--:(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    uint64
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
    ++--ro odu-type?                     identityref
    ++--ro (oduflex-type)?
    ++--:(generic)
      | ++--ro nominal-bit-rate        uint64
      ++--:(cbr)
      | ++--ro client-type             identityref
      ++--:(gfp-n-k)
      | ++--ro gfp-n                   uint8
      | ++--ro gfp-k?                  gfp-k
      ++--:(flexe-client)
---ro flexe-client flexe-client-rate
---ro flexe-aware uint16
---ro opuflex-payload-rate uint64

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:
---ro otn

---rw otn
---rw (oduflex-type)?
---ro (oduflex-type)?
---ro otu-type? identityref
---ro otu-type? identityref

---rw otn
---rw (oduflex-type)?
---ro (oduflex-type)?
---ro otu-type? identityref
---ro otu-type? identityref

---rw otn
---rw (oduflex-type)?
---ro (oduflex-type)?
---ro otu-type? identityref
---ro otu-type? identityref

---rw otn
---rw (oduflex-type)?
---ro (oduflex-type)?
---ro otu-type? identityref
---ro otu-type? identityref


```
+--rw otn
   +--rw odu-type?  identityref
   +--rw (oduflex-type)?
      +--:(generic)
         |  +--rw nominal-bit-rate  uint64
      +--:(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  uint64

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
   +--ro odu-type?  identityref
   +--ro (oduflex-type)?
      +--:(generic)
         |  +--ro nominal-bit-rate  uint64
      +--:(cbr)
         |  +--ro client-type  identityref
      +--:(gfp-n-k)
         |  +--ro gfp-n  uint8
         |  +--ro gfp-k?  gfp-k
      +--:(flexe-client)
         |  +--ro flexe-client  flexe-client-rate
      +--:(flexe-aware)
         |  +--ro flexe-aware-n  uint16
      +--:(packet)
         +--ro opuflex-payload-rate  uint64

augment /te:te/te:globals/te:named-path-constraints
         /te:named-path-constraint/te:path-in-segment
         /te:label-restrictions/te:label-restriction:
      +--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 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 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 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 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 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 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 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 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 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-always
   /te:route-object-exclude-always/te:type/te:label
   /te:label-hop/te:te-label/te:technology:
   +--:(otn)
      +--rw otn-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-always
   /te:route-object-exclude-always/te:type/te:label
   /te:label-hop/te:te-label/te:technology:
   +--:(otn)
      +--rw otn-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 (range-type)?
         +--:(trib-port)
            +--rw otn-tpn?  otn-tpn
         +--:(trib-slot)
            +--rw otn-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:label/te:technology:
   +--:(otn)
      +--rw (range-type)?
         +--:(trib-port)
Internet-Draft            OTN Tunnel YANG Model                July 2021

|  +--rw otn-tpn?   otn-tpn
|  +-- (trib-slot)
  +--rw otn-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 (range-type)?
|  +-- (trib-port)
| |  +--rw otn-tpn?   otn-tpn
| |  +-- (trib-slot)
| |  +--rw otn-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 (range-type)?
|  +-- (trib-port)
| |  +--rw otn-tpn?   otn-tpn
| |  +-- (trib-slot)
| |  +--rw otn-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 (range-type)?
|  +-- (trib-port)
| |  +--rw otn-tpn?   otn-tpn
| |  +-- (trib-slot)
| |  +--rw otn-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 (range-type)?
|  +-- (trib-port)
| |  +--rw otn-tpn?   otn-tpn
| |  +-- (trib-slot)
| |  +--rw otn-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-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:route-object-include-object/te:type/te:label
         /te:route-object-include-object/te:type/te:label
+++:(otn)
  +++rw otn-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-always
         /te:route-object-exclude-always/te:type/te:label
         /te:route-object-exclude-always/te:type/te:label
+++:(otn)
  +++rw otn-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:technolog:
+++:(otn)
  +++rw (range-type)?
     +++:(trib-port)
      |   +++rw otn-tpn?   otn-tpn
     +++:(trib-slot)
      |   +++rw otn-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 (range-type)?
     +++:(trib-port)
      |   +++rw otn-tpn?   otn-tpn
     +++:(trib-slot)
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 (range-type)?
        |  +--rw otn-tpn?   otn-tpn
        +--:(trib-slot)
        +--rw otn-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 (range-type)?
        |  +--rw otn-tpn?   otn-tpn
        +--:(trib-slot)
        +--rw otn-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 (range-type)?
        |  +--rw otn-tpn?   otn-tpn
        +--:(trib-slot)
        +--rw otn-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 (range-type)?
        |  +--rw otn-tpn?   otn-tpn
        +--:(trib-slot)
        +--rw otn-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-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-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-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-always
   /te:route-object-exclude-objects-always/te:type/te:label
   /te:label-hop/te:te-label/te:technology:
--- (otn)
   --- rw otn-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-always
   /te:route-object-include-exclude/te:type/te:label
   /te:label-hop/te:te-label/te:technology:
--- (otn)
