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

Abstract

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

To be completed

Status of This Memo

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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 $\text{penalty} = f(\text{CD}, \text{PMD})$.

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

3. Layer0 Types Revision 2 YANG CODE

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

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

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

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

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

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

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      <mailto:Sergio.Belotti@nokia.com>

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

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

  // Additional contacts TBA (contributors)

  description
    "Description to be added!!!

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    as authors of the code. All rights reserved.

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

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

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

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

/*
 * Identities
 */

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

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

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

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

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

identity DP-QAM8 {
  base modulation;
```

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

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

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

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

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

  identity g-fec {
    base fec-type;
    description
      "G-FEC (Generic-FEC)";
  }

  identity e-fec {
    base fec-type;
    description
      "E-FEC (Enhanced-FEC)";
  }

  identity no-fec {
    base fec-type;
    description
      "No FEC";
  }

  identity reed-solomon {
```

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

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

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

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

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

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

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

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

identity wavelength-assignment {
```

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

  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 recommendation";
  reference "ITU-T G.698.2 (11/2018)";
}

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

typedef frequency-thz {
  type decimal64 {
```

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

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

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

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

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

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

/*
 * Groupings
 */

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

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

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

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

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

```

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

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

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

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

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

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

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

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

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

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



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

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

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

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

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

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

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

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

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

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

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

```
    uses pdl-penalty ;
}

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

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

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

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

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

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

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

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

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

```
        description "Available FEC";
    }

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

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

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

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

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

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

```
leaf minimum-channel-spacing {
  type frequency-ghz;
  config false;
  description
    "This 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 (WSO or Flexi-Grid) Tunnels.";
  leaf fec-type {
    type identityref {
      base fec-type;
    }
    description
      "FEC type.";
  }
  leaf termination-type {
    type identityref {
      base term-type;
    }
    description
      "Termination type.";
  }
  leaf bit-stuffing {
```

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

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

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

Figure 1

4. Acknowledgements

To be added if any.

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6. IANA Considerations

This memo includes no request to IANA.

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

7. Security Considerations

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

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A YANG Data Model for Transport Network Client Signals
draft-ietf-ccamp-client-signal-yang-06

Abstract

A transport network is a server-layer network to provide connectivity services to its client. The topology and tunnel information in the transport layer has already been defined by generic Traffic-engineered models and technology-specific models (e.g., OTN, WSON). However, how the client signals are accessing to the network has not been described. These information is necessary to both client and provider.

This draft describes how the client signals are carried over transport network and defines YANG data models which are required during configuration procedure. More specifically, several client signal (of transport network) models including ETH, STM-n, FC and so on, are defined in this draft.

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1. Introduction

1.1. Overview

A transport network is a server-layer network designed to provide connectivity services for a client-layer network to carry the client traffic transparently across the server-layer network resources. Currently the topology and tunnel models have been defined for transport networks, including [I-D.ietf-ccamp-otn-topo-yang] and [I-D.ietf-ccamp-otn-tunnel-model], providing server-layer topology abstraction and tunnel configuration between PEs. However, there is a missing piece for configuring how the PEs should map the client-layer traffic, received from the CE, over the server-layer tunnels: this gap is expected to be solved in this document.

This document defines a data model of all transport network client signals, using YANG language defined in [RFC7950]. The model can be used by applications exposing to a transport network controller via a RESTconf interface. Furthermore, it can be used by an application for the following purposes (but not limited to):

- * To request/update an end-to-end service by driving a new tunnel to be set up to support this service;
- * To request/update an end-to-end service by using an existing tunnel;
- * To receive notification with regard to the information change of the given service;

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

1.2. Prefixs in Model Names

In this document, names of data nodes and other data model objects are prefixed using the standard prefix associated with the corresponding YANG imported modules, including [RFC6991], [RFC8294] and [I-D.ietf-ccamp-otn-tunnel-model], which are shown as follow.

Prefix	YANG module	Reference
yang	ietf-yang-types	[RFC6991]
te-types	ietf-te-types	[RFC8776]
rt-types	ietf-routing-types	[RFC8294]
ll-types	ietf-layer1-types	[ietf-ccamp-layer1-types]
eth-types	ietf-eth-tran-types	This Document
clnsvcs	ietf-trans-client-service	This Document
ethsvcs	ietf-eth-tran-service	This Document
clnsvcs-types	ietf-trans-client-svc-types	This Document

2. Terminology and Notations

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

- * 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.

3. Transport Network Client Signal Overview

3.1. Overview of Service Request and Network Configuration Scenarios

A global view of a multi-domain service can be described as the Figure 1 . The customer is usually responsible to configure the CE nodes and to request to the provider the service intent, from the CE nodes perspective, while the provider is responsible to configure the whole network (including the PE nodes) to support the customer service intent. Generally speaking, the network configurations required to support a customer service can be split into two different groups: CE-PE and PE-PE. The CE-PE configuration deals with the client layer one-hop access link, while PE-PE configuration

deals with the server layer tunnel. In Figure 1 we mark the intermediate nodes as 'P', which has same switching capability of PE but just not the 'end-point'. In this example, the link P-P and PE-P are a server-layer intra-domain or inter-domain link.

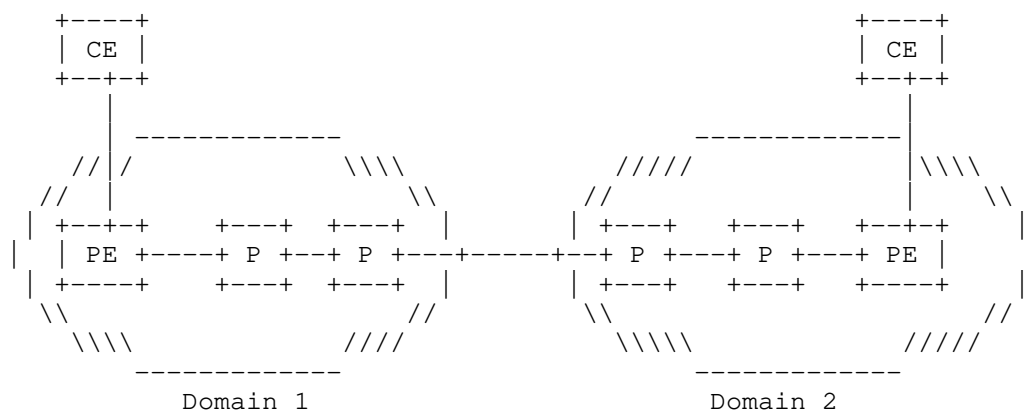


Figure 1: Global view of Client Service with the Network Provider

According to the responsibilities of each controller in [RFC8453], the controllers have different views of the service request and network configuration. The duty of CNC is to give the MDSC a description of the customer service intent: candidate YANG models include L1CSM [I-D.ietf-ccamp-llcsm-yang], L2SM [RFC8466] and L3SM [RFC8299], which are classified as customer service models, according to [RFC8309]. These models provide necessary attributes to describe the customer service intent from the customer/CE perspective, and do not provide any specific network configuration. These models also implies that the customer service description can be considered in a separate manner rather than integratig with network configurations, which also enable the controllers to abstract/virtualize the network resource to make them visible to the customer and also easier to manage. In other words, the network knowledge is not necessary at CNC and CMI, which is seen in an abstracted form as shown in Figure 2.

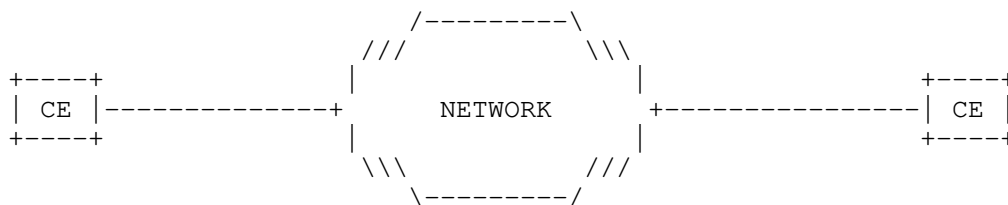


Figure 2: CNC Viewpoint on the Client Service

The functionalities of MDSC have been described in [RFC8453], which include the customer mapping/translation and multi-domain coordination. By receiving the request from CNC, MDSC need to understand what network configuration can support the customer service intent and turn to the corresponding PNCs for configuration. The service request is therefore decomposed by MDSC into a few network configurations and forwarded to one or multiple PNCs respectively in single-domain and multi-domain scenario. In general, the MDSC has the view of both PE and CE nodes and of some abstract information regarding the P nodes, as shown in Figure 3. It is worth noting that this MDSC view is different with Figure 1 at the intra-domain link. Usually these details are hidden, for scalability purposes, and therefore the MDSC has only an abstract view of each domain internal topology.

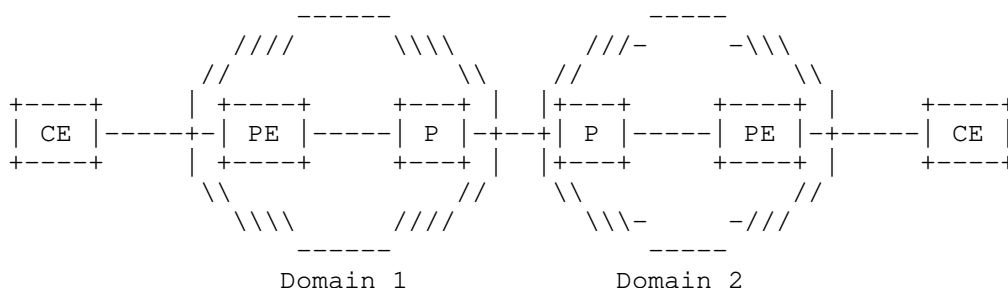


Figure 3: MDSC view of both Client Service and Network Abstraction

PNC is the controller that configure the physical devices, based on the network configuration received from the MDSC. Each PNC has the detailed view of its own domain, the example of view from PNC in domain 1 is shown in Figure 4. The PNC has all the detailed topology information on PE and P nodes and on the intra-domain links. The PNC configures the tunnel/tunnel segment within its domain based on the network configuration provided by the MDSC. The PNC also configures

the network part of the CE-PE access links as well as the mapping of the client-layer traffic and the server-layer tunnels, based on the network configuration provided by the MDSC. The interaction between PNC and MDSC for the client-layer network configuration is accomplished by the models defined in this draft.

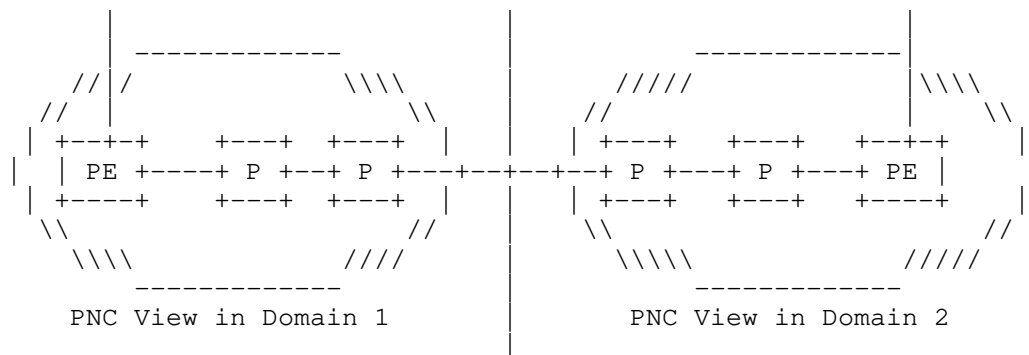


Figure 4: PNC view on Network Configuration

3.2. Applicability of Proposed Model

Existing TE and technology-specific models, such as topology models and tunnel models, support the network configuration among PEs and Ps. The customer service models, such as L1CSM, L2SM and L3SM, focus on describing the attributes among CEs. However, there is a missing piece on how to configure the CE-PE session. The models defined in this document provide the configuration on CE-PE when the provider server-layer network is TE-based technology.

In the example of OTN as the server-layer transport network, a full list of G-PID was summarized in [RFC7139], which can be divided into a few categories. The G-PID signals can be categorized into transparent and non-transparent. Examples of transparent signals may include Ethernet physical interfaces, FC, STM-n and so on. In this approach the OTN devices is not aware of the client signal type, and this information is only necessary among the controllers. Once the OTN tunnel is set up, there is no switching requested on the client layer, and therefore only signal mapping is needed, without a client tunnel set up. The models that supporting the configuration of transparent signals are defined in Section 4.2. The other category would be non-transparent, such as Carrier Ethernet and MPLS-TP, with a switching request on the client layer. Once the OTN tunnel is set up, a corresponding tunnel in the client layer has to be set up to carry services. The models that supporting the configuration of transparent signals are defined in Section 4.1.

It is also worth noting that some client signal can be carried over multiple types of networks. For example, the Ethernet services can be carried over either OTN or Ethernet TE tunnels (over optical or microwave networks). The model specified in this document allows the support from networks with different technologies. The list of identities for client signals are defined in [I-D.ietf-ccamp-layer1-types].

3.3. State of Services

States have been defined to retrieve the status of the delivered services. A few generic states defined in [RFC8776] are reused in this document. These states include the operational state and the provisioning state.

A few other parameters are defined for the management of the services. Given the complicated labor division, the creation, update and maintainance may have different responsible systems. So the log of the service would be helpful and should be easy to retrived in a standard way as well. These information include, but not restricted to the following:

- * When the service is created and has been last updated, these are specified in the creation-time and last-updated-time.
- * Who created the service and who made the last update to the service, these are specified in the created-by and last-updated-by.

- * The owner of the service is specified as owned-by, which would be useful when the service is delegated by or to a specific system. The identifier of the system is used to represent such information.

4. YANG Model for Transport Network Client Signal

4.1. YANG Tree for Ethernet Service

```

module: ietf-eth-tran-service
  +--rw etht-svc
    +--rw globals
      +--rw named-bandwidth-profiles* [bandwidth-profile-name]
        +--rw bandwidth-profile-name      string
        +--rw bandwidth-profile-type?
          |   etht-types:bandwidth-profile-type
        +--rw CIR?                          uint64
        +--rw CBS?                          uint64
        +--rw EIR?                          uint64
        +--rw EBS?                          uint64
        +--rw color-aware?                  boolean
        +--rw coupling-flag?                boolean
    +--rw etht-svc-instances* [etht-svc-name]
      +--rw etht-svc-name                    string
      +--rw etht-svc-title?                  string
      +--rw etht-svc-descr?                  string
      +--rw etht-svc-customer?               string
      +--rw etht-svc-type?                   etht-types:service-type
      +--rw etht-svc-lifecycle?              etht-types:lifecycle-status
      +--rw te-topology-identifier
        +--rw provider-id?   te-global-id
        +--rw client-id?     te-global-id
        +--rw topology-id?   te-topology-id
      +--rw resilience
        +--rw 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 etht-svc-end-points* [etht-svc-end-point-name]
|   +---rw etht-svc-end-point-name                             string
|   +---rw etht-svc-end-point-id?                             string
|   +---rw etht-svc-end-point-descr?                           string
|   +---rw topology-role?
|       | identityref
+---rw resilience
+---rw etht-svc-access-points* [access-point-id]
|   +---rw access-point-id                                     string
|   +---rw access-node-id?                                     te-types:te-node-id
|   +---rw access-ltp-id?                                     te-types:te-tp-id
|   +---rw access-role?                                       identityref
+---rw pm-config
|   +---rw pm-enable?                                         boolean
|   +---rw sending-rate-high?                                 uint64
|   +---rw sending-rate-low?                                 uint64
|   +---rw receiving-rate-high?                               uint64
|   +---rw receiving-rate-low?                                 uint64
+---ro state
|   +---ro operational-state?                                  identityref
|   +---ro provisioning-state?                                identityref
+---ro performance?                                           identityref
+---rw service-classification-type?
|   identityref
+---rw (service-classification)?
|   +---:(port-classification)
|   +---:(vlan-classification)
|       +---rw outer-tag!
|           +---rw tag-type?
|               | etht-types:eth-tag-classify
|           +---rw (individual-bundling-vlan)?
|               +---:(individual-vlan)
|                   | +---rw vlan-value? etht-types:vlanid
|               +---:(vlan-bundling)
|                   +---rw vlan-range?
|                       etht-types:vid-range-type
+---rw second-tag!
|   +---rw tag-type?
|       | etht-types:eth-tag-classify
|   +---rw (individual-bundling-vlan)?
|       +---:(individual-vlan)
|           | +---rw vlan-value? etht-types:vlanid
|       +---:(vlan-bundling)
|           +---rw vlan-range?
|               etht-types:vid-range-type
+---rw split-horizon-group?                                    string
+---rw (direction)?

```

```

+---:(symmetrical)
  +---rw ingress-egress-bandwidth-profile
    +---rw (style)?
      +---:(named)
        | +---rw bandwidth-profile-name?   leafref
        +---:(value)
          +---rw bandwidth-profile-type?
            | etht-types:bandwidth-profile-type
            +---rw CIR?                      uint64
            +---rw CBS?                      uint64
            +---rw EIR?                      uint64
            +---rw EBS?                      uint64
            +---rw color-aware?              boolean
            +---rw coupling-flag?            boolean
      +---:(asymmetrical)
        +---rw ingress-bandwidth-profile
          +---rw (style)?
            +---:(named)
              | +---rw bandwidth-profile-name?   leafref
              +---:(value)
                +---rw bandwidth-profile-type?
                  | etht-types:bandwidth-profile-type
                  +---rw CIR?                      uint64
                  +---rw CBS?                      uint64
                  +---rw EIR?                      uint64
                  +---rw EBS?                      uint64
                  +---rw color-aware?              boolean
                  +---rw coupling-flag?            boolean
        +---rw egress-bandwidth-profile
          +---rw (style)?
            +---:(named)
              | +---rw bandwidth-profile-name?   leafref
              +---:(value)
                +---rw bandwidth-profile-type?
                  | etht-types:bandwidth-profile-type
                  +---rw CIR?                      uint64
                  +---rw CBS?                      uint64
                  +---rw EIR?                      uint64
                  +---rw EBS?                      uint64
                  +---rw color-aware?              boolean
                  +---rw coupling-flag?            boolean
+---rw vlan-operations
  +---rw (direction)?
    +---:(symmetrical)
      +---rw symmetrical-operation
        +---rw pop-tags?      uint8
        +---rw push-tags
        +---rw outer-tag!

```

```

    |
    | |
    | | |
    | | | +---rw tag-type?
    | | | |   etht-types:eth-tag-type
    | | | +---rw vlan-value?   etht-types:vlanid
    | | | +---rw default-pcp?   uint8
    | | +---rw second-tag!
    | | |
    | | | +---rw tag-type?
    | | | |   etht-types:eth-tag-type
    | | | +---rw vlan-value?   etht-types:vlanid
    | | | +---rw default-pcp?   uint8
    | +---:(asymmetrical)
    | |
    | | +---rw asymmetrical-operation
    | | |
    | | | +---rw ingress
    | | | |
    | | | | +---rw pop-tags?   uint8
    | | | | +---rw push-tags
    | | | | |
    | | | | | +---rw outer-tag!
    | | | | | |
    | | | | | | +---rw tag-type?
    | | | | | | |   etht-types:eth-tag-type
    | | | | | | +---rw vlan-value?
    | | | | | | |   etht-types:vlanid
    | | | | | | +---rw default-pcp?   uint8
    | | | | | +---rw second-tag!
    | | | | | |
    | | | | | | +---rw tag-type?
    | | | | | | |   etht-types:eth-tag-type
    | | | | | | +---rw vlan-value?
    | | | | | | |   etht-types:vlanid
    | | | | | | +---rw default-pcp?   uint8
    | | | | +---rw egress
    | | | | |
    | | | | | +---rw pop-tags?   uint8
    | | | | | +---rw push-tags
    | | | | | |
    | | | | | | +---rw outer-tag!
    | | | | | | |
    | | | | | | | +---rw tag-type?
    | | | | | | | |   etht-types:eth-tag-type
    | | | | | | | +---rw vlan-value?
    | | | | | | | |   etht-types:vlanid
    | | | | | | | +---rw default-pcp?   uint8
    | | | | | +---rw second-tag!
    | | | | | |
    | | | | | | +---rw tag-type?
    | | | | | | |   etht-types:eth-tag-type
    | | | | | | +---rw vlan-value?
    | | | | | | |   etht-types:vlanid
    | | | | | | +---rw default-pcp?   uint8
    | | +---rw underlay
    | | |
    | | | +---rw (technology)?
    | | | |
    | | | | +---:(native-ethernet)
    | | | | |
    | | | | | +---rw eth-tunnels* [name]
    | | | | | |
    | | | | | | +---rw name
    | | | | | | |   -> /te:te/tunnels/tunnel/name
    | | | | | +---rw encoding?   identityref

```



```

|         +---rw switching-type?    identityref
+---:(frame-base)
|         +---rw otn-tunnels* [name]
|         |         +---rw name
|         |         |         -> /te:te/tunnels/tunnel/name
|         |         +---rw encoding?    identityref
|         |         +---rw switching-type?    identityref
+---:(mpls-tp)
|         +---rw pw
|         |         +---rw pw-id?                string
|         |         +---rw pw-name?              string
|         |         +---rw transmit-label?
|         |         |         rt-types:mpls-label
|         |         +---rw receive-label?
|         |         |         rt-types:mpls-label
|         |         +---rw encapsulation-type?    identityref
|         |         +---ro oper-status?          identityref
|         |         +---rw ingress-bandwidth-profile
|         |         |         +---rw (style)?
|         |         |         |         +---:(named)
|         |         |         |         |         +---rw bandwidth-profile-name?    leafref
|         |         |         |         |         +---:(value)
|         |         |         |         |         |         +---rw bandwidth-profile-type?
|         |         |         |         |         |         |         etht-types:bandwidth-profile-type
|         |         |         |         |         |         +---rw CIR?                uint64
|         |         |         |         |         |         +---rw CBS?                uint64
|         |         |         |         |         |         +---rw EIR?                uint64
|         |         |         |         |         |         +---rw EBS?                uint64
|         |         +---rw pw-paths* [path-id]
|         |         |         +---rw path-id        uint8
|         |         |         +---rw tp-tunnels* [name]
|         |         |         |         +---rw name    string
+---rw src-split-horizon-group?    string
+---rw dst-split-horizon-group?    string
+---rw admin-status?                identityref
+---ro state
|         +---ro operational-state?    identityref
|         +---ro provisioning-state?    identityref
|         +---ro creation-time?         yang:date-and-time
|         +---ro last-updated-time?     yang:date-and-time
|         +---ro created-by?            string
|         +---ro last-updated-by?       string
|         +---ro owned-by?              string

```

4.2. YANG Tree for other Transport Network Client Signal Model

```

module: ietf-trans-client-service
  +--rw client-svc
    +--rw client-svc-instances* [client-svc-name]
      +--rw client-svc-name          string
      +--rw client-svc-title?       string
      +--rw client-svc-descr?       string
      +--rw client-svc-customer?    string
      +--rw resilience
      +--rw te-topology-identifier
        +--rw provider-id?    te-global-id
        +--rw client-id?      te-global-id
        +--rw topology-id?    te-topology-id
      +--rw admin-status?        identityref
      +--rw src-access-ports
        +--rw access-node-id?    te-types:te-node-id
        +--rw access-ltp-id?     te-types:te-tp-id
        +--rw client-signal?     identityref
      +--rw dst-access-ports
        +--rw access-node-id?    te-types:te-node-id
        +--rw access-ltp-id?     te-types:te-tp-id
        +--rw client-signal?     identityref
      +--rw direction?           identityref
      +--rw svc-tunnels* [tunnel-name]
        +--rw tunnel-name        string
      +--ro operational-state?    identityref
      +--ro provisioning-state?   identityref
      +--ro creation-time?        yang:date-and-time
      +--ro last-updated-time?    yang:date-and-time
      +--ro created-by?           string
      +--ro last-updated-by?      string
      +--ro owned-by?             string

```

5. YANG Code for Transport Network Client Signal

5.1. The ETH Service YANG Code

This module imports typedefs and modules from [RFC6991], [RFC8294], [RFC8776].

```
<CODE BEGINS> file "ietf-eth-tran-service@2021-01-11.yang"
module ietf-eth-tran-service {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-eth-tran-service";

  prefix "ethtsvc";

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

  import ietf-te-types {
    prefix "te-types";
    reference "RFC 8776 - Traffic Engineering Common YANG Types";
  }

  import ietf-eth-tran-types {
    prefix "ethht-types";
    reference "RFC XXXX - A YANG Data Model for Transport
              Network Client Signals";
  }

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

  import ietf-te {
    prefix "te";
    reference "RFC YYYY - A YANG Data Model for Traffic
              Engineering Tunnels and Interfaces";
  }

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

      ID-draft editor:
        Haomian Zheng (zhenghaomian@huawei.com);
        Italo Busi (italo.busi@huawei.com);
        Aihua Guo (aihuaguo.ietf@gmail.com);
        Anton Snitser (asnizar@cisco.com);
        Francesco Lazzeri (francesco.lazzeri@ericsson.com);
```

```
    ";

description
  "This module defines a YANG data model for describing
  the Ethernet 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 2021-01-11 {
  description
    "version -04 as an WG document";
  reference
    "draft-ietf-ccamp-client-signal-yang";
}

/*
 * Groupings
 */

grouping vlan-classification {
  description
    "A grouping which represents classification
    on an 802.1Q VLAN tag.";

  leaf tag-type {
    type eth-types:eth-tag-classify;
    description
      "The tag type used for VLAN classification.";
  }

  choice individual-bundling-vlan {
    description
      "VLAN based classification can be individual
      or bundling.";

    case individual-vlan {
      leaf vlan-value {
        type eth-types:vlanid;
      }
    }
  }
}
```

```
        description
            "VLAN ID value.";
    }
}

case vlan-bundling {
    leaf vlan-range {
        type ethht-types:vid-range-type;
        description
            "List of VLAN ID values.";
    }
}
}

grouping vlan-write {
    description
        "A grouping which represents push/pop operations
        of an 802.1Q VLAN tag.";

    leaf tag-type {
        type ethht-types:eth-tag-type;
        description
            "The VLAN tag type to push/swap.";
    }
    leaf vlan-value {
        type ethht-types:vlanid;
        description
            "The VLAN ID value to push/swap.";
    }
}

/*
 * To be added: this attribute is used when:
 * a) the ETH service has only one CoS (as in current version)
 * b) as a default when a mapping between a given CoS value
 *    and the PCP value is not defined (in future versions)
 */
leaf default-pcp {
    type uint8 {
        range "0..7";
    }
    description
        "The default Priority Code Point (PCP) value to push/swap";
}

grouping vlan-operations {
    description
        "A grouping which represents VLAN operations.";
```

```
    leaf pop-tags {
      type uint8 {
        range "1..2";
      }
      description
        "The number of VLAN tags to pop (or swap if used in
        conjunction with push-tags)";
    }
    container push-tags {
      description
        "The VLAN tags to push (or swap if used in
        conjunction with pop-tags)";

      container outer-tag {
        presence
          "Indicates existence of the outermost VLAN tag to
          push/swap";

        description
          "The outermost VLAN tag to push/swap.";

        uses vlan-write;
      }
      container second-tag {
        must
          '../outer-tag/tag-type = "eth-types:s-vlan-tag-type" and ' +
          'tag-type = "eth-types:c-vlan-tag-type"'
          {
            error-message
              "
                When pushing/swapping two tags, the outermost tag must
                be specified and of S-VLAN type and the second
                outermost tag must be of C-VLAN tag type.
              ";
            description
              "
                For IEEE 802.1Q interoperability, when pushing/swapping
                two tags, it is required that the outermost tag exists
                and is an S-VLAN, and the second outermost tag is a
                C-VLAN.
              ";
          }

            presence
              "Indicates existence of a second outermost VLAN tag to
              push/swap";
          }
        }
      }
    }
  }
}
```

```
        description
            "The second outermost VLAN tag to push/swap.";

        uses vlan-write;
    }
}

grouping named-or-value-bandwidth-profile {
    description
        "A grouping to configure a bandwidth profile either by
        referencing a named bandwidth profile or by
        configuring the values of the bandwidth profile attributes.";
    choice style {
        description
            "Whether the bandwidth profile is named or defined by value";

        case named {
            description
                "Named bandwidth profile.";
            leaf bandwidth-profile-name {
                type leafref {
                    path "/ethtsvc:etht-svc/ethtsvc:globals/"
                        + "ethtsvc:named-bandwidth-profiles/"
                        + "ethtsvc:bandwidth-profile-name";
                }
            }
            description
                "Name of the bandwidth profile.";
        }
        case value {
            description
                "Bandwidth profile configured by value.";
            uses etht-types:etht-bandwidth-profiles;
        }
    }
}

grouping bandwidth-profiles {
    description
        "A grouping which represent bandwidth profile configuration.";

    choice direction {
        description
            "Whether the bandwidth profiles are symmetrical or
            asymmetrical";
        case symmetrical {
            description
```

```
        "The same bandwidth profile is used to describe both
        the ingress and the egress bandwidth profile.";
    container ingress-egress-bandwidth-profile {
        description
            "The bandwidth profile used in both directions.";
        uses named-or-value-bandwidth-profile;
    }
}
case asymmetrical {
    description
        "Ingress and egress bandwidth profiles can be specified.";
    container ingress-bandwidth-profile {
        description
            "The bandwidth profile used in the ingress direction.";
        uses named-or-value-bandwidth-profile;
    }
    container egress-bandwidth-profile {
        description
            "The bandwidth profile used in the egress direction.";
        uses named-or-value-bandwidth-profile;
    }
}
}
}

grouping etht-svc-access-parameters {
    description
        "ETH services access parameters";

    leaf access-node-id {
        type te-types:te-node-id;
        description
            "The identifier of the access node in
            the ETH topology.";
    }
    leaf access-ltp-id {
        type te-types:te-tp-id;
        description
            "The TE link termination point identifier, used
            together with access-node-id to identify the
            access LTP.";
    }
    leaf access-role {
        type identityref {
            base etht-types:access-role;
        }
        description
            "Indicate the role of access, e.g., working or protection. ";
    }
}
```



```
    }

    container pm-config {
      uses pm-config-grouping;
      description
        "This grouping is used to set the threshold value for
        performance monitoring. ";
    }

    container state {
      config false;
      description
        "The state is used to monitor the status of service. ";
      leaf operational-state {
        type identityref {
          base te-types:tunnel-state-type;
        }
        description
          "Indicating the operational state of client signal. ";
      }
      leaf provisioning-state {
        type identityref {
          base te-types:lsp-state-type;
        }
        description
          "Indicating the provisional state of client signal,
          especially when there is a change, i.e., revise, create. ";
      }
    }

    leaf performance {
      type identityref {
        base ethht-types:performance;
      }
      config false;
      description
        "Performance Monitoring for the service. ";
    }
  }

  grouping ethht-svc-tunnel-parameters {
    description
      "ETH services tunnel parameters.";
    choice technology {
      description
        "Service multiplexing is optional and flexible.";
    }
  }
```

```
    case native-ethernet {
      /*
        placeholder to support proprietary multiplexing
        (for further discussion)
      */
      list eth-tunnels {
        key name;
        description
          "ETH Tunnel list in native Ethernet scenario.";
        uses tunnels-grouping;
      }
    }

    case frame-base {
      list otn-tunnels {
        key name;
        description
          "OTN Tunnel list in Frame-based scenario.";
        uses tunnels-grouping;
      }
    }

    case mpls-tp {
      container pw {
        description
          "Pseudowire information for Ethernet over MPLS-TP.";
        uses pw-segment-grouping;
      }
    }
  }

  /*
   * Open issue: can we constraints it to be used only with mp services?
   */
  leaf src-split-horizon-group {
    type string;
    description
      "Identify a split horizon group at the Tunnel source TTP";
  }
  leaf dst-split-horizon-group {
    type string;
    description
      "Identify a split horizon group at the Tunnel destination TTP";
  }
}

grouping etht-svc-pm-threshold-config {
  description
```

```
    "Configuraiton parameters for Ethernet service PM thresholds.";

    leaf sending-rate-high {
        type uint64;
        description
            "High threshold of packet sending rate in kbps.";
    }
    leaf sending-rate-low {
        type uint64;
        description
            "Low threshold of packet sending rate in kbps.";
    }
    leaf receiving-rate-high {
        type uint64;
        description
            "High threshold of packet receiving rate in kbps.";
    }
    leaf receiving-rate-low {
        type uint64;
        description
            "Low threshold of packet receiving rate in kbps.";
    }
}

grouping etht-svc-pm-stats {
    description
        "Ethernet service PM statistics.";

    leaf sending-rate-too-high {
        type uint32;
        description
            "Counter that indicates the number of times the
            sending rate is above the high threshold";
    }
    leaf sending-rate-too-low {
        type uint32;
        description
            "Counter that indicates the number of times the
            sending rate is below the low threshold";
    }
    leaf receiving-rate-too-high {
        type uint32;
        description
            "Counter that indicates the number of times the
            receiving rate is above the high threshold";
    }
    leaf receiving-rate-too-low {
        type uint32;
    }
}
```

```
        description
            "Counter that indicates the number of times the
             receiving rate is below the low threshold";
    }
}

grouping ethht-svc-instance-config {
    description
        "Configuraiton parameters for Ethernet services.";

    leaf ethht-svc-name {
        type string;
        description
            "Name of the ETH service.";
    }

    leaf ethht-svc-title {
        type string;
        description
            "The Identifier of the ETH service.";
    }

    leaf ethht-svc-descr {
        type string;
        description
            "Description of the ETH service.";
    }

    leaf ethht-svc-customer {
        type string;
        description
            "Customer of the ETH service.";
    }

    leaf ethht-svc-type {
        type ethht-types:service-type;
        description
            "Type of ETH service (p2p, mp2mp or rmp).";
        /* Add default as p2p */
    }

    leaf ethht-svc-lifecycle {
        type ethht-types:lifecycle-status;
        description
            "Lifecycle state of ETH service.";
        /* Add default as installed */
    }
}
uses te-types:te-topology-identifier;
```

```
    uses resilience-grouping;

    list etht-svc-end-points {
        key etht-svc-end-point-name;
        description
            "The logical end point for the ETH service. ";
        uses etht-svc-end-point-grouping;
    }

    container underlay {
        description
            "The unterlay tunnel information that carrying the
            ETH service. ";
        uses etht-svc-tunnel-parameters;
    }

    leaf admin-status {
        type identityref {
            base te-types:tunnel-admin-state-type;
        }
        default te-types:tunnel-admin-state-up;
        description "ETH service administrative state.";
    }
}

grouping etht-svc-instance-state {
    description
        "State parameters for Ethernet services.";

    leaf operational-state {
        type identityref {
            base te-types:tunnel-state-type;
        }
        default te-types:tunnel-state-up;
        description "ETH service operational state.";
    }

    leaf provisioning-state {
        type identityref {
            base te-types:lsp-state-type;
        }
        description "ETH service provisioning state.";
    }

    leaf creation-time {
        type yang:date-and-time;
        description
            "Time of ETH service creation.";
    }
}
```

```
    leaf last-updated-time {
      type yang:date-and-time;
      description
        "Time of ETH service last update.";
    }

    leaf created-by {
      type string;
      description
        "The client signal is created by whom,
        can be a system or staff ID.";
    }
    leaf last-updated-by {
      type string;
      description
        "The client signal is last updated by whom,
        can be a system or staff ID.";
    }
    leaf owned-by {
      type string;
      description
        "The client signal is last updated by whom,
        can be a system ID.";
    }
  }
}

/*
 * Data nodes
 */

container ethht-svc {
  description
    "ETH services.";

  container globals {
    description
      "Globals Ethernet configuration data container";
    list named-bandwidth-profiles {
      key bandwidth-profile-name;
      description
        "List of named bandwidth profiles used by
        Ethernet services.";

      leaf bandwidth-profile-name {
        type string;
        description
          "Name of the bandwidth profile.";
      }
    }
  }
}
```

```
        uses etht-types:etht-bandwidth-profiles;
    }
}

list etht-svc-instances {
    key etht-svc-name;
    description
        "The list of p2p ETH service instances";

    uses etht-svc-instance-config;

    container state {
        config false;
        description
            "Ethernet Service states.";

        uses etht-svc-instance-state;
    }
}

grouping resilience-grouping {
    description
        "Grouping for resilience configuration. ";
    container resilience {
        description
            "To configure the data plane protection parameters,
            currently a placeholder only, future candidate attributes
            include, Revert, WTR, Hold-off Timer, ...";
        uses te:protection-restoration-properties;
    }
}

grouping etht-svc-end-point-grouping {
    description
        "Grouping for the end point configuration.";
    leaf etht-svc-end-point-name {
        type string;
        description
            "The name of the logical end point of ETH service. ";
    }

    leaf etht-svc-end-point-id {
        type string;
        description
            "The identifier of the logical end point of ETH service.";
    }
}
```