   --- rw otn-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 (range-type)?
     --- (trib-port)
        --- rw otn-tpn? otn-tpn
---: (trib-slot)
  ---: (otn-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)
  ---: (range-type)?
  ---: (trib-port)
    |  ---: (otn-tpn)  otn-tpn
  ---: (trib-slot)
    ---: (otn-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:te-label
  /te:technology:
---: (otn)
  ---: (range-type)?
  ---: (trib-port)
    |  ---: (otn-tpn)  otn-tpn
  ---: (trib-slot)
    ---: (otn-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)
  ---: (range-type)?
  ---: (trib-port)
    |  ---: (otn-tpn)  otn-tpn
  ---: (trib-slot)
    ---: (otn-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:
/te:label-restriction/te:label-step/te:technology:
  +--:(otn)
    +--rw (range-type)?
      +--:(trib-port)
      |   +--rw otn-tpn? otn-tpn
      +--:(trib-slot)
          +--rw otn-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-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-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-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-exclude-objects
              /te:route-object-exclude-object/te:type/te:label
              /te:label-hop/te:te-label/te:technology:
    +--:(otn)
      +--rw otn-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-always
              /te:route-object-exclude-objects/te:type/te:label
              /te:label-hop/te:te-label/te:technology:
    +--:(otn)
      +--rw otn-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-always
              /te:route-object-exclude-exclude/te:type/te:label
              /te:label-hop/te:te-label/te:technology:
/te:label-hop/te:te-label/te:technology:
  +--:(otn)
    +--rw otn-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 (range-type)?
      +--:(trib-port)
        |  +--rw otn-tpn?  otn-tpn
      +--:(trib-slot)
        +--rw otn-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 (range-type)?
      +--:(trib-port)
        |  +--rw otn-tpn?  otn-tpn
      +--:(trib-slot)
        +--rw otn-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:te-label/te:technology:
  +--:(otn)
    +--rw (range-type)?
      +--:(trib-port)
        |  +--rw otn-tpn?  otn-tpn
      +--:(trib-slot)
        +--rw otn-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 (range-type)?
      +--:(trib-port)
        |  +--rw otn-tpn?  otn-tpn
      +--:(trib-slot)
        +--rw otn-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 (range-type)?
      +--:(trib-port)
        |  +--rw otn-tpn?  otn-tpn
        +--:(trib-slot)
          +--rw otn-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 (range-type)?
      +--:(trib-port)
        |  +--rw otn-tpn?  otn-tpn
        +--:(trib-slot)
          +--rw otn-ts?  otn-ts
    augment /te:te/te:tunnels/te:tunnel/te:secondary-paths
      /te:computed-paths-properties
      /te:path-properties
      /te:path-route-objects/te:path-route-object/te:type
      /te:label-hop/te:te-label/te:technology:
  +--ro otn-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-tpn?  otn-tpn
    +--rw tsg?     identityref
    +--rw ts-list? string
    augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
      /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-tpn?  otn-tpn
    +--rw tsg?     identityref
    +--rw ts-list? string
    augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
      /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-tpn?  otn-tpn
      +--rw tsg?     identityref
      +--rw ts-list? string
      augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
        /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-tpn?  otn-tpn
          +--rw tsg?     identityref
          +--rw ts-list? string
          augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
            /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-tpn?  otn-tpn
    +--rw tsg?     identityref
    +--rw ts-list? string
    augment /te:te/te:tunnels/te:tunnel/te:secondary-reverse-paths
      /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:
/te:explicit-route-objects-always
/te:route-object-exclude-always/te:type/te:label
/te:label-hop/te:te-label/te:technology:
  +--:(otn)
    +--rw otn-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-always
    /te:route-object-include-exclude/te:type/te:label
    /te:label-hop/te:te-label/te:technology:

  +--:(otn)
    +--rw otn-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 (range-type)?
    |  +--:(trib-port)
    |      +--rw otn-tpn? otn-tpn
    |  +--:(trib-slot)
    |      +--rw otn-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 (range-type)?
    |  +--:(trib-port)
    |      +--rw otn-tpn? otn-tpn
    |  +--:(trib-slot)
    |      +--rw otn-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 (range-type)?
    |  +--:(trib-port)
    |      +--rw otn-tpn? otn-tpn
    |  +--:(trib-slot)
    |      +--rw otn-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 (range-type)?
  +--:(trib-port)
   |  +--rw otn-tpn?  otn-tpn
  +--:(trib-slot)
   +--rw otn-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 (range-type)?
  +--:(trib-port)
   |  +--rw otn-tpn?  otn-tpn
  +--:(trib-slot)
   +--rw otn-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:te-label/te:technology:
+--:(otn)
  +--rw (range-type)?
  +--:(trib-port)
   |  +--rw otn-tpn?  otn-tpn
  +--:(trib-slot)
   +--rw otn-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-tpn?  otn-tpn
  +--ro tsg?  identityref
  +--ro ts-list?  string
augment /te:te/te:lsps/te:lsp/te:lsp-record-route-information
  /te:lsp-record-route-information/te:type/te:label
  /te:label-hop/te:te-label/te:technology:
+--:(otn)
  +--ro otn-tpn?  otn-tpn
  +--ro tsg?  identityref
  +--ro ts-list?  string
5. OTN Tunnel YANG Code