```
    leaf etht-svc-end-point-descr {
        type string;
        description
            "The description of the logical end point of ETH service. ";
    }

    leaf topology-role {
        type identityref {
            base etht-types:topology-role;
        }
        description
            "Indicating the underlay topology role,
            e.g., hub,spoke, any-to-any ";
    }

    container resilience {
        description
            "Placeholder for resilience configuration, for future study. ";
    }

    list etht-svc-access-points {
        key access-point-id;
        min-elements "1";
    }
    /*
    Open Issue:
    Is it possible to limit the max-elements only for p2p services?
    max-elements "2";
    */
    description
        "List of the ETH trasport services access point instances.";

    leaf access-point-id {
        type string;
        description
            "ID of the service access point instance";
    }
    uses etht-svc-access-parameters;
}

leaf service-classification-type {
    type identityref {
        base etht-types:service-classification-type;
    }
    description
        "Service classification type.";
}

choice service-classification {
```



```
description
  "Access classification can be port-based or
  VLAN based.";

case port-classification {
  /* no additional information */
}

case vlan-classification {
  container outer-tag {
    presence "The outermost VLAN tag exists";
    description
      "Classifies traffic using the outermost VLAN tag.";

    uses vlan-classification;
  }
  container second-tag {
    must
      '../outer-tag/tag-type = "eth-types:classify-s-vlan" and ' +
      'tag-type = "eth-types:classify-c-vlan"'
    {
      error-message
        "
          When matching two tags, the outermost tag must be
          specified and of S-VLAN type and the second
          outermost tag must be of C-VLAN tag type.
        ";
      description
        "
          For IEEE 802.1Q interoperability, when matching two
          tags, it is required that the outermost tag exists
          and is an S-VLAN, and the second outermost tag is a
          C-VLAN.
        ";
    }
    presence "The second outermost VLAN tag exists";

    description
      "Classifies traffic using the second outermost VLAN tag.";

    uses vlan-classification;
  }
}

/*
 * Open issue: can we constraints it to be used only with mp services?
 */
```

```
leaf split-horizon-group {
  type string;
  description "Identify a split horizon group";
}

uses bandwidth-profiles;

container vlan-operations {
  description
    "Configuration of VLAN operations.";
  choice direction {
    description
      "Whether the VLAN operations are symmetrical or
      asymmetrical";
    case symmetrical {
      container symmetrical-operation {
        uses vlan-operations;
        description
          "Symmetrical operations.
          Expressed in the ingress direction, but
          the reverse operation is applied to egress traffic";
      }
    }
    case asymmetrical {
      container asymmetrical-operation {
        description "Asymmetrical operations";
        container ingress {
          uses vlan-operations;
          description "Ingress operations";
        }
        container egress {
          uses vlan-operations;
          description "Egress operations";
        }
      }
    }
  }
}

grouping pm-config-grouping {
  description
    "Grouping used for Performance Monitoring Configuration. ";
  leaf pm-enable {
    type boolean;
    description
      "Whether to enable the performance monitoring.";
  }
}
```

```
    leaf sending-rate-high {
      type uint64;
      description
        "The upperbound of sending rate.";
    }

    leaf sending-rate-low {
      type uint64;
      description
        "The lowerbound of sending rate.";
    }

    leaf receiving-rate-high {
      type uint64;
      description
        "The upperbound of receiving rate.";
    }

    leaf receiving-rate-low {
      type uint64;
      description
        "The lowerbound of receiving rate.";
    }
  }

  grouping pw-segment-grouping {
    description
      "Grouping used for PW configuration. ";
    leaf pw-id {
      type string;
      description
        "The Identifier information of pseudowire. ";
    }

    leaf pw-name {
      type string;
      description
        "The name information of pseudowire.";
    }

    leaf transmit-label {
      type rt-types:mpls-label;
      description
        "Transmit label information in PW. ";
    }

    leaf receive-label {
      type rt-types:mpls-label;
```

```
    description
      "Receive label information in PW. ";
  }

  leaf encapsulation-type {
    type identityref {
      base ethht-types:encapsulation-type;
    }
    description
      "The encapsulation type, raw or tag. ";
  }

  leaf oper-status {
    type identityref {
      base te-types:tunnel-state-type;
    }
    config false;
    description
      "The operational state of the PW segment. ";
  }

  container ingress-bandwidth-profile {
    description
      "Bandwidth Profile for ingress. ";
    uses pw-segment-named-or-value-bandwidth-profile;
  }

  list pw-paths {
    key path-id;
    description
      "A list of pw paths. ";

    leaf path-id {
      type uint8;
      description
        "The identifier of pw paths. ";
    }
  }

  list tp-tunnels {
    key name;
    description
      "Names of TP Tunnel underlay";
    leaf name {
      type string;
      description
        "Names of TP Tunnel underlay";
    }
  }
```

```
    }
  }
}

grouping pw-segment-named-or-value-bandwidth-profile {
  description
    "A grouping to configure a bandwidth profile either by
    referencing a named bandwidth profile or by
    configuring the values of the bandwidth profile attributes.";
  choice style {
    description
      "Whether the bandwidth profile is named or defined by value";
    case named {
      description
        "Named bandwidth profile.";
      leaf bandwidth-profile-name {
        type leafref {
          path "/ethtsvc:ethht-svc/ethtsvc:globals/"
            + "ethtsvc:named-bandwidth-profiles/"
            + "ethtsvc:bandwidth-profile-name";
        }
        description
          "Name of the bandwidth profile.";
      }
    }
    case value {
      description
        "Bandwidth profile configured by value.";
      uses ethht-types:pw-segment-bandwidth-profile-grouping;
    }
  }
}

grouping tunnels-grouping {
  description
    "A group of tunnels. ";
  leaf name {
    type leafref {
      path "/te:te/te:tunnels/te:tunnel/te:name";
      require-instance false;
    }
    description "Dependency tunnel name";
  }
  leaf encoding {
    type identityref {
      base te-types:lsp-encoding-types;
    }
  }
}
```

```

        description "LSP encoding type";
        reference "RFC3945";
    }
    leaf switching-type {
        type identityref {
            base te-types:switching-capabilities;
        }
        description "LSP switching type";
        reference "RFC3945";
    }
}
}
<CODE ENDS>

```

5.2. YANG Code for ETH type

This module references a few documents including [RFC2697], [RFC2698], [RFC4115], [IEEE802.1ad], [IEEE802.1q] and [MEF10].

```

<CODE BEGINS> file "ietf-eth-tran-types@2021-07-07.yang"
module ietf-eth-tran-types {
    yang-version 1.1;
    namespace "urn:ietf:params:xml:ns:yang:ietf-eth-tran-types";

    prefix "eth-t-types";

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

            ID-draft editor:
            Haomian Zheng (zhenghaomian@huawei.com);
            Italo Busi (italo.busi@huawei.com);
            Aihua Guo (aihuaguo.ietf@gmail.com);
            Anton Snitser (asnizar@cisco.com);
            Francesco Lazzeri (francesco.lazzeri@ericsson.com);
        ";

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

        Copyright (c) 2019 IETF Trust and the persons
        identified as authors of the code. All rights reserved.

```

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```
revision 2021-07-07 {
  description
    "version -05 as a WG draft";
  reference
    "draft-ietf-ccamp-client-signal-yang";
}

/*
 * Identities
 */

identity eth-vlan-tag-type {
  description
    "ETH VLAN tag type.";
}

identity c-vlan-tag-type {
  base eth-vlan-tag-type;
  description
    "802.1Q Customer VLAN";
}

identity s-vlan-tag-type {
  base eth-vlan-tag-type;
  description
    "802.1Q Service VLAN (QinQ)";
}

identity service-classification-type {
  description
    "Service classification.";
}

identity port-classification {
  base service-classification-type;
  description
    "Port classification.";
}
```

```
identity vlan-classification {
  base service-classification-type;
  description
    "VLAN classification.";
}

identity eth-vlan-tag-classify {
  description
    "VLAN tag classification.";
}

identity classify-c-vlan {
  base eth-vlan-tag-classify;
  description
    "Classify 802.1Q Customer VLAN tag.
     Only C-tag type is accepted";
}

identity classify-s-vlan {
  base eth-vlan-tag-classify;
  description
    "Classify 802.1Q Service VLAN (QinQ) tag.
     Only S-tag type is accepted";
}

identity classify-s-or-c-vlan {
  base eth-vlan-tag-classify;
  description
    "Classify S-VLAN or C-VLAN tag-classify.
     Either tag is accepted";
}

identity bandwidth-profile-type {
  description
    "Bandwidth Profile Types";
}

identity mef-10-bwp {
  base bandwidth-profile-type;
  description
    "MEF 10 Bandwidth Profile";
}

identity rfc-2697-bwp {
  base bandwidth-profile-type;
  description
    "RFC 2697 Bandwidth Profile";
}
```



```
identity rfc-2698-bwp {
  base bandwidth-profile-type;
  description
    "RFC 2698 Bandwidth Profile";
}

identity rfc-4115-bwp {
  base bandwidth-profile-type;
  description
    "RFC 4115 Bandwidth Profile";
}

identity service-type {
  description
    "Type of Ethernet service.";
}

identity p2p-svc {
  base service-type;
  description
    "Ethernet point-to-point service (EPL, EVPL).";
}

identity rmp-svc {
  base service-type;
  description
    "Ethernet rooted-multitpoint service (E-TREE, EP-TREE).";
}

identity mp2mp-svc {
  base service-type;
  description
    "Ethernet multipoint-to-multitpoint service (E-LAN, EP-LAN).";
}

identity lifecycle-status {
  description
    "Lifecycle Status.";
}

identity installed {
  base lifecycle-status;
  description
    "Installed.";
}

identity planned {
  base lifecycle-status;
```

```
        description
            "Planned.";
    }

    identity pending-removal {
        base lifecycle-status;
        description
            "Pending Removal.";
    }

    /*
     * Type Definitions
     */

    typedef eth-tag-type {
        type identityref {
            base eth-vlan-tag-type;
        }
        description
            "Identifies a specific ETH VLAN tag type.";
    }

    typedef eth-tag-classify {
        type identityref {
            base eth-vlan-tag-classify;
        }
        description
            "Identifies a specific VLAN tag classification.";
    }

    typedef vlanid {
        type uint16 {
            range "1..4094";
        }
        description
            "The 12-bit VLAN-ID used in the VLAN Tag header.";
    }

    typedef vid-range-type {
        type string {
            pattern "([1-9][0-9]{0,3}(-[1-9][0-9]{0,3})?" +
                "(,[1-9][0-9]{0,3}(-[1-9][0-9]{0,3})?)*)";
        }
        description
            "A list of VLAN Ids, or non overlapping VLAN ranges, in
            ascending order, between 1 and 4094.
            This type is used to match an ordered list of VLAN Ids, or
            contiguous ranges of VLAN Ids. Valid VLAN Ids must be in the
```

range 1 to 4094, and included in the list in non overlapping ascending order.

For example: 1,10-100,50,500-1000";

}

```
typedef bandwidth-profile-type {  
  type identityref {  
    base bandwidth-profile-type;  
  }  
  description  
    "Identifies a specific Bandwidth Profile type.";  
}
```

```
typedef service-type {  
  type identityref {  
    base service-type;  
  }  
  description  
    "Identifies the type of Ethernet service.";  
}
```

```
typedef lifecycle-status {  
  type identityref {  
    base lifecycle-status;  
  }  
  description  
    "Identifies the Lifecycle Status .";  
}
```

/*

* Grouping Definitions

*/

```
grouping etht-bandwidth-profiles {  
  description  
    "Bandwidth profile configuration paramters.";  
  
  leaf bandwidth-profile-type {  
    type etht-types:bandwidth-profile-type;  
    description  
      "The type of bandwidth profile.";  
  }  
  leaf CIR {  
    type uint64;  
    description  
      "Committed Information Rate in Kbps";  
  }  
}
```

```
leaf CBS {
    type uint64;
    description
        "Committed Burst Size in in KBytes";
}
leaf EIR {
    type uint64;
    /* Need to indicate that EIR is not supported by RFC 2697

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

    must
        '../bw-profile-type != "rfc-2697-bwp"'
    */
    description
        "Excess Information Rate in Kbps
        In case of RFC 2698, PIR = CIR + EIR";
}
leaf EBS {
    type uint64;
    description
        "Excess Burst Size in KBytes.
        In case of RFC 2698, PBS = CBS + EBS";
}
leaf color-aware {
    type boolean;
    description
        "Indicates weather the color-mode is
        color-aware or color-blind.";
}
leaf coupling-flag {
    type boolean;
    /* Need to indicate that Coupling Flag is defined only for MEF 10

    must
        '../bw-profile-type = "mef-10-bwp"'
    */
    description
        "Coupling Flag.";
}
}

identity topology-role {
    description
        "The role of underlay topology: e.g., hub, spoke,
```

```
        any-to-any.";
    }

    identity resilience {
        description
            "Placeholder for resilience information in data plane,
            for future study. ";
    }

    identity access-role {
        description
            "Indicating whether the access is a working or protection access.";
    }

    identity root-primary {
        base access-role;
        description
            "Designates the primary root UNI of an E-Tree service, and may also
            designates the UNI access role of E-LINE and E-LAN service.";
    }

    identity root-backup {
        base access-role;
        description
            "Designates the backup root UNI of an E-Tree service.";
    }

    identity leaf-access {
        base access-role;
        description
            "Designates the leaf UNI of an E-Tree service.";
    }

    identity performance {
        description
            "Placeholder for performance information, for future study.";
    }

    identity encapsulation-type {
        description
            "Indicating how the service is encapsulated (to PW), e.g, raw or tag. ";
    }

    grouping pw-segement-bandwidth-profile-grouping {
        description
            "bandwidth profile grouping for PW segment. ";
        leaf bandwidth-profile-type {
            type etht-types:bandwidth-profile-type;
        }
    }
}
```

```
        description
            "The type of bandwidth profile.";
    }
    leaf CIR {
        type uint64;
        description
            "Committed Information Rate in Kbps";
    }
    leaf CBS {
        type uint64;
        description
            "Committed Burst Size in in KBytes";
    }
    leaf EIR {
        type uint64;
        /* Need to indicate that EIR is not supported by RFC 2697

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

        must
            '../bw-profile-type != "rfc-2697-bwp"'
        */
        description
            "Excess Information Rate in Kbps
            In case of RFC 2698, PIR = CIR + EIR";
    }
    leaf EBS {
        type uint64;
        description
            "Excess Burst Size in KBytes.
            In case of RFC 2698, PBS = CBS + EBS";
    }
}

grouping eth-bandwidth {
    description
        "Available bandwidth for ethernet.";
    leaf eth-bandwidth {
        type uint64{
            range "0..100000000000";
        }
        units "Kbps";
        description
            "Available bandwidth value expressed in kilobits per second";
    }
}
```

```
    grouping eth-label-restriction {
      description
        "Label Restriction for ethernet.";
      leaf tag-type {
        type eth-types:eth-tag-type;
        description "VLAN tag type.";
      }
      leaf priority {
        type uint8;
        description "priority.";
      }
    }
    grouping eth-label {
      description
        "Label for ethernet.";
      leaf vlanid {
        type eth-types:vlanid;
        description
          "VLAN tag id.";
      }
    }

    grouping eth-label-step {
      description "Label step for Ethernet VLAN";
      leaf eth-step {
        type uint16 {
          range "1..4095";
        }
      }
      default 1;
      description
        "Label step which represent possible increments for
        an Ethernet VLAN tag.";
      reference
        "IEEE 802.1ad: Provider Bridges.";
    }
  }
}
<CODE ENDS>
```

5.3. Other Client Signal YANG Code

This module imports typedefs and modules from [RFC6991], [I-D.ietf-ccamp-otn-tunnel-model], [RFC8776].

```
<CODE BEGINS> file "ietf-trans-client-service@2021-01-11.yang"
module ietf-trans-client-service {
  /* TODO: FIXME */
  yang-version 1.1;

  namespace "urn:ietf:params:xml:ns:yang:ietf-trans-client-service";
  prefix "clntsvc";

  import ietf-te-types {
    prefix "te-types";
    reference "RFC 8776 - Traffic Engineering Common YANG Types";
  }

  import ietf-layer1-types {
    prefix "layer1-types";
    reference "RFC ZZZZ - A YANG Data Model for Layer 1 Types";
  }

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

  import ietf-trans-client-svc-types {
    prefix "clntsvc-types";
    reference "RFC XXXX - A YANG Data Model for
      Transport Network Client Signals";
  }

  organization
    "Internet Engineering Task Force (IETF) CCAMP WG";
  contact
    "
      ID-draft editor:
      Haomian Zheng (zhenghaomian@huawei.com);
      Aihua Guo (aihuaguo.ietf@gmail.com);
      Italo Busi (italo.busi@huawei.com);
      Anton Snitser (asnizar@cisco.com);
      Francesco Lazzeri (francesco.lazzeri@ericsson.com);
    ";

  description
    "This module defines a YANG data model for describing
      transport network client 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."
```


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```
revision 2021-01-11 {
  description
    "version -04 as a WG document";
  reference
    "draft-ietf-ccamp-client-signal-yang";
}

/*
 * Groupings
 */
grouping client-svc-access-parameters {
  description
    "Transport network client signals access parameters";

  leaf access-node-id {
    type te-types:te-node-id;
    description
      "The identifier of the access node in the underlying
       transport network topology.";
  }

  leaf access-ltp-id {
    type te-types:te-tp-id;
    description
      "The TE link termination point identifier, used together with
       access-node-id to identify the access LTP.";
  }

  leaf client-signal {
    type identityref {
      base layer1-types:client-signal;
    }
    description
      "Identify the client signal type associated with this port";
  }
}
```

```
grouping client-svc-tunnel-parameters {
  description
    "Transport network client signals tunnel parameters";

  leaf tunnel-name {
    type string;
    description
      "TE tunnel instance name.";
  }
}

grouping client-svc-instance-config {
  description
    "Configuration parameters for client services.";
  leaf client-svc-name {
    type string;
    description
      "Identifier of the p2p transport network client signals.";
  }

  leaf client-svc-title {
    type string;
    description
      "Name of the p2p transport network client signals.";
  }

  leaf client-svc-descr {
    type string;
    description
      "Description of the transport network client signals.";
  }

  leaf client-svc-customer {
    type string;
    description
      "Customer of the transport network client signals.";
  }

  container resilience {
    description "Place holder for resilience functionalities";
  }

  uses te-types:te-topology-identifier;

  leaf admin-status {
    type identityref {
      base te-types:tunnel-admin-state-type;
    }
  }
}
```

```
    default te-types:tunnel-admin-state-up;
    description "Client signals administrative state.";
  }

  container src-access-ports {
    description
      "Source access port of a client signal.";
    uses client-svc-access-parameters;
  }

  container dst-access-ports {
    description
      "Destination access port of a client signal.";
    uses client-svc-access-parameters;
  }

  leaf direction {
    type identityref {
      base clntsvc-types:direction;
    }
    description "Uni-dir or Bi-dir for the client signal.";
  }

  list svc-tunnels {
    key tunnel-name;
    description
      "List of the TE Tunnels supporting the client signal.";
    uses client-svc-tunnel-parameters;
  }
}

grouping client-svc-instance-state {
  description
    "State parameters for client services.";
  leaf operational-state {
    type identityref {
      base te-types:tunnel-state-type;
    }
    config false;
    description "Client signal operational state.";
  }
  leaf provisioning-state {
    type identityref {
      base te-types:lsp-state-type;
    }
    config false;
    description "Client signal provisioning state.";
  }
}
```

```
    leaf creation-time {
        type yang:date-and-time;
        config false;
        description "The time of the client signal be created.";
    }
    leaf last-updated-time {
        type yang:date-and-time;
        config false;
        description "The time of the client signal's latest update.";
    }
    leaf created-by {
        type string;
        config false;
        description
            "The client signal is created by whom,
             can be a system or staff ID.";
    }
    leaf last-updated-by {
        type string;
        config false;
        description
            "The client signal is last updated by whom,
             can be a system or staff ID.";
    }
    leaf owned-by {
        type string;
        config false;
        description
            "The client signal is owned by whom,
             can be a system ID.";
    }
}

/*
 * Data nodes
 */

container client-svc {
    description
        "Transport client services.";

    list client-svc-instances {
        key client-svc-name;
        description
            "The list of p2p transport client service instances";

        uses client-svc-instance-config;
        uses client-svc-instance-state;
    }
}
```

```
    }  
  }  
}  
<CODE ENDS>
```

5.4. Other Client Signal Types YANG Code

This module defines the types for other client signal types.