<CODE BEGINS>file "ietf-otn-tunnel@2021-06-25.yang"
module ietf-otn-tunnel {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-otn-tunnel";
  prefix "otn-tunnel";

  import ietf-te {
    prefix "te";
    revision-date "2021-02-20";
    reference
      "I-D.ietf-teas-yang-te-19: A YANG Data Model for Traffic
       Engineering Tunnels and Interfaces. ";
  }

  import ietf-layer1-types {
    prefix "l1-types";
    reference
      "I-D.ietf-ccamp-layer1-types:
       A YANG Data Model for Layer 1 Types. ";
  }

  organization
    "IETF CCAMP Working Group";
  contact
    "WG Web:  <http://tools.ietf.org/wg/ccamp/>"
    "WG List:  <mailto:ccamp@ietf.org>
    Editor:   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.lopezalvarez@telefonica.com>
    Editor:   Yunbin Xu
              <mailto:xuyunbin@ritt.cn>";

  description
    "This module defines a model for OTN Tunnel 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 "2021-06-25" {
  description "Updated revision to align with the latest TE tunnel model.";
  reference "RFC XXXX: OTN Tunnel YANG Model";
  // 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 11-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 11-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 11-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 11-types:otn-path-bandwidth;
    }
  }
uses li1-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 li1-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 li1-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 primary path.";
 uses li1-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 primary path.";
 uses li1-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 primary 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 primary 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-always/
  + "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-always/
  + "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;
}
}
description
"Augment TE label range end for the ingress segment
of the named path constraint.";
case otn {
  uses l1-types:otn-label-start-end;
}
}
description
"Augment TE label range step for the ingress segment
of the named path constraint.";
case otn {
  uses l1-types:otn-label-step;
}
}
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-always/
  + 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-always/
  + 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:label/te:technology" {
  description
  "Augment TE label range start for the ingress segment
  of the primary 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 primary path.";
    case otn {
        uses ll-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 primary path.";
    case otn {
        uses ll-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 primary path.";
    case otn {
        uses ll-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 primary path.";
    case otn {
        uses ll-types:otn-label-start-end;
    }
}
The code block contains augment statements that augment specific YANG modules and define additional configurations. Here are the augmented sections:

1. Augment TE label range end for the egress segment of the primary path:
   ```yts
   description "Augment TE label range end for the egress segment of the primary path.";
   case otn {
      uses l1-types:otn-label-step;
   }
   }
   ```

2. Augment TE label hop for the route object of the computed primary path:
   ```yts
   description "Augment TE label hop for the route object of the computed primary path.";
   case otn {
      uses l1-types:otn-label-hop;
   }
   }
   ```

3. Augment TE label hop for the optimization of the explicit route objects excluded by the path computation of the primary reverse path:
   ```yts
   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;
   }
   }
   ```

4. Augment TE label hop for the optimization of the explicit route objects included by the path computation of the primary reverse path:
   ```yts
   ```
+ "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;
}
}

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;
}
}

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;
}
}

+ "te:te-label/te:technology" {
  description
  "Augment TE label range start for the ingress segment of the primary 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 step for the ingress segment of the primary 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-in-segment/te:label-restrictions/
  + "te:label-restriction/te:label-step/te:technology" {
  description
  "Augment TE label range step for the egress segment of the primary 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 primary 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 primary 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 primary 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 li-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-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 included by the path computation of the
  secondary path.";
  case otn {
    uses li-types:otn-label-hop;
  }
}

augment "/te:te/te:tunnels/te:tunnel/
  + "te:secondary-paths/te: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
  "Augment TE label hop for the explicit route objects always
  excluded by the path computation of the secondary path.";
  case otn {
    uses li-types:otn-label-hop;
  }
}

augment "/te:te/te:tunnels/te:tunnel/
  + "te:secondary-paths/te:secondary-path/"
  + "te:explicit-route-objects-always/"
  + "te:route-object-exclude-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;
}
}
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-always/"
    + "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-always/"
    + "te:route-object-exclude-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."

```yin
  case otn {
    uses l1-types:otn-label-hop;
  }
}
```

```yin
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;
  }
}
```

```yin
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;
  }
}
```

```yin
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;
  }
}
```

```yin
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: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;
6. Security Considerations

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

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

There are a number of data nodes defined in this YANG module that are writable/creatable/deletable (i.e., config true, which is the default). These data nodes may be considered sensitive or vulnerable in some network environments. Write operations (e.g., edit-config) to these data nodes without proper protection can have a negative effect on network operations. Considerations in Section 10 of [I-D.ietf-teas-yang-te] are also applicable to their subtrees in the module defined in this document.

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. Considerations in Section 10 of
7. IANA Considerations

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

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

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

   name:         ietf-otn-tunnel
   prefix:       otn-tunnel
   reference:    RFC XXXX

8. Acknowledgements

   TBD.

9. Contributors

   Aihua Guo
   Futurewei
   Email: aihuaguo.ietf@gmail.com

   Anurag Sharma
   Google
   Email: ansha@google.com

   Rajan Rao
   Infinera
   Email: rrao@infinera.com

   Yunbo Li
   China Mobile
   Email: liyunbo@chinamobile.com

   Dieter Beller
   Nokia
10. References

10.1. Normative References

[I-D.ietf-ccamp-layer1-types]

[I-D.ietf-ccamp-otn-topo-yang]

[I-D.ietf-teas-yang-te]

[ITU-Tg709]


10.2. Informative References

[I-D.ietf-teas-actn-yang]


Authors’ Addresses

Haomian Zheng
Huawei Technologies
H1, Huawei Xiliu Beipo Village, Songshan Lake
Dongguan, Guangdong  523808
China

Email: zhenghaomian@huawei.com

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

Email: Italo.Busi@huawei.com

Sergio Belotti
Nokia

Email: sergio.belotti@nokia.com
Victor Lopez
Nokia
Email: victor.lopez@nokia.com

Yunbin Xu
CAICT
Email: xuyunbin@caict.ac.cn
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

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at https://datatracker.ietf.org/drafts/current/.
Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on 25 April 2022.

Copyright Notice

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

This document is subject to BCP 78 and the IETF Trust’s Legal Provisions Relating to IETF Documents (https://trustee.ietf.org/license-info) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents
1. Introduction ........................................... 3
   1.1. Definition of OTN Slice ............................ 3
2. Use Cases for OTN Network Slicing .......................... 4
   2.1. Leased Line Services with OTN ....................... 4
   2.2. Co-construction and Sharing ......................... 5
   2.3. Wholesale of optical resources ...................... 5
   2.4. Vertical dedicated network with OTN ................. 5
   2.5. End-to-end network slicing ......................... 6
3. Framework for OTN Slicing ................................ 6
4. YANG Data Model for OTN Slicing Configuration ............ 9
   4.1. OTN Slicing YANG Model for MPI ..................... 9
      4.1.1. MPI YANG Model Overview ....................... 9
      4.1.2. MPI YANG Model Tree ......................... 10
      4.1.3. MPI YANG Code .............................. 10
   4.2. OTN Slicing YANG Model for OTN-SC NBI ............... 14
      4.2.1. NBI YANG Model Overview ....................... 14
      4.2.2. NBI YANG Model Tree for Transport Network Slice . 14
      4.2.3. NBI YANG Code for Transport Network Slice ........ 15
      4.2.4. NBI YANG Model Tree for OTN slice ............. 26
      4.2.5. NBI YANG Code for OTN Slice ................... 26
5. Manageability Considerations ............................. 26
6. Security Considerations .................................. 26
7. IANA Considerations ..................................... 26
8. References .............................................. 26
   8.1. Normative References ............................... 26
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.
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                        |
                    +------------------------+
                        | 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.

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;
  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).