```
<CODE BEGINS> file "ietf-trans-client-svc-types@2019-11-03.yang"  
module ietf-trans-client-svc-types {  
  namespace "urn:ietf:params:xml:ns:yang:ietf-trans-client-svc-types";  
  prefix "clntsvc-types";  
  
  organization  
    "Internet Engineering Task Force (IETF) CCAMP WG";  
  contact  
    "  
    ID-draft editor:  
      Haomian Zheng (zhenghaomian@huawei.com);  
      Aihua Guo (aihuaguo.ietf@gmail.com);  
      Italo Busi (italo.busi@huawei.com);  
      Anton Snitser (asnizar@cisco.com);  
      Francesco Lazzeri (francesco.lazzeri@ericsson.com);  
    ";  
  
  description  
    "This module defines a YANG data model for describing  
    transport network client types. The model fully conforms  
    to the Network Management Datastore Architecture (NMDA).  
  
    Copyright (c) 2019 IETF Trust and the persons  
    identified as authors of the code. All rights reserved.  
  
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    to the license terms contained in, the Simplified BSD License  
    set forth in Section 4.c of the IETF Trust's Legal Provisions  
    Relating to IETF Documents  
    (https://trustee.ietf.org/license-info).  
    This version of this YANG module is part of RFC XXXX; see  
    the RFC itself for full legal notices.";  
  
  revision 2019-11-03 {  
    description  
      "version -01 as a WG document";  
    reference  
      "draft-ietf-ccamp-client-signal-yang";
```

```
    }

    identity direction {
      description
        "Direction information of Client Signal.";
    }

    identity bidirectional {
      base direction;
      description
        "Client Signal is bi-directional.";
    }

    identity unidirectional {
      base direction;
      description
        "Client Signal is uni-directional.";
    }
  }
}
<CODE ENDS>
```

6. Implementation Status

[Note to the RFC Editor - remove this section before publication, as well as remove the reference to RFC [RFC7942].]

This section records the status of known implementations of the protocol defined by this specification at the time of posting of this Internet-Draft, and is based on a proposal described in [RFC7942]. The description of implementations in this section is intended to assist the IETF in its decision processes in progressing drafts to RFCs. Please note that the listing of any individual implementation here does not imply endorsement by the IETF. Furthermore, no effort has been spent to verify the information presented here that was supplied by IETF contributors. This is not intended as, and must not be construed to be, a catalog of available implementations or their features. Readers are advised to note that other implementations may exist.

According to [RFC7942], "this will allow reviewers and working groups to assign due consideration to documents that have the benefit of running code, which may serve as evidence of valuable experimentation and feedback that have made the implemented protocols more mature. It is up to the individual working groups to use this information as they see fit".

6.1. Usage of the ETH Service YANG Model on ONAP

The implementation of the CCVPN (Cross Domain and Cross Layer VPN) use-case on ONAP follows the ACTN [RFC8453] architecture. In the design of CCVPN, ONAP presumes the responsibility of the MDSC, and third party network domain controllers the PNCs. Consequently, the ETH Service YANG model is used as the MPI between ONAP and the domain controllers.

- * Organization: China Mobile, Huawei Technologies, etc.
- * Implementation: ONAP CCVPN uses the ETH Service YANG model as the ACTN MPI
- * Description: ONAP CCVPN realizes the E-LINE and E-TREE service on a multi-domain network. Both of the services are modeled on ONAP by the ETH Service YANG model, and the model instances (e.g., JSON objects) are sent between ONAP and the domain controllers. Refer to the following CCVPN wiki for more information:
<https://wiki.onap.org/display/DW/CCVPN%28Cross+Domain+and+Cross+Layer+VPN%29+USE+CASE>
- * Maturity Level: Prototype
- * Coverage: Partial
- * Contact: henry.yu1@huawei.com

7. IANA Considerations

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

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

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

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

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

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

name: ietf-eth-tran-service
namespace: urn:ietf:params:xml:ns:yang:ietf-eth-tran-service
prefix: ethtsvc
reference: RFC XXXX: A YANG Data Model for Transport
Network Client Signals

name: ietf-eth-tran-types
namespace: urn:ietf:params:xml:ns:yang:ietf-eth-tran-types
prefix: etht-types
reference: RFC XXXX: A YANG Data Model for Transport
Network Client Signals

name: ietf-trans-client-service
namespace: urn:ietf:params:xml:ns:yang:ietf-trans-client-service
prefix: clntsvc
reference: RFC XXXX: A YANG Data Model for Transport
Network Client Signals

name: ietf-trans-client-svc-types
namespace: urn:ietf:params:xml:ns:yang:ietf-trans-client-svc-types
prefix: clntsvc-types
reference: RFC XXXX: A YANG Data Model for Transport
Network Client Signals

8. Manageability Considerations

TBD.

9. Security Considerations

The data following the model defined in this document is exchanged via, for example, the interface between an orchestrator and a network domain controller.

The YANG module defined in this document can be accessed via the RESTCONF protocol defined in [RFC8040], or maybe via the NETCONF protocol [RFC6241].

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

10. Acknowledgements

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A YANG model to manage the optical interface parameters for an external
transponder in a WDM network
draft-ietf-ccamp-dwdm-if-param-yang-06

Abstract

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

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

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1. Introduction

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

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

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

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

2. The Internet-Standard Management Framework

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

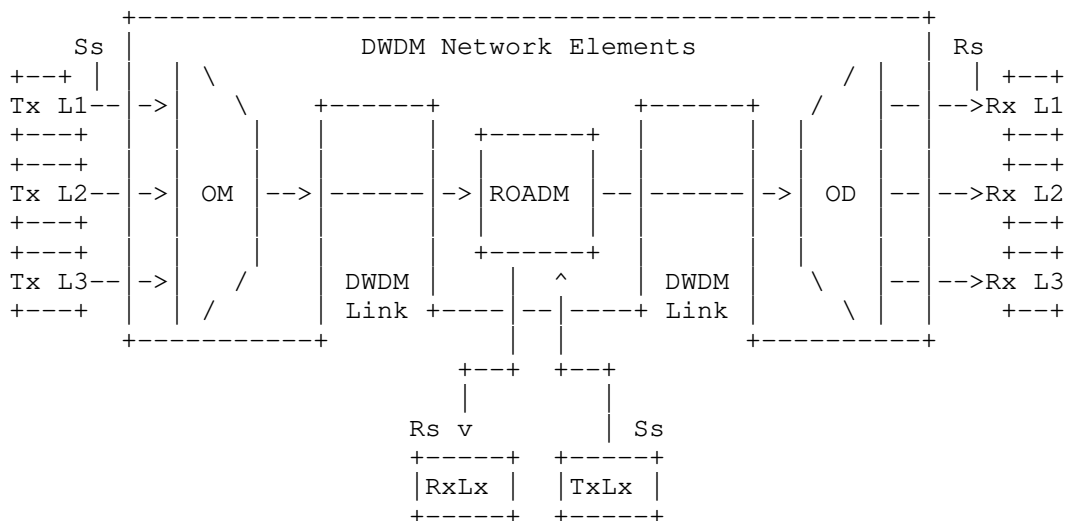
This memo specifies a Yang model for optical interfaces.

3. Conventions

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

4. Overview

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



Ss = reference point at the DWDM network element tributary output

Rs = reference point at the DWDM network element tributary input

Lx = Lambda x

OM = Optical Mux

OD = Optical Demux

ROADM = Reconfigurable Optical Add Drop Mux

from Fig. 5.1/G.698.2

Figure 1: External transponder in WDM networks

4.1. Optical Parameters Description

The link between the external transponders through a WDM network media channels are managed at the edges, i.e. at the transmitters (Tx) and receivers (Rx) attached to the S and R reference points respectively.

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

4.1.1. Parameters at Ss

output-power:

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

central frequency:

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

4.1.2. Interface at point Rs

input-power:

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

Curr-OSNR:

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

Curr-q-factor:

"Q" factor estimated at Rx Transceiver port.

4.2. Use Cases

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

4.3. Optical Interface for external transponder in a WDM network

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

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

```

+--ro mode-id?                               string
+--ro (mode)
  +--:(G.698.2)
    +--ro standard-mode?                     standard-mode
  +--:(organizational-mode)
    +--ro organizational-mode
      +--ro operational-mode?
        | operational-mode
      +--ro organization-identifier?
        | organization-identifier
      +--ro min-central-frequency?
        | frequency-thz
      +--ro max-central-frequency?
        | frequency-thz
      +--ro minimum-channel-spacing?
        | 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?
    +--:(explicit-mode)
      +--ro explicit-mode
        +--ro supported-modes
          | +--ro supported-application-codes*
          | | -> ../../../../mode-id
          | +--ro supported-organizational-modes*
          | | -> ../../../../mode-id
        +--ro line-coding-bitrate?
          | identityref
        +--ro min-central-frequency?
          | layer0-types:frequency-thz
        +--ro max-central-frequency?
          | layer0-types:frequency-thz
        +--ro min-channel-input-power?         dbm-t
        +--ro max-channel-input-power?         dbm-t
        +--ro min-channel-output-power?        dbm-t
        +--ro max-channel-output-power?        dbm-t
        +--ro osnr-margin?                     int32
        +--ro q-margin?                        int32
        +--ro fec-info?                        string
        +--ro fec-bitrate?                     string
        +--ro fec-gain?                        string
        +--ro pre-fec-ber-mantissa-threshold?  uint32
        +--ro pre-fec-ber-exponent-threshold?  int32
        +--ro number-of-lanes?                 uint32
        +--ro min-laser-temperature?           int32
        +--ro max-laser-temperature?           int32

```

```

    +--ro max-total-rx-optical-power?          dbm-t
    +--ro chromatic-and-polariz-disp-penal* []
      | +--ro chromatic-dispersion
      | | decimal64
      | +--ro polarization-mode-dispersion
      | | decimal64
      | +--ro penalty
      | | decimal64
    +--ro max-chromatic-dispersion?             int32
    +--ro max-diff-group-delay?                 int32
    +--ro max-polarization-dependent-loss?
      | decimal64
    +--ro modulation-format?                   string
    +--ro baud-rate?                           uint32
    +--ro bits-per-symbol?                     uint32
    +--ro num-symbols-in-alphabet?             uint32
    +--ro symbols-index?                       uint32
+--ro if-supported-mode
  | +--ro number-of-modes-supported?           uint32
+--rw if-supported-modes*
  | +--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?
    | | | organization-identifier
    | | +--ro min-central-frequency?
    | | | frequency-thz
    | | +--ro max-central-frequency?
    | | | frequency-thz
    | | +--ro minimum-channel-spacing?
    | | | 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?
    +--:(explicit-mode)
    | +--ro explicit-mode
    | +--ro supported-modes
    | | +--ro supported-application-codes*
    | | | -> ../../../../mode-id
    | | +--ro supported-organizational-modes*
    | | | -> ../../../../mode-id

```

```

+--ro line-coding-bitrate?
| | identityref
+--ro min-central-frequency?
| | layer0-types:frequency-thz
+--ro max-central-frequency?
| | layer0-types:frequency-thz
+--ro min-channel-input-power? dbm-t
+--ro max-channel-input-power? dbm-t
+--ro min-channel-output-power? dbm-t
+--ro max-channel-output-power? dbm-t
+--ro osnr-margin? int32
+--ro q-margin? int32
+--ro fec-info? string
+--ro fec-bitrate? string
+--ro fec-gain? string
+--ro pre-fec-ber-mantissa-threshold? uint32
+--ro pre-fec-ber-exponent-threshold? int32
+--ro number-of-lanes? uint32
+--ro min-laser-temperature? int32
+--ro max-laser-temperature? int32
+--ro max-total-rx-optical-power? dbm-t
+--ro chromatic-and-polariz-disp-penal* []
| +--ro chromatic-dispersion
| | decimal64
| +--ro polarization-mode-dispersion
| | decimal64
| +--ro penalty
| | decimal64
+--ro max-chromatic-dispersion? int32
+--ro max-diff-group-delay? int32
+--ro max-polarization-dependent-loss?
| decimal64
+--ro modulation-format? string
+--ro baud-rate? uint32
+--ro bits-per-symbol? uint32
+--ro num-symbols-in-alphabet? uint32
+--ro symbols-index? uint32
+--rw provisioning-opt-if-och-mode-params
+--rw provisioning-opt-if-och-mode-params
+--rw mode-id? string
+--rw (mode)
+--rw central-frequency?
| layer0-types:frequency-thz
+--rw channel-output-power? dbm-t
+--ro channel-input-power? dbm-t
+--ro total-input-power? dbm-t
+--rw number-of-tcas-supported? uint32
+--rw mode-list* [tca-type]

```

```

    | +--rw tca-type          opt-if-och-tca-types
    | +--rw min-threshold?   int32
    | +--rw max-threshold?   int32
+--ro cur-osnr?              int32
+--ro cur-q-factor?          int32
+--ro uncorrected-words?     uint64
+--ro pre-fec-ber-mantissa?  uint32
+--ro pre-fec-ber-exponent?  int32
+--ro cd-pmd-penalty
|   layer0-types:cd-pmd-penalty
+--ro pdl-penalty
|   layer0-types:pdl-penalty
+--ro diff-group-delay       int32
+--rw explicit-mode-provisioning
    +--rw fec                 string
    +--rw pre-fec-ber-mantissa-threshold?  uint32
    +--rw pre-fec-ber-exponent-threshold?  int32
    +--rw number-of-lanes?    uint32
    +--rw modulation-format?  string
    +--rw baud-rate?          uint32
    +--rw bits-per-symbol?     uint32
    +--rw num-symbols-in-alphabet?  uint32
    +--rw symbols-index?       uint32

```

notifications:

```

+---n opt-if-och-central-frequency-change
|   +--ro if-name?          -> /if:interfaces/interface/name
|   +--ro new-opt-if-och-central-frequency
|       +--ro central-frequency?  layer0-types:frequency-thz
+---n opt-if-och-mode-change
|   +--ro if-name?          -> /if:interfaces/interface/name
|   +--ro mode-id?          string
+---n opt-if-och-min-tca
    +--ro if-name?          -> /if:interfaces/interface/name
    +--ro tca-type?         opt-if-och-tca-types

```

5. Structure of the Yang Module

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

6. Yang Module

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

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

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

  import ietf-interfaces {
    prefix if;
  }

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

  organization
    "IETF CCAMP
    Working Group";

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

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

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

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

  revision "2021-06-28" {
    description
```

```
        "Revision 1.6";
    reference
        "";
}

revision "2020-03-09" {
    description
        "Revision 1.5";
    reference
        "";
}

revision "2019-11-04" {
    description
        "Revision 1.4";
    reference
        "";
}

revision "2019-07-08" {
    description
        "Revision 1.3";
    reference
        "";
}

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

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

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

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



```
}
```

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

```
typedef opt-if-och-tca-types {  
    type enumeration {  
        enum max-laser-linewdt {  
            description "The maximum laser linewidth";  
        }  
        enum min-tx-power-tca {  
            description "The min tx power TCA";  
        }  
        enum max-tx-power-tca {  
            description "The min tx power TCA";  
        }  
        enum min-rx-power-tca{  
            description "The min tx power TCA";  
        }  
        enum max-rx-power-tca{  
            description "The min tx power TCA";  
        }  
        enum max-pol-power-diff-tca{  
            description "The power difference between polarization  
                TCA";  
        }  
        enum max-pol-skew-diff-tca{  
            description "The skew between the two polarization TCA";  
        }  
        enum min-frequency-offset-tca{  
            description "Min Frequency offset TCA";  
        }  
        enum max-frequency-offset-tca{  
            description "Max Frequency offset TCA";  
        }  
        enum min-osnr-tca{  
            description "Min OSNR TCA";  
        }  
    }
```

```
    enum max-osnr-tca{
        description "Max OSNR TCA";
    }
    enum min-laser-temperature-tca{
        description "The min tx power TCA";
    }
    enum max-laser-temperature-tca{
        description "Temperature TCA";
    }
    enum min-fec-ber-tca{
        description "Min Pre Fec BER TCA";
    }
    enum max-fec-ber-tca{
        description "Max Pre Fec BER TCA";
    }
    enum min-q-tca{
        description "Min Q TCA";
    }
    enum max-q-tca {
        description "Max Q TCA";
    }
}
description "The different types of TCA's";
}

grouping opt-if-och-power {
    description "Interface optical Power";

    leaf channel-output-power {
        type dbm-t;
        description "The output power for this interface in .01 dBm.
                    The setting of the output power is optional";
    }

    leaf channel-input-power {
        type dbm-t;
        config false;
        description "The current channel input power of this
                    interface";
    }

    leaf total-input-power {
        type dbm-t;
        config false;
        description "The total input power of this interface";
    }
}
```

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

grouping opt-if-och-fec {
  description "FEC info";

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

grouping opt-if-och-central-frequency {
  description "Interface Central Frequency";
```

```
    leaf central-frequency {
      type layer0-types:frequency-thz;
      description "This parameter indicates the frequency of this
                  interface ";
    }
  }

  grouping opt-if-och-modulation-params {
    description "Optical modulation parameters for the lane";

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

  grouping opt-if-och-lane-param {
    description "Optical parameters for the lane";

    leaf number-of-lanes {
      type uint32;
      config false;
      description "Number of optical lanes of this interface";
    }
    leaf min-laser-temperature {
      type int32;
      units ".01C";
      config false;
      description "Minimum Laser Temperature of this mode for
```

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

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

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

```
    }
    leaf min-fec-ber-exponent-threshold {
        type int32;
        description "Min Exponent of the FEC BER threshold";
    }
    leaf max-fec-ber-mantissa-threshold {
        type uint32;
        description "Max Mantissa of the FEC BER threshold";
    }
    leaf max-fec-ber-exponent-threshold {
        type int32;
        description "Max Exponent of the FEC BER threshold";
    }
}

grouping opt-if-och-mode-params {
    description "OCh mode parameters";
    leaf mode-id {
        type string { length "1..255"; }
        description "ID for the OCh mode template";
    }
    leaf min-osnr-margin {
        type int32;
        units "dB";
        config false;
        description "OSNR margin to FEC threshold";
    }
    leaf q-margin {
        type int32;
        units "dB";
        config false;
        description "Q-Factor margin to FEC threshold";
    }
    uses opt-if-och-central-frequency;
    uses opt-if-och-power;
    uses opt-if-och-fec-tca-thresholds;
    uses opt-if-och-tca-list;
}

grouping opt-if-och-statistics {
    description "OCh statistics";
    leaf cur-osnr {
        type int32;
        units "dB";
        config false;
        description "OSNR margin to FEC threshold";
    }
    leaf cur-q-factor {
```

```
        type int32;
        units "dB";
        config false;
        description "Q-Factor of the interface";
    }
    leaf uncorrected-words {
        type uint64;
        config false;
        description "Post-FEC errored words";
    }
    leaf pre-fec-ber-mantissa {
        type uint32;
        config false;
        description "Pre-FEC errored words mantissa";
    }
    leaf pre-fec-ber-exponent {
        type int32;
        config false;
        description "Pre-FEC errored words exponent";
    }
}

grouping opt-if-och-mode {
    description "OCh mode template";

    leaf mode-id {
        type string { length "1..255"; }
        config false;
        description "ID for the OCh mode template";
    }
    leaf application-identifier {
        type uint32;
        config false;
        description "This parameter indicates the application
                    identifier according to G.698.2";
    }

    leaf min-central-frequency {
        type layer0-types:frequency-thz;
        config false;
        description
            "his parameter indicates the minimum frequency for
             this template";
    }
    leaf max-central-frequency {
        type layer0-types:frequency-thz;
        config false;
    }
}
```

```
        description "This parameter indicates the minimum frequency
                    for this template";
    }
    leaf min-channel-input-power {
        type dbm-t;
        config false;
        description "The minimum input power of this interface";
    }
    leaf max-channel-input-power {
        type dbm-t;
        config false;
        description "The maximum input power of this interface";
    }
    leaf min-channel-output-power {
        type dbm-t;
        config false;
        description "The minimum output power of this interface";
    }
    leaf max-channel-output-power {
        type dbm-t;
        config false;
        description "The maximum output power of this interface";
    }
    leaf osnr-margin {
        type int32;
        units "dB";
        config false;
        description "OSNR margin to FEC threshold";
    }
    leaf q-margin {
        type int32;
        units "dB";
        config false;
        description "Q-Factor margin to FEC threshold";
    }
    uses opt-if-och-fec;
    uses opt-if-och-lane-param;
}

grouping opt-if-och-mode-list {
    description "List of Mode list group";

    leaf number-of-modes-supported {
        type uint32;
        description "Number of modes supported by this interface";
    }
    list mode-list {
        key "mode-id";
```



```
        description "List of the modes";
        uses opt-if-och-mode;
    }
}

notification opt-if-och-central-frequency-change {
    description "A change of Central Frequency has been detected";

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

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

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

notification opt-if-och-min-tca {
    description "A min output TCA notification";

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

augment "/if:interfaces/if:interface" {
    description "Parameters for an optical interface";

    container optIfOChRsSs {
```

```
    description "RsSs path configuration for an interface";

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

<CODE ENDS>
```

7. Security Considerations

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

8. IANA Considerations

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

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

Registrant Contact: The IESG.

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

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

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

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

9. Acknowledgements

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Appendix A. Change Log

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

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

Appendix B. Open Issues

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

Appendix C. Applicability examples

As an example here below is the way an OpenROADM compliant equipment could be managed using the Yang models described in this draft.

In OpenROADM MSA there is a limited number of DWDM interfaces supported. Basically only the 100G Staircase FEC and 400G oFEC are supported and these two kind of interfaces can be easily summarized with the "mode-id" and the "application-identifier" strings.

The models below are enough to identify the interface and few working parameters:

```

module: ietf-ext-xponder-wdm-if
augment /if:interfaces/if:interface:
  +--rw optIfOChRsSs
    +--rw if-current-mode
      |   +--ro mode-id?                string
      |   +--ro application-identifier? string
      .
      .
      .
    +--rw current-opt-if-och-mode-params
      +--rw mode-id?                string
      +--rw central-frequency?      frequency-thz
      +--rw channel-output-power?   dbm-t
      +--ro channel-input-power?    dbm-t
      .
      .
      .
      +--ro cur-osnr?                int32
      +--ro cur-q-factor?            int32
      +--ro uncorrected-words?       uint64
      +--ro pre-fec-ber-mantissa?    uint32
      +--ro pre-fec-ber-exponent?    int32

```

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

Abstract

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

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

Status of This Memo

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

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1. Introduction

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:

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

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

- o configuration data
- o state data

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

3. Flexi-Grid Media-Channel Overview

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

- o source address
- o source flexi-grid port
- o source flexi-grid transponder
- o destination address
- o destination flexi-grid port

- o destination flexi-grid transponder
- o list of links that defines the path
- o other optical attributes

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

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

4. Example of Use

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

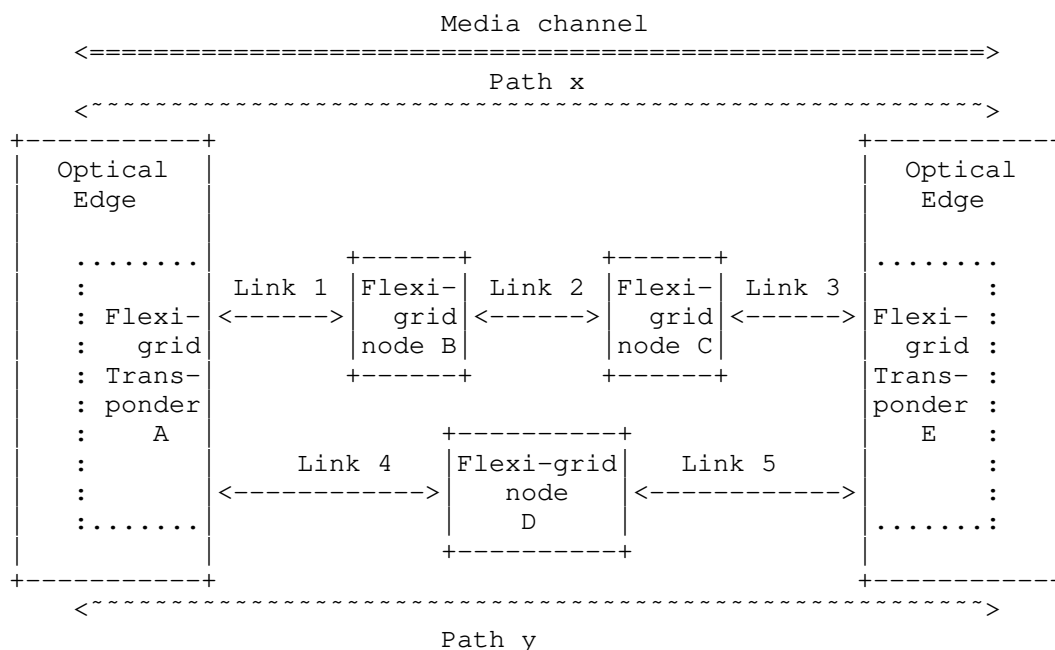


Figure 1: Topology Example

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

- o Depending on the case, it is possible to define either the source and destination node ports, or the source and destination node and transponder. In our case, we would define a network media channel, with source transponder A and source node B, and destination transponder E and destination node C. Thus, we are going to follow path x.
- o Then, for each link in the path x, we indicate which channel we are going to use, providing information about the slots, and what nodes are connected.
- o Finally, the flexi-grid topology has to be updated with each element usage status each time a media channel is created or torn down.

5. YANG Model for Flexi-Grid Media Channel

5.1. YANG Tree

```

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

```

```

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

```

```

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

```



```

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

```

```

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

```

```

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

```

```

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

```

```

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

```

```

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

```

```

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

```

```

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

```



```

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

```

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

```

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

```

```

+--ro usage identityref
+--ro values* srlg
+--ro path-srlgs-names
+--ro path-srlgs-name* [usage]
+--ro usage identityref
+--ro names* string
+--ro path-route-objects
+--ro path-computed-route-object*
    [index]
+--ro index
    |
    uint32
+--ro (type)?
+--:(numbered-node-hop)
    +--ro numbered-node-hop
        +--ro node-id te-node-id
        +--ro hop-type?
            te-hop-type
+--:(numbered-link-hop)
    +--ro numbered-link-hop
        +--ro link-tp-id te-tp-id
        +--ro hop-type?
            |
            te-hop-type
        +--ro direction?
            te-link-direction
+--:(unnumbered-link-hop)
    +--ro unnumbered-link-hop
        +--ro link-tp-id te-tp-id
        +--ro node-id
            |
            te-node-id
        +--ro hop-type?
            |
            te-hop-type
        +--ro direction?
            te-link-direction
+--:(as-number)
    +--ro as-number-hop
        +--ro as-number
            |
            inet:as-number
        +--ro hop-type?
            te-hop-type
+--:(label)
    +--ro label-hop
        +--ro te-label
            +--ro (technology)?
                +--:(generic)
                    +--ro generic?
                        rt-types:generalized-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}?
            +---rw optimization-metric* [metric-type]
                +---rw metric-type
                    | identityref
                +---rw weight?
                    | uint8
                +---rw explicit-route-exclude-objects
                    +---rw route-object-exclude-object*
                        [index]
                +---rw index
                    | uint32
                +---rw (type)?
                    +---:(numbered-node-hop)
                        +---rw numbered-node-hop
                            +---rw node-id
                                | te-node-id
                            +---rw hop-type?
                                | te-hop-type
                    +---:(numbered-link-hop)
                        +---rw numbered-link-hop
                            +---rw link-tp-id
                                | te-tp-id
                            +---rw hop-type?
                                | te-hop-type
                            +---rw direction?
                                | te-link-direction
                    +---:(unnumbered-link-hop)
                        +---rw unnumbered-link-hop
                            +---rw link-tp-id
                                | te-tp-id

```

```

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

```

```

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

```

```

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

```



```

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

```

```

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

```

```

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

```

[illegible]

```

+--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-secondary-reverse-path
  +--rw secondary-path?      leafref
  +--rw path-setup-protocol?  identityref
+--rw candidate-p2p-secondary-paths
  +--rw candidate-p2p-secondary-path*
      [secondary-path]
      +--rw secondary-path      leafref
      +--rw path-setup-protocol? identityref
      +--ro active?             boolean
+--rw p2p-secondary-paths
  +--rw p2p-secondary-path* [name]
      +--rw name                  string
      +--rw path-setup-protocol?  identityref
      +--rw path-computation-method? identityref
      +--rw path-computation-server?
      |
      inet:ip-address
      +--rw compute-only?          empty
      +--rw use-path-computation?  boolean
      +--rw lockdown?              empty
      +--ro path-scope?             identityref
      +--rw optimizations
      |
      +--rw (algorithm)?
      |
      +--:(metric) {path-optimization-metric}?
      |
      |
      +--rw optimization-metric* [metric-type]
      |
      |
      +--rw metric-type
      |
      |
      identityref
      +--rw weight?
      |
      |
      uint8

```

```

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

```



```

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

```

```

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

```

```

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

```

```

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

```

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

```

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

```

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

```

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

```



```

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

```

```

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

```

```

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

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

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

```

5.2. YANG Code

```

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

```

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

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

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

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

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

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

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

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

```
identified as authors of the code. All rights reserved.
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set forth in Section 4.c of the IETF Trust's Legal Provisions
Relating to IETF Documents
(https://trustee.ietf.org/license-info).
This version of this YANG module is part of RFC XXXX; see
the RFC itself for full legal notices.";

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

/*
 * Data nodes
 */

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

/*
 * Augment TE label.
 */

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

```
}

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

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

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

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

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

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

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

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

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



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

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

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

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

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

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

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

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

6. Security Considerations

To Be discussed.

7. IANA Considerations

To be discussed.

8. Contributors

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

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

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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.

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

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].

Prefix	YANG module	Reference
10-types	RFC9093	[RFCXXXX]
flexgt	ietf-flexi-grid-topology	[RFCYYYY]
nw	ietf-network	[RFC8345]
nt	ietf-network-topology	[RFC8345]
tet	ietf-te-topology	[RFC8795]

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.

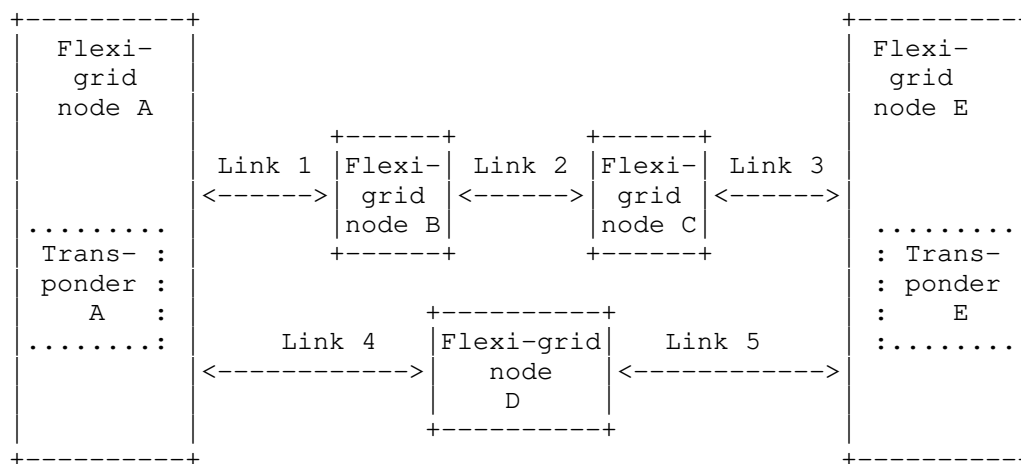


Figure 2: Topology Example

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.

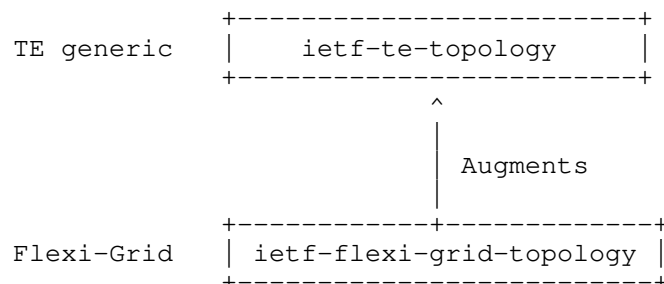


Figure 3: Relationship between Flexi-Grid and TE topology models

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
augment /nw:networks/tet:te/tet:templates/tet:link-template
    /tet:te-link-attributes/tet:label-restrictions
    /tet:label-restriction:
+---rw grid-type?      identityref
+---rw priority?       uint8
+---rw flexi-grid
    +---rw slot-width-granularity?  identityref
    +---rw min-slot-width-factor?    uint16
    +---rw max-slot-width-factor?    uint16
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:te-node-attributes/tet:connectivity-matrices
    /tet:label-restrictions/tet:label-restriction
    /tet:label-start/tet:te-label/tet:technology:
+---:(flexi-grid)
    +---rw flexi-n?     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: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:te-node-attributes/tet:connectivity-matrices
  /tet:underlay/tet:backup-path/tet:path-element/tet:type
  /tet:label/tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
  +---rw (single-or-super-channel)?
    +---:(single)
      |   +---rw flexi-n?           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:
+---:(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-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: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:connectivity-matrix/tet:underlay/tet:primary-path
        /tet:path-element/tet:type/tet:label/tet:label-hop
        /tet:te-label/tet:technology:
    +---:(flexi-grid)
        +---rw (single-or-super-channel)?
            +---:(single)
                |   +---rw flexi-n?                    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:connectivity-matrix/tet:underlay/tet:backup-path
        /tet:path-element/tet:type/tet:label/tet:label-hop
        /tet:te-label/tet:technology:
    +---:(flexi-grid)
        +---rw (single-or-super-channel)?
            +---:(single)
                |   +---rw flexi-n?                    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:connectivity-matrix/tet:optimizations/tet:algorithm
        /tet:metric/tet:optimization-metric
        /tet:explicit-route-exclude-objects
        /tet:route-object-exclude-object/tet:type/tet:label
        /tet:label-hop/tet:te-label/tet:technology:

```

```

+---:(flexi-grid)
  +---rw (single-or-super-channel)?
    +---:(single)
      |   +---rw flexi-n?           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:connectivity-matrix/tet:optimizations/tet:algorithm
  /tet:metric/tet:optimization-metric
  /tet:explicit-route-include-objects
  /tet:route-object-include-object/tet:type/tet:label
  /tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
  +---rw (single-or-super-channel)?
    +---:(single)
      |   +---rw flexi-n?           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:connectivity-matrix/tet:path-properties
  /tet:path-route-objects/tet:path-route-object/tet:type
  /tet:label/tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
  +---ro (single-or-super-channel)?
    +---:(single)
      |   +---ro flexi-n?           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-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: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: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:underlay/tet:primary-path/tet:path-element/tet:type
        /tet:label/tet:label-hop/tet:te-label/tet:technology:
    +---:(flexi-grid)
        +---ro (single-or-super-channel)?
        +---:(single)
            | +---ro flexi-n?                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:underlay/tet:backup-path/tet:path-element/tet:type
        /tet:label/tet:label-hop/tet:te-label/tet:technology:
    +---:(flexi-grid)
        +---ro (single-or-super-channel)?
        +---:(single)
            | +---ro flexi-n?                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: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: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:connectivity-matrix/tet:to/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:underlay/tet:primary-path
  /tet:path-element/tet:type/tet:label/tet:label-hop
  /tet:te-label/tet:technology:
  +---:(flexi-grid)
    +---ro (single-or-super-channel)?
      +---:(single)
        | +---ro flexi-n?                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:underlay/tet:backup-path
  /tet:path-element/tet:type/tet:label/tet:label-hop
  /tet:te-label/tet:technology:
  +---:(flexi-grid)

```