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 "2021-10-22" {
  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.";
}

    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;
}
4.2. OTN Slicing YANG Model for OTN-SC NBI

4.2.1. NBI YANG Model Overview

The YANG model for OTN-SC NBI is OTN-technology specific, but shares many common constructs and attributes with generic network slicing YANG models. Furthermore, the OTN-SC NBI YANG is expected to support both connectivity-based and resource-based slice configuration, which is likely a common requirement for supporting slicing at other transport network layers, e.g. WDM or MPLS-TP. Therefore, the OTN-SC NBI YANG model is designed into two models, a common base model for transport network slicing, and an OTN slicing model which augments the base model with OTN technology-specific constructs.

The base model defines a transport network slice (TNS) with the following constructs and attributes:
- Common attributes, which include a set of common attributes like slice identifier, name, description and names of customers who use the slice.  
- Endpoints, which represent conceptual points of connection from a customer device to the TNS. An endpoint is mapped to specific physical or virtual resources of the customer and provider, and such mapping is pre-negotiated and known to both the customer and provider prior to the slice configuration. The mechanism for endpoint negotiation is outside the scope of this draft.  
- Network topology, which represent set of shared, reserved resources organized as a virtual topology between all of the endpoints. A customer could use such network topology to define detailed connectivity path traversing the topology, and allow sharing of resources between its multiple endpoint pairs.
- Connectivity matrix, which represent the intended virtual connections between the endpoints within a TNS. A connectivity matrix entry could be associated with an explicit path over the above network topology.  
- Service-level objectives (SLOs) associated with different objects, including the TNS, node, link, termination point, and explicit path, within a TNS.

4.2.2. NBI YANG Model Tree for Transport Network Slice

module: ietf-transport-network-slice
  +--rw network-slices
    +--rw network-slice* [ns-id]  
      +--rw ns-id                    string
      +--rw ns-name?                 string
      +--rw ns-description?          string
      +--rw customer-name*           string
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;
    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
    network slice realization.
    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
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:"
    }
  }
}
"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;
        }
      }
    }
  }
}
container network-topologies {
  description
  "A network slice is described as a network topology";
}

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

container connectivity-matrices {
  description
  "Connectivity matrices";
}

list connectivity-matrix {
  key "connectivity-matrix-id";
  description
  "List of connectivity matrix entities";
  leaf connectivity-matrix-id {
    type uint32;
    description
    "Connectivity matrix identifier";
  }
  leaf topology-id {
    type leafref {
      path "../../../network-topologies/network-topology/topology-id";
    }
    description
    "Relative reference to network topology id.";
  }
  leaf src-endpoint {
    type leafref {
      path "../../../endpoints/endpoint/endpoint-id";
    }
    description
    "Relative reference to endpoint id.";
  }
}
leaf dst-endpoint {
    type leafref {
        path " ../../../endpoints/endpoint/endpoint-id";
    }
    description
        "Relative reference to endpoint id.";
    uses connectivity-matrix-entry-slo;
    uses explicit-path;
} //connectivity-matrix
} //connectivity-matrices
} //network-slice
} //network slices
}
<CODE ENDS>

Figure 7: YANG model for transport network slice

4.2.4. NBI YANG Model Tree for OTN slice

TBD.

4.2.5. NBI YANG Code for OTN Slice

TBD.

5. Manageability Considerations

To ensure the security and controllability of physical resource isolation, slice-based independent operation and management are required to achieve management isolation. Each optical slice typically requires dedicated accounts, permissions, and resources for independent access and O&M. This mechanism is to guarantee the information isolation among slice tenants and to avoid resource conflicts. The access to slice management functions will only be permitted after successful security checks.

6. Security Considerations

<Add any security considerations>

7. IANA Considerations

<Add any IANA considerations>

8. References

8.1. Normative References
8.2. Informative References

[I-D.ietf-teas-yang-te]


Acknowledgments

This document was prepared using kramdown.

Previous versions of this document were prepared using 2-Word-v2.0.template.dot.

Contributors’ Addresses
Henry Yu
Huawei Technologies Canada
Email: henry.yu@huawei.com

Jiang Sun
China Mobile
Email: sunjiang@chinamobile.com

Authors’ Addresses

Haomian Zheng
Huawei Technologies
H1, Xiliu Beipo Village, Songshan Lake
Dongguan
China
Email: zhenghaomian@huawei.com

Italo Busi
Huawei Technologies
Email: italo.busi@huawei.com

Aihua Guo
Futurewei Technologies
Email: aihuaguo.ietf@gmail.com

Luis M. Contreras
Telefonica
Email: luismiguel.contrerasmurillo@telefonica.com

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

Victor Lopez
Nokia