```

    +---ro (single-or-super-channel)?
      +---:(single)
        |   +---ro flexi-n?           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: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:connectivity-matrix/tet:optimizations/tet:algorithm
  /tet:metric/tet:optimization-metric
  /tet:explicit-route-include-objects
  /tet:route-object-include-object/tet:type/tet:label
  /tet:label-hop/tet:te-label/tet:technology:
+---:(flexi-grid)
  +---ro (single-or-super-channel)?
    +---:(single)
      |   +---ro flexi-n?           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/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: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: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: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: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: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: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-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: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-end/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
augment /nw:networks/tet:te/tet:templates/tet:link-template
      /tet:te-link-attributes/tet:underlay/tet:primary-path
      /tet:path-element/tet:type/tet:label/tet:label-hop
      /tet:te-label/tet:technology:
    +---:(flexi-grid)
      +---rw (single-or-super-channel)?
        +---:(single)
          | +---rw flexi-n?                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/tet:te/tet:templates/tet:link-template
      /tet:te-link-attributes/tet:underlay/tet:backup-path
      /tet:path-element/tet:type/tet:label/tet:label-hop
      /tet:te-label/tet:technology:
    +---:(flexi-grid)
      +---rw (single-or-super-channel)?
        +---:(single)
          | +---rw flexi-n?                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/tet:te/tet:templates/tet:link-template
  /tet:te-link-attributes/tet:label-restrictions
  /tet:label-restriction/tet:label-start/tet:te-label
  /tet:technology:
+---:(flexi-grid)
  +---rw flexi-n?   10-types:flexi-n
augment /nw:networks/tet:te/tet:templates/tet:link-template
  /tet:te-link-attributes/tet:label-restrictions
  /tet:label-restriction/tet:label-end/tet:te-label
  /tet:technology:
+---:(flexi-grid)
  +---rw flexi-n?   10-types:flexi-n
augment /nw:networks/tet:te/tet:templates/tet:link-template
  /tet:te-link-attributes/tet:label-restrictions
  /tet:label-restriction/tet:label-step/tet:technology:
+---:(flexi-grid)
  +---rw flexi-grid-channel-spacing?  identityref
  +---rw flexi-n-step?                uint8

```

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;
  namespace "urn:ietf:params:xml:ns:yang:ietf-flexi-grid-topology";
  prefix "flexgt";

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

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

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

```

```
    (TE) Topologies";
}

import ietf-layer0-types {
  prefix "l0-types";
  reference
    "RFC 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";
```

```
// 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" {
  description
    "Augment network types to define flexi-grid topology type.";
  container flexi-grid-topology {
    presence
      "Its presence identifies the flexi-grid topology type.";
    description
      "Introduce new network type for flexi-grid topology.";
  }
}

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

/*
 * Augment TE label range information
 */

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



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

```

    description
      "Augment TE label range information for the TE node
        connectivity matrices information source.";
    uses l0-types:flexi-grid-label-range-info;
  }

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

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

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

```

```

    description
      "Augment TE label range information for the Tunnel
      Termination Point (TTP) Local Link Connectivities.";
    uses l0-types:flexi-grid-label-range-info;
  }

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

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

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

```

```

        information source.";
    uses l0-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 l0-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 l0-types:flexi-grid-label-start-end;
    }
}

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

```

```

connectivity matrices.";
case flexi-grid {
  uses l0-types:flexi-grid-label-start-end;
}
}

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

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

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:te-node-attributes/tet:connectivity-matrices/"
+ "tet:underlay/tet:backup-path/tet:path-element/"

```

```

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

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

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:optimizations/tet:algorithm/tet:metric/"
    + "tet:optimization-metric/"
    + "tet:explicit-route-include-objects/"
    + "tet:route-object-include-object/"
    + "tet:type/tet:label/tet:label-hop/"

```

```

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

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

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

```

```

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

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

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

```



```

    uses l0-types:flexi-grid-label-step;
  }
}

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

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

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

```

```

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

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

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/"
    + "tet:underlay/tet:backup-path/tet:path-element/"
    + "tet:type/tet:label/tet:label-hop/"
    + "tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"

```

```

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

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

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

```

```

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

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

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

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}

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

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

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

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

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

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

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

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

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

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

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

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

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/"

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

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

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

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

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

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

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}

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

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

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

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

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

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:tunnel-termination-point/"
    + "tet:local-link-connectivities/"
    + "tet:label-restrictions/tet:label-restriction/"
    + "tet:label-start/"

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

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

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:tunnel-termination-point/"
    + "tet:local-link-connectivities/"
    + "tet:label-restrictions/tet:label-restriction/"
    + "tet:label-step/"
    + "tet:technology"{
when "../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "flexgt:flexi-grid-topology" {
description
    "Augmentation parameters apply only for networks with

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        flexi-grid topology type.";
    }
    description
        "Augment TE label range step for the TTP
        Local Link Connectivities.";
    case flexi-grid {
        uses l0-types:flexi-grid-label-step;
    }
}

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

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

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}

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

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

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    }

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

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

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

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

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

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

```

```

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

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

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:tunnel-termination-point/"
    + "tet:local-link-connectivities/"
    + "tet:local-link-connectivity/"
    + "tet:optimizations/tet:algorithm/tet:metric/"
    + "tet:optimization-metric/"
    + "tet:explicit-route-exclude-objects/"
    + "tet:route-object-exclude-object/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
    when "../.../.../.../.../.../.../.../.../..."
        + "nw:network-types/tet:te-topology/"
        + "flexgt:flexi-grid-topology" {
        description
            "Augmentation parameters apply only for networks with
            flexi-grid topology type.";
    }
}

```

```

    description
      "Augment TE label hop for the explicit route objects excluded
      by the path computation of the TTP Local Link
      Connectivity entry.";
    case flexi-grid {
      uses l0-types:flexi-grid-label-hop;
    }
  }

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

augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:tunnel-termination-point/"
+ "tet:local-link-connectivities/"
+ "tet:local-link-connectivity/"
+ "tet:path-properties/tet:path-route-objects/"
+ "tet:path-route-object/tet:type/"
+ "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../..."
+ "nw:network-types/tet:te-topology/"
+ "flexgt:flexi-grid-topology" {
  description
    "Augmentation parameters apply only for networks with
    flexi-grid topology type.";
}
}

```

```

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

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

  augment "/nw:networks/nw:network/nt:link/tet:te/"
    + "tet:te-link-attributes/"
    + "tet:label-restrictions/tet:label-restriction/"

```

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

```

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

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

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

```

```
        information source.";
    case flexi-grid {
        uses l0-types:flexi-grid-label-step;
    }
}

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

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

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

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

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

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

8. Security Considerations

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

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

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

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


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

9. IANA Considerations

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

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

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

```
Name: ietf-flexi-grid-topology
Namespace: urn:ietf:params:xml:ns:yang:ietf-flexi-grid-topology
Prefix: flexi-grid-topology
Reference: [This.I-D]
```

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A YANG Data Model for Optical Impairment-aware Topology
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Abstract

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

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

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1. Introduction

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

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

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

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 YANG model defined in [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].

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

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

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

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

1.2. Tree Diagram

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

1.3. Prefixes in Data Node Names

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

Prefix	YANG module	Reference
optical-imp-topo	ietf-optical-impairment-topology	[RFCXXXX]
layer0-types	ietf-layer0-types	[RFC9093]
l0-types-ext	ietf-layer0-types-ext	[I-D.ietf-ccamp-layer0-types-ext]
nw	ietf-network	[RFC8345]
nt	ietf-network-topology	[RFC8345]
tet	ietf-te-topology	[RFC8795]

Table 1: Prefixes and corresponding YANG modules

[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.

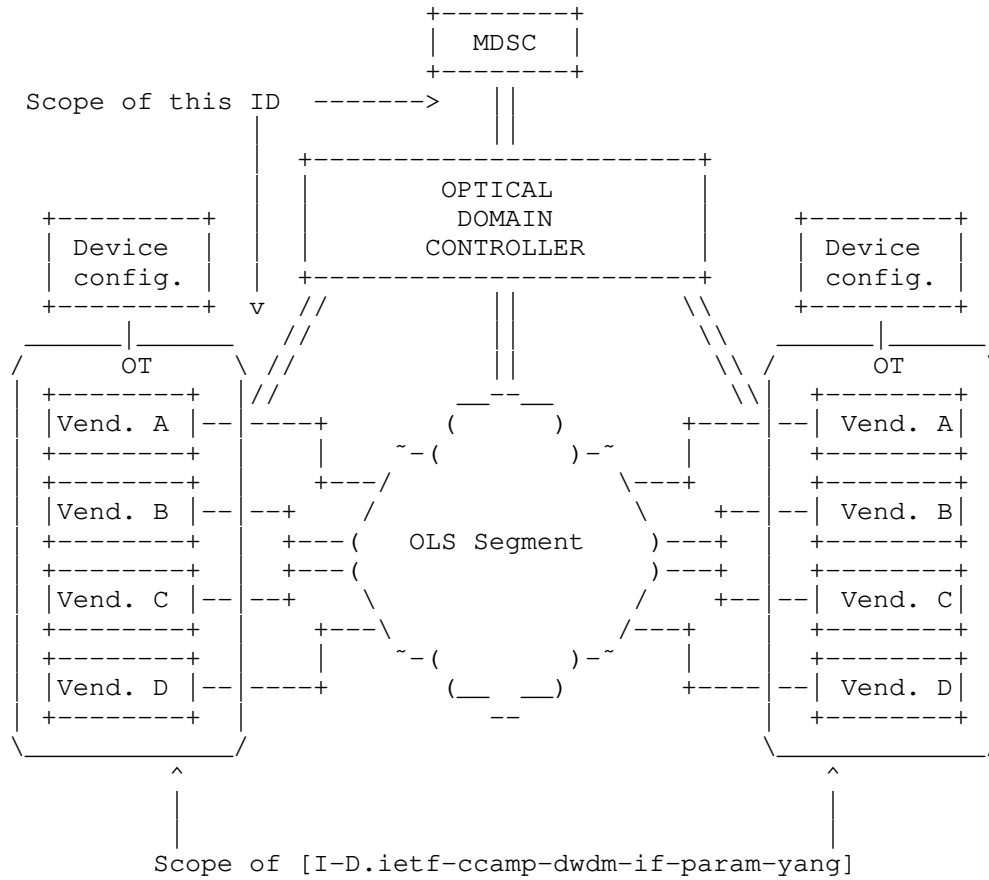


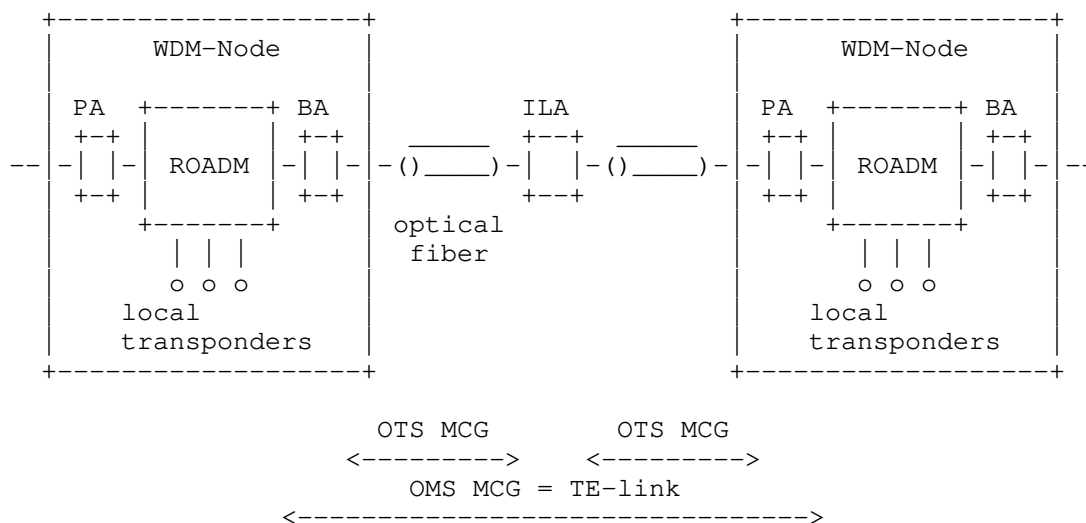
Figure 1: Scope of draft-ietf-ccamp-dwdm-if-param-yang

The topology model developed in this document is an abstracted topology YANG model that can be used at 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. Optical Transport Network Data Plane

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

Figure 2 shows the reference architecture.



BA: Booster Amplifier (or egress amplifier)

PA: Pre-Amplifier (or ingress amplifier)

ILA: In-Line Amplifier

MCG: Media Channel Group

Figure 2: Reference Architecture for Optical Transport Network

BA (on the left side WDM-TE-node) is the engress Amplifier and PA (on the right side WDM-TE-node) is the ingress amplifier for the OMS Media Channel Group (MCG) Figure 2.

2.3. OTS and OMS Media Channel Group

According to [G.807] and [G.872], an OTS Media Channel Group (MCG) represents a topological construct between two adjacent amplifiers, such as:

- (i) between a WDM-TE-node's BA and the adjacent ILA,
- (ii) between a pair of ILAs,
- (iii) between an ILA and the adjacent WDM-TE-node's PA.

According to [G.807] and [G.872], an OMS Media Channel Group (MCG) represents a topological construct between two WDM-TE-nodes.

Specifically, it originates at the ROADM in the source WDM-TE-node and terminates at the ROADM in the destination WDM-TE-node including the Booster Amplifier (BA) and the Pre-Amplifier (PA) in the WDM-TE-nodes as well as the In-Line Amplifiers (ILAs) between the two WDM-TE-nodes.

An OMS MCG can be decomposed into a sequence of OTS MCGs and amplifiers.

An OMS MCG can be described as a sequence of elements such as BA, fiber section, ILA, PA, and concentrated loss wherever there is an insertion loss caused for example by a fiber connector.

In TE-topology terms, the OMS MCG is modeled as a WDM TE-link interconnecting two WDM-TE-nodes. A network controller can retrieve the optical impairment data for all the WDM TE-link elements defined in the layer-0 topology YANG model.

The optical impairments related to the link between remote optical transponders, located in a different WDM-TE-node (an IP router with integrated optical transponders for example), can also be modeled as a WDM TE-link using the same optical impairments as those defined for a WDM TE-link between WDM-TE-nodes (OMS MCG). In this scenario, the node containing the remote optical transponders can be considered as WDM-TE-node with termination capability only and no no switching capabilities.

An OMS MCG 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 based on the published [G.807] revision!]

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 WDM-TE-node in the network to know the OTSi signals that are added to or dropped from an WDM TE-link (OMS MCG)link as well as the optical power of these OTSi signals to check whether the WDM-TE-node's optical power constraints are met.

The 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 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.

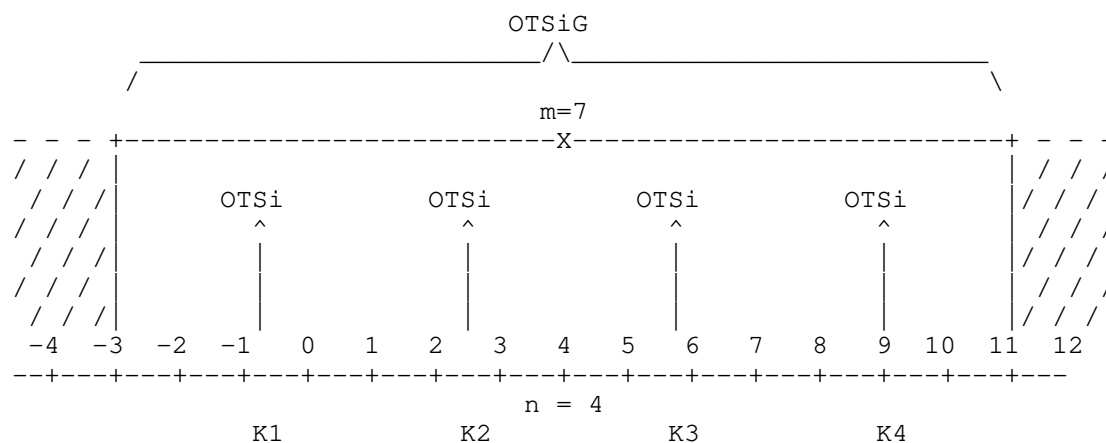


Figure 3: MC Example containing all 4 OTSi signals of an OTSiG

2.3.3. Media Channel (MC)

[G.807] defines a "media channel" as "A media association that represents both the topology (i.e., the path through the media) and the resource (i.e., frequency slot or effective frequency slot) that it occupies." In this document, the term "channel" is occasionally used to indicate the resource of an MC (i.e., frequency slot or effective frequency slot), without representing topology.

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.

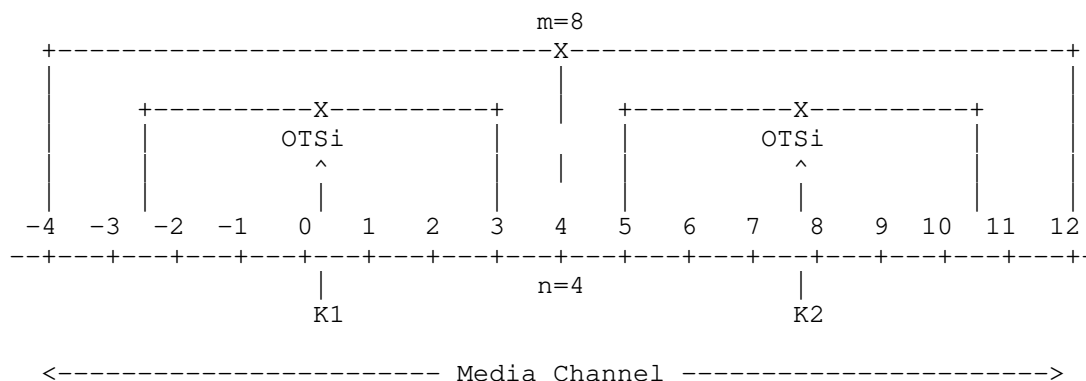


Figure 4: Figure Caption TBA

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

2.3.4. 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.

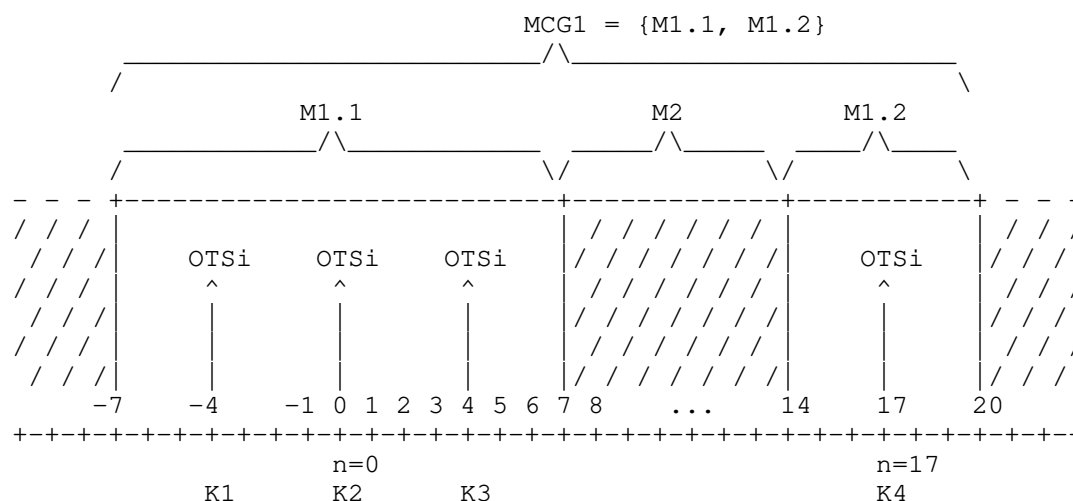


Figure 5: Figure Caption TBA

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 used in WDM networks for amplifying the optical signal in the optical domain without any optical to electrical and electrical to optical conversion. There are three main optical amplifier technologies:

- * Erbium Doped Fiber Amplifiers (EDFAs)
- * Raman Amplifiers
- * Semiconductor Optical Amplifiers (SOAs)

In today's WDM networks EDFAs and Raman amplifiers are widely used. Raman amplifiers have become attractive due to their large spectral gain bandwidth, which can be quite flat, with similar or even lower noise figures compared to EDFAs. On the other hand, Raman amplifiers consume more power and are usually more expensive than EDFAs.

Raman amplifiers are distributed amplifiers where an optical pump signal is injected typically in opposite direction to the optical signal that is amplified (backward pump, counter-propagating pump light). Injecting the optical pump signal in the same direction is also possible (forward pump, co-propagating pump light). For optical amplifiers, the YANG model defines Raman pump light attributes describing the direction (raman-direction) with respect to the signal that is amplified and optical frequency and power for the pump light source(s) contained in the raman-pump list. These Raman amplifier-specific attributes are optional as they are only applicable to Raman amplifiers. For determining the optical amplifier type, i.e., to figure out whether an optical amplifier is a Raman amplifier, the type-variety attribute is used. Due to the distributed nature of the Raman amplifier it is difficult to clearly separate the amplifier from the fiber span into which the pump signal is injected. From a topology modeling perspective, the Raman amplifier is modeled as two OMS line elements:

1. a passive fiber element accounting for the fiber loss only and not the resulting loss including the Raman gain

2. an amplifier element providing all optical amplifier properties (gain, tilt, etc.). On the OMS-link, the amplifier element is placed where the pump is located and the geolocation information also indicates the location of the pump.

Amplifiers can be classified according to their location along the TE-link (OMS MCG). There are three basic amplifier types: In-Line Amplifiers, Pre-Amplifiers and Booster Amplifiers. ILAs are separate physical devices while Pre-Amplifiers and Booster Amplifiers are integral elements of a WDM-node. From a data modeling perspective, node-internal details should not be modeled and should be abstracted as much as possible. For Pre-Amplifiers and Booster Amplifiers, however, a different approach has been taken and they are modeled as TE-link elements as they have the same optical impairments as ILAs.

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

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

2.5. Transponders

[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 will be available. 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 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

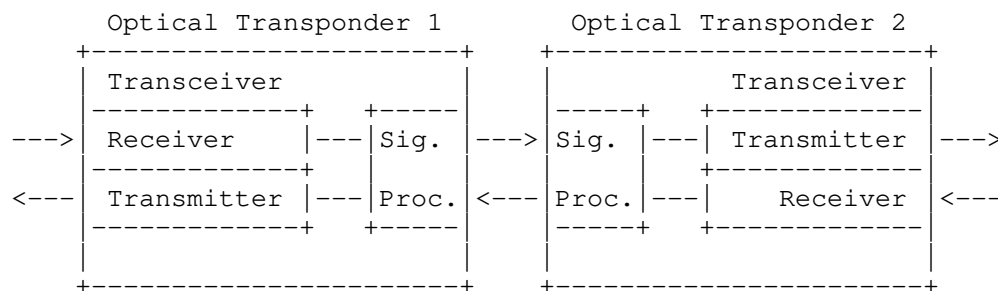
2.6. 3R Regenerators

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 regeneration compound function is illustrated in section 10.1 of [G.798.1], and sections 10.3 and 10.4 provide examples of a ROADM architecture and a photonic cross-connect architecture including 3R regenerators. Based on the 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 regenerator function, two different configurations are possible involving the pair of optical transceivers of the two optical transponders:

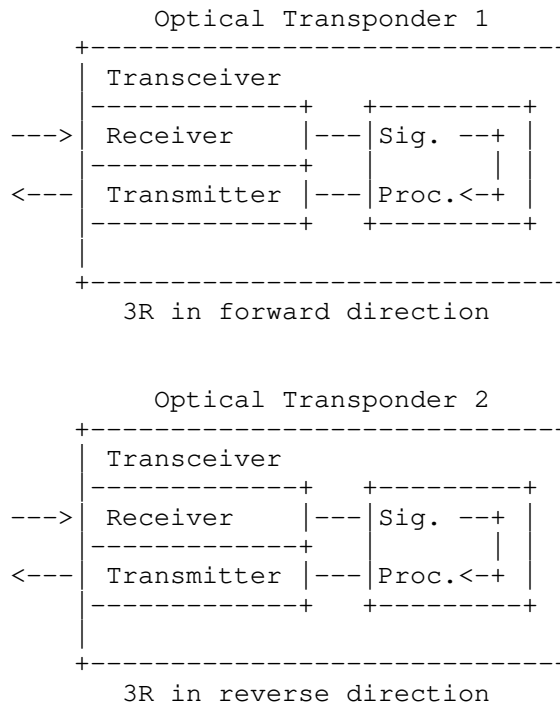
- * The two transponders can be operated in a back-to-back configuration where the transceiver of each optical transponder receives and transmits the optical signal from/to the same segment of the end-to-end tunnel. This means that each transceiver is operated in a bi-directional mode.



Sig. Proc. = Signal Processing

Figure 6: Back-to-back 3R Regenerator Example

- * The two transponders can be operated in a configuration where each transponder performs the 3R regeneration function in one direction, one in forward direction (from source to destination) and the other in the reverse direction. In this configuration, the transceiver of each optical transponder receives the signal from one segment and transmits the regenerated optical signal into the adjacent segment. This configuration is also called cross-regeneration and each transceiver is operated in a uni-directional mode.



Sig. Proc. = Signal Processing

Figure 7: Cross-3R Regenerator Example

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. WDM-Node Architectures

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

- * Integrated WDM-node architecture with local optical transponders
- * Integrated WDM-node architecture with local optical transponders and single channel add/drop ports for remote optical transponders
- * Disaggregated WDM-node architecture where the WDM-TE-node is composed of degree, add/drop, and optical transponder subsystems handled as separate WDM-nodes

The TE topology YANG model augmentations including optical impairments for DWDM networks defined below intend to cover all the 3 categories of WDM-node architectures listed above. In the case of a disaggregated WDM-node architecture, it is assumed that the optical

domain controller already performs some form of abstraction and presents the WDM-TE-node representing the disaggregated WDM-node in the same way as an integrated WDM-TE-node with local optical transponders if the optical transponder subsystems and the add/drop subsystems are collocated (short fiber links not imposing any significant optical impairments).

The different WDM-node 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 WDM-TE-node requires further investigations and will be addressed in a future revision of this document.]

2.9.1. Integrated WDM-node Architecture with Local Optical Transponders

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

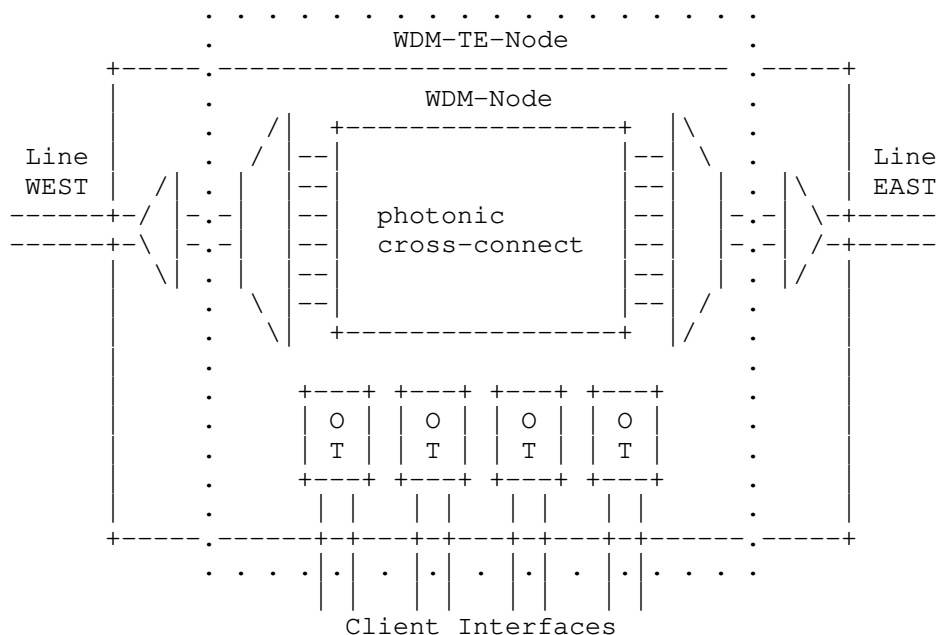


Figure 8: Integrated WDM-node Architectiure with Local Transponders

2.9.2. Integrated WDM-node with Integrated Optical Transponders and Single Channel Add/Drop Interfaces for Remote Optical Transponders

Figure 9 below shows the extreme case where all optical transponders are not integral parts of the WDM-node but are separate devices that are connected to the add/drop ports of the WDM-node. If the optical transponders and the WDM-node are collocated and if short single channel fiber links are used to interconnect the optical transponders with an add/drop port of the WDM-node, the optical domain controller may present these optical transponders in the same way as local optical transponders. If, however, the optical impairments of the single channel fiber link between the optical transponder and the add/drop port of the WDM-node cannot be neglected, it is necessary to represent the fiber link with its optical impairments in the topology model. This also implies that the optical transponders belong to a separate TE-node.

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

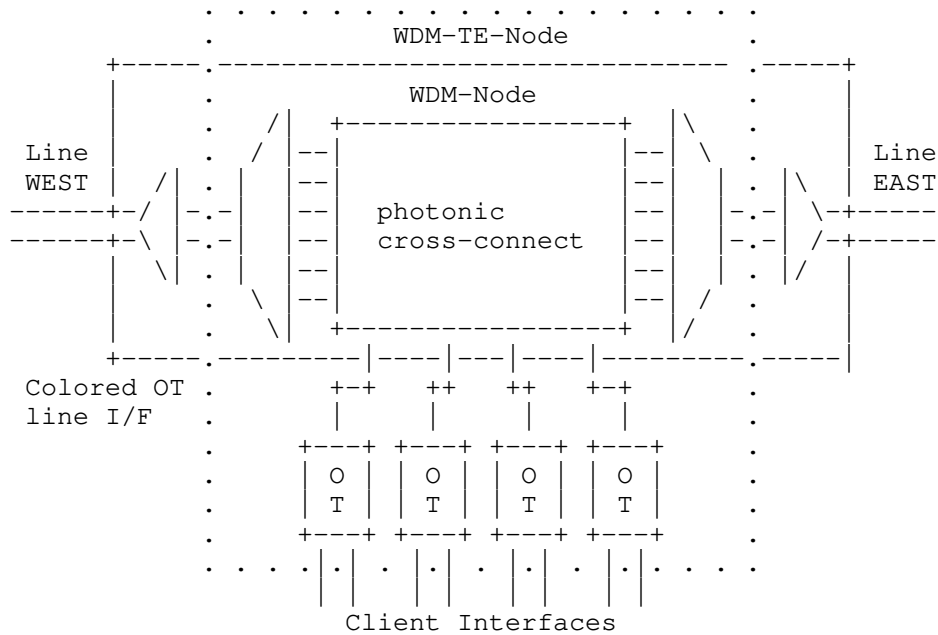


Figure 9: Integrated WDM-node Architectiure with Remote Transponders

2.9.3. Disaggregated WDM-TE-node Subdivided into Degree, Add/Drop, and Optical Transponder Subsystems

Recently, some DWDM network operators started demanding WDM 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 WDM-TE-node are:

- * Single degree subsystems
- * Add/drop subsystems
- * Optical transponder subsystems

These subsystems are separate network elements and each network element provides a separate management and control interface. The subsystems are typically interconnected using short fiber patch cables and form together a disaggregated WDM-TE-node. This disaggregated WDM-TE-node architecture is depicted in Figure 10 below.

As this document defines TE topology YANG model augmentations [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 WDM-TE-node and presents the disaggregated WDM-TE-node in the same way as an integrated WDM-node hiding all the interconnects that are not relevant from an external TE topology view.

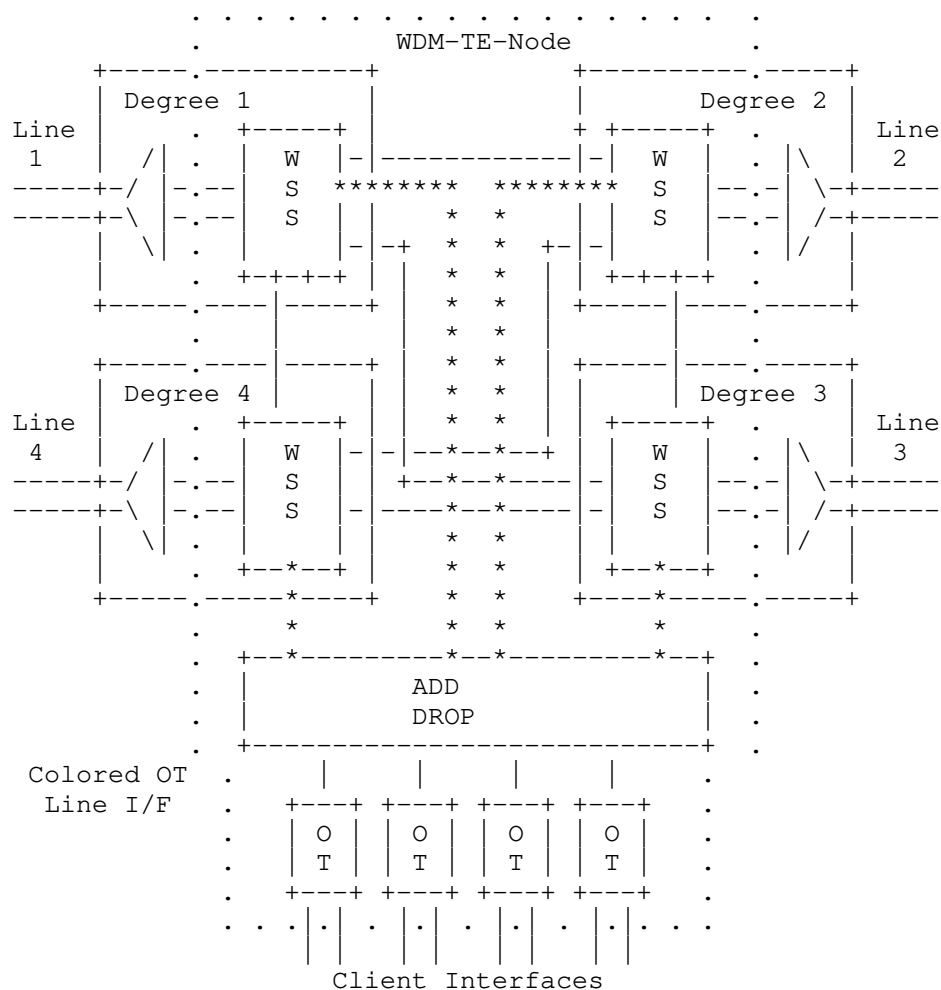


Figure 10: Disaggregated WDM-TE-node Architecture with Remote Transponders

2.9.4. Optical Impairments Imposed by WDM-TE-Nodes

[Editor's note: the following text still needs to be updated based on the agreed terminology]

When an optical OTSi signal traverses a ROADM node, optical impairments are imposed on the signal by various passive or active optical components inside the ROADM node. Examples of optical impairments are:

- * Chromatic dispersion (CD)
- * Polarization mode dispersion (PMD)
- * Polarization dependent loss (PDL)
- * Optical amplifier noise due to amplified spontaneous emission (ASE)
- * In-band cross-talk
- * Filtering effects (for further study)

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? union
      +--ro tx-channel-power?    union
      +--ro rx-channel-power?    union
      +--ro rx-total-power?      union
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?
          |   | organization-identifier
          |   +--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
          +--:(explicit-mode)
            +--ro explicit-mode
              +--ro supported-modes
                +--ro supported-application-codes*
                | -> ../../../../mode-id
                +--ro supported-organizational-modes*
                | -> ../../../../mode-id
              +--ro line-coding-bitrate?
              | identityref
              +--ro bitrate?
              | uint16
              +--ro max-polarization-mode-dispersion?
              | decimal64
              +--ro max-chromatic-dispersion?
              | decimal64
              +--ro chromatic-and-polarization-dispersion-penalty* []
              | +--ro chromatic-dispersion
              | | union
              | +--ro polarization-mode-dispersion
              | | union
              +--ro penalty

```

```

|
|
|
|         union
|         +---ro max-diff-group-delay?
|         |         int32
|         +---ro max-polarization-dependent-loss-penalty* []
|         |         +---ro max-polarization-dependent-loss
|         |         |         power-in-db-or-null
|         |         +---ro penalty
|         |         |         union
|         +---ro available-modulation-type?
|         |         identityref
|         +---ro min-OSNR?
|         |         snr
|         +---ro min-Q-factor?
|         |         int32
|         +---ro available-baud-rate?
|         |         uint32
|         +---ro roll-off?
|         |         decimal64
|         +---ro min-carrier-spacing?
|         |         frequency-ghz
|         +---ro available-fec-type?
|         |         identityref
|         +---ro fec-code-rate?
|         |         decimal64
|         +---ro fec-threshold?
|         |         decimal64
|         +---ro 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:snr
    +--ro equalization-mode         identityref
    +--ro (power-param)?
    |   +--:(channel-power)
    |   |   +--ro nominal-carrier-power?
    |   |   |   10-types:power-in-dbm-or-null
    |   +--:(power-spectral-density)
    |   |   +--ro nominal-power-spectral-density?  union
+--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?     10-types:power-in-dbm-or-null
+--ro OMS-elements* [elt-index]
    +--ro elt-index          uint16
    +--ro oms-element-uid?    union
    +--ro reverse-element-ref
    |   +--ro link-ref?
    |   |   -> ../../../../nt:link/link-id
    |   +--ro oms-element-ref*  leafref
+--ro (element)
    +--:(amplifier)
    |   +--ro geolocation
    |   |   +--ro altitude?     int64
    |   |   +--ro latitude?     geographic-coordinate-degree
    |   |   +--ro longitude?    geographic-coordinate-degree
    |   +--ro amplifier
    |   |   +--ro type-variety    string
    |   |   +--ro operational
    |   |   |   +--ro amplifier-element* []
    |   |   |   |   +--ro name?
    |   |   |   |   |   string

```

```

    +---ro frequency-range
    |   +---ro lower-frequency    frequency-thz
    |   +---ro upper-frequency   frequency-thz
    +---ro actual-gain
    |   10-types:power-in-db-or-null
    +---ro tilt-target
    |   10-types:decimal-2-digits-or-null
    +---ro out-voa
    |   10-types:power-in-db-or-null
    +---ro in-voa
    |   10-types:power-in-db-or-null
    +---ro total-output-power
    |   10-types:power-in-db-or-null
    +---ro (power-param)?
    |   +---:(channel-power)
    |   |   +---ro nominal-carrier-power?
    |   |   |   10-types:power-in-dbm-or-null
    |   +---:(power-spectral-density)
    |   |   +---ro nominal-power-spectral-density?
    |   |   union
    +---ro raman-direction?
    |   enumeration
    +---ro raman-pump* []
    |   +---ro frequency?    10-types:frequency-thz
    |   +---ro power?
    |   |   10-types:decimal-2-digits-or-null
    +---:(fiber)
    |   +---ro fiber
    |   |   +---ro type-variety    string
    |   |   +---ro length
    |   |   |   10-types:decimal-2-digits-or-null
    |   |   +---ro loss-coef
    |   |   |   10-types:decimal-2-digits-or-null
    |   |   +---ro total-loss      10-types:power-in-db-or-null
    |   |   +---ro pmd?
    |   |   |   10-types:decimal-2-digits-or-null
    |   |   +---ro conn-in?        10-types:power-in-db-or-null
    |   |   +---ro conn-out?       10-types:power-in-db-or-null
    +---:(concentratedloss)
    |   +---ro concentratedloss
    |   |   +---ro loss      10-types:power-in-db-or-null
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?                union
          +--ro roadm-cd?                 union
          +--ro roadm-pdl?
            | 10-types:power-in-db-or-null
          +--ro roadm-inband-crosstalk?
            | 10-types:power-in-db-or-null
          +--ro roadm-maxloss?
            | 10-types:power-in-db-or-null
      +--:(roadm-add-path)
        +--ro roadm-add-path* []
          +--ro frequency-range
            | +--ro lower-frequency      frequency-thz
            | +--ro upper-frequency      frequency-thz
          +--ro roadm-pmd?                union
          +--ro roadm-cd?                 union
          +--ro roadm-pdl?
            | 10-types:power-in-db-or-null
          +--ro roadm-inband-crosstalk?
            | 10-types:power-in-db-or-null
          +--ro roadm-maxloss?
            | 10-types:power-in-db-or-null
          +--ro roadm-pmax?
            | 10-types:power-in-dbm-or-null
          +--ro roadm-osnr?                10-types:snr-or-null
          +--ro roadm-noise-figure?        union
      +--:(roadm-drop-path)
        +--ro roadm-drop-path* []
          +--ro frequency-range
            | +--ro lower-frequency      frequency-thz
            | +--ro upper-frequency      frequency-thz
          +--ro roadm-pmd?                union
          +--ro roadm-cd?                 union
          +--ro roadm-pdl?
            | 10-types:power-in-db-or-null
          +--ro roadm-inband-crosstalk?

```

```

        | 10-types:power-in-db-or-null
    +--ro roadm-maxloss?
        | 10-types:power-in-db-or-null
    +--ro roadm-minloss?
        | 10-types:power-in-db-or-null
    +--ro roadm-typlloss?
        | 10-types:power-in-db-or-null
    +--ro roadm-pmin?
        | 10-types:power-in-dbm-or-null
    +--ro roadm-pmax?
        | 10-types:power-in-dbm-or-null
    +--ro roadm-ptyp?
        | 10-types:power-in-dbm-or-null
    +--ro roadm-osnr? 10-types:snr-or-null
    +--ro roadm-noise-figure? union
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
  /tet:te-node-attributes/tet:connectivity-matrices
  /tet:connectivity-matrix:
  +--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
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point
  /tet:local-link-connectivities
  /tet:local-link-connectivity:
  +--ro add-path-impairments? leafref
  +--ro drop-path-impairments? leafref
  +--ro llc-transceiver* [ttp-transponder-ref ttp-transceiver-ref]
    +--ro ttp-transponder-ref
      | -> ../../../../ttp-transceiver/transponder-ref
    +--ro ttp-transceiver-ref
      | -> ../../../../ttp-transceiver/transceiver-ref
    +--ro is-allowed? boolean
    +--ro add-path-impairments? leafref

```

```
+--ro drop-path-impairments?  leafref
```

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;

  namespace "urn:ietf:params:xml:ns:yang:ietf-optical-impairment-topology";

  prefix "optical-imp-topo";

  import ietf-network {
    prefix "nw";
  }

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

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

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

  organization
    "IETF CCAMP Working Group";

  contact
    "Editor:   Young Lee <younglee.tx@gmail.com>
     Editor:   Haomian Zheng <zhenghaomian@huawei.com>
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description

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

Within this module, if the value of a mandatory attribute is
unknown, it MUST be reported using the empty type.
If an optional attribute is applicable but its value is unknown,
it MUST be reported using the empty type.
If an optional attribute is not applicable to an entity, it MUST
be omitted (not be present in the datastore).

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

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

// RFC Ed.: replace XXXX with actual RFC number and remove
// this note

// replace the revision date with the module publication date
// the format is (year-month-day)

```
revision 2022-03-07 {  
  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.";
  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 10-types:frequency-range;
}
leaf actual-gain {
    type 10-types:power-in-db-or-null;
    mandatory true ;
    description "..";
}
leaf tilt-target {
    type 10-types:decimal-2-digits-or-null;
    mandatory true ;
    description "..";
}
leaf out-voa {
    type 10-types:power-in-db-or-null;
    units dB;
    mandatory true;
    description "..";
}
leaf in-voa {
    type 10-types:power-in-db-or-null;
    mandatory true;
    description "..";
}
leaf total-output-power {
    type 10-types:power-in-db-or-null;
    mandatory true;
    description
        "It represent total output power measured in the range
        specified by the frequency-range.

        Optical power is especially needed to re-compute/check
        consistency of span (fiber+ concentrated loss) loss
        value, with respect to loss/gain information on
        elements.";
}
uses power-param;
leaf raman-direction {
    type enumeration {
        enum co-propagating {
            description
                "Co-propagating indicates that optical pump light
                is injected in the same direction to the optical
                signal that is amplified (forward pump).";
        }
        enum counter-propagating {
            description
```

```
        "Counter-propagating indicates that optical pump
        light is injected in opposite direction to the
        optical signal that is amplified (backward pump).";
    }
}
description
    "The direction of injection of the raman pump.";
}
list raman-pump {
    description
        "The list of pumps for the Raman amplifier.";
    leaf frequency {
        type 10-types:frequency-thz;
        description
            "The raman pump central frequency.";
    }
    leaf power {
        type 10-types:decimal-2-digits-or-null;
        units "Watts";
        description
            "The total pump power considering a depolarized pump
            at the raman pump central frequency.";
    }
}
} // 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 10-types:decimal-2-digits-or-null;
        units km;
        mandatory true ;
        description "length of fiber";
    }
    leaf loss-coef {
        type 10-types:decimal-2-digits-or-null;
```

```
        units dB/km;
        mandatory true ;
        description "loss coefficient of the fiber";
    }
    leaf total-loss {
        type 10-types:power-in-db-or-null;
        mandatory true ;
        description
            "includes all losses: fiber loss and conn-in and
             conn-out losses";
    }
    leaf pmd{
        type 10-types:decimal-2-digits-or-null;
        units sqrt(ps);
        description "pmd of the fiber";
    }
    leaf conn-in{
        type 10-types:power-in-db-or-null;
        description "connector-in";
    }
    leaf conn-out{
        type 10-types:power-in-db-or-null;
        description "connector-out";
    }
}

grouping roadm-express-path {
    description
        "The optical impairments of a ROADM express path.";
    leaf roadm-pmd {
        type union {
            type decimal64 {
                fraction-digits 8;
                range "0..max";
            }
            type empty;
        }
        units "ps/(km)^0.5";
        description
            "Polarization Mode Dispersion";
    }
    leaf roadm-cd {
        type union {
            type decimal64 {
                fraction-digits 5;
            }
            type empty;
        }
    }
}
```

```
    }
    units "ps/nm";
    description "Chromatic Dispersion";
  }
  leaf roadm-pdl {
    type l0-types:power-in-db-or-null;
    description "Polarization dependent loss";
  }
  leaf roadm-inband-crosstalk {
    type l0-types:power-in-db-or-null;
    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 l0-types:power-in-db-or-null;
    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 union {
      type decimal64 {
        fraction-digits 8;
        range "0..max";
      }
      type empty;
    }
    units "ps";
    description
      "Polarization Mode Dispersion";
  }
  leaf roadm-cd {
    type union {
      type decimal64 {
        fraction-digits 5;
      }
      type empty;
    }
    units "ps/nm";
    description "Cromatic Dispersion";
  }
}
```

```
}
leaf roadm-pdl {
  type 10-types:power-in-db-or-null;
  description "Polarization dependent loss";
}
leaf roadm-inband-crosstalk {
  type 10-types:power-in-db-or-null;
  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 10-types:power-in-db-or-null;
  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 10-types:power-in-dbm-or-null;
  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:snr-or-null;
  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 union {  
      type decimal64 {  
        fraction-digits 5;  
      }  
      type empty;  
    }  
    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.";  
  }  
}  
  
grouping roadm-drop-path {  
  description "roadm drop block path optical impairments";  
  leaf roadm-pmd {  
    type union {  
      type decimal64 {  
        fraction-digits 8;  
        range "0..max";  
      }  
      type empty;  
    }  
    units "ps/(km)^0.5";  
    description  
      "Polarization Mode Dispersion";  
  }  
  leaf roadm-cd {  
    type union {  
      type decimal64 {  
        fraction-digits 5;  
      }  
    }  
  }
```

```
    type empty;
  }
  units "ps/nm";
  description "Chromatic Dispersion";
}
leaf roadm-pdl {
  type 10-types:power-in-db-or-null;
  description "Polarization dependent loss";
}
leaf roadm-inband-crosstalk {
  type 10-types:power-in-db-or-null;
  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 10-types:power-in-db-or-null;
  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 10-types:power-in-db-or-null;
  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-typlloss {
  type 10-types:power-in-db-or-null;
  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 10-types:power-in-dbm-or-null;
  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 10-types:power-in-dbm-or-null;
  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 10-types:power-in-dbm-or-null;
        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 10-types:snr-or-null;
        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
             ( $P_{\text{carrier}} = \text{Pref} + 10 \log(\text{carrier-baudrate} / \text{ref-baud}) + \text{delta-power}$ )
             and the input inferred NF ( $\text{NF.drop}$ ),
             and this OSNR value, are defined,
             the minimum value between these two should be used";
    }
    leaf roadm-noise-figure {
        type union {
            type decimal64 {
                fraction-digits 5;
            }
            type empty;
        }
        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 10-types:power-in-db-or-null;
      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 {
      when "/nw:networks/nw:network/nt:link/tet:te
        /tet:te-link-attributes/OMS-attributes
        /equalization-mode='carrier-power'";
      leaf nominal-carrier-power{
        type 10-types:power-in-dbm-or-null;
        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{
      when "/nw:networks/nw:network/nt:link/tet:te
        /tet:te-link-attributes/OMS-attributes
        /equalization-mode='power-spectral-density'";
      leaf nominal-power-spectral-density{
        type union {
          type decimal64 {
            fraction-digits 16;
          }
        }
      }
    }
  }
}
```

```
        type empty;
      }
      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:snr;
    description "generalized snr";
  }
  leaf equalization-mode {
    type identityref {
      base 10-types: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: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-list 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 l0-types:power-in-dbm-or-null;
      description
        " Deviation from the reference carrier power defined for
        the OMS.";
    }
  } // media channels list
} // media-channel-groups list
} // media media-channel-groups grouping
```

```
grouping oms-element {
  description "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 union {
        type string;
        type empty;
      }
      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;
        }
        case fiber {
            uses fiber-params;
        }
        case concentratedloss {
            uses concentratedloss-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 */

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

```

```
augment "/nw:networks/nw:network" {
  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 an 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: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 received by the transceiver's received.";
        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
            list of 3R groups.";
    }
    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 "../.../.../transponder[transponder-id=current()] " +
        "../transponder-ref]/transceiver/transceiver-id";
    }
    description
      "The reference to the transceiver of the TTP.";
  }
} // list of transceivers
} // end of augment

augment "/nw:networks/nw:network/nw:node/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";
  }
  description
    "node attributes augmentation for optical-impairment ROADM
    node";

  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: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: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 l0-types: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";
    }
    config 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

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

augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "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";
    }
} // 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" ;
        }
        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 "../../../../../ttp-transceiver/transponder-ref";
    }
    description
      "The reference to the transponder hosting the transceiver
      of this LLCL entry.";
  }
  leaf ttp-transceiver-ref {
    type leafref {
      path "../../../../../ttp-transceiver/transceiver-ref";
    }
    description
      "The reference to the 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" ;
    }
    config false;
    description "pointer to the list set of ROADM
    optical impairments";
  }
}
} // augmentation local-link-connectivity
```

```
}  
<CODE ENDS>
```

5. Security Considerations

The configuration, state, and action data defined in this document are designed to be accessed via a management protocol with a secure transport layer, such as NETCONF [RFC6241]. The NETCONF access control model [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]:

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

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

```
-----  
name: ietf-optical-impairment-topology  
namespace: urn:ietf:params:xml:ns:yang:ietf-optical-impairment-  
topology  
prefix: optical-imp-topo  
reference: RFC XXXX (TDB)  
-----
```

7. Acknowledgments

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YANG Data Model for FlexE Management
draft-wang-ccamp-flex-e-yang-cm-02

Abstract

This document defines a service provider targeted YANG data model for the configuration and management of a Flex Ethernet (FlexE) network, including FlexE groups. It also supports the configuration of each FlexE client as an interface. The YANG module in this document conforms to the Network Management Datastore Architecture (NMDA).

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1. Introduction

From a service provider's point of view, a transport network with Flex Ethernet (FlexE) support are usually deployed with all FlexE Groups configured at first, and then FlexE clients are added one by one at a later stage. This document defines a service provider targeted YANG data model for the configuration and management of FlexE, including FlexE groups and FlexE clients. It supports the configuration of FlexE client as an interface as the data model of FlexE client is augmented based on the generic interfaces data model as defined in [RFC8343]. Furthermore, when a FlexE transport network is used to backhaul 5G mobile services, synchronization channel can also be imbedded in a FlexE PHY. The specific PHY used for synchronization channel can be retrieved for management. Other FlexE attributes are based on the FlexE 2.1 Implementation Agreement as specified in [FLEXE].

Note that this document would only focus on the configuration and maintenance of the FlexE interfaces. Cross connection of FlexE timeslots in a network node is tentatively out of the scope of this document.

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

1.1. Conventions used in this document

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

1.2. Terminology

Most terminologies used in this document are extracted from [FLEXE].

Calendar: The total capacity of a FlexE Group is represented as a collection of slots. The calendar for a FlexE Group composed of n PHYs is represented in each PHY as an array of slots (e.g., each representing 5Gbps of bandwidth), i.e., timeslot-list string.

Ethernet PHY: an entity representing Ethernet Physical Coding Sublayer (PCS), Physical Media Attachment (PMA), and Physical Media Dependent (PMD) layers. Each PHY is consisted of one or more FlexE Instance (e.g., a 400GBASE-R PHY has four FlexE Instances).

FlexE: Flex Ethernet.

FlexE Client: An Ethernet flow based on a MAC data rate that may or may not correspond to any Ethernet PHY rate.

FlexE Group: A FlexE Group is composed of from 1 to n Ethernet PHYs.

FlexE PHY: 50GBASE-R, 100GBASE-R, 200GBASE-R, 400GBASE-R are defined as FlexE PHY by OIF IA FlexE.

2. YANG Model Hierarchy for FlexE

This section describes the hierarchy of the YANG modules for the FlexE management.

Configuration management of FlexE group includes:

- o flexe-groups specifies management configuration of all FlexE groups
- o flexe-phys specifies management configuration of a list of PHYs in a specific FlexE group

Configuration management of a FlexE client includes:

- o flexe-client specifies the FlexE slots used for the FlexE Client in FlexE group

2.1. Tree Diagram of FlexE Group

A simplified YANG tree diagram [RFC8340] representing the data model is typically used by YANG modules. This document uses the same tree diagram syntax as described in [RFC8340].

A tree diagram of FlexE group is depicted as the following:

```
module: ietf-flexe-cm
  +--rw flexe
    +--rw flexe-groups
      +--rw flexe-group* [group-index]
        +--rw index                uint32
        +--rw group-num            uint32
        +--rw negotiation-mode     negotiation-mode-type
        +--ro total-bandwidth      string
        +--ro free-bandwidth?      string
        +--ro sync-phy-number      uint32
        +--rw flexe-phys
          +--rw flexe-phy-list* [port-name]
            +--rw port-name        if:interface-ref
            +--rw phy-number       uint32
            +--ro free-timeslot-list string
            +--ro used-timeslot-list string
```

2.2. Tree Diagram of FlexE Client

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

```
augment /if:interfaces/if:interface:
  +--rw flexe-client
    +--rw client-index            uint32
    +--rw group-index             leafref
    +--rw client-num              uint32
    +--rw timeslot-lists
      +--rw timeslot-list* [port-name]
        +--rw port-name          if:interface-ref
        +--rw time-slot           string
```

3. YANG Module for FlexE Management

The following YANG data module augments the interface container defined in [RFC8343] for a FlexE group interface. It imports iana-if-type [RFC7224] and ietf-interfaces [RFC8343].

3.1. YANG Module of FlexE Group

```
<CODE BEGINS> file "ietf-flexex-cm@2022-03-03.yang"
module ietf-flexex-cm {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-flexex-cm";
  prefix "flexex-cm";

  import iana-if-type {
    prefix ianaift;
  }
  import ietf-interfaces {
    prefix if;
    reference
      "RFC8343: A YANG Data Model for Interface Management";
  }

  organization "IETF CCAMP Working Group";
  contact
    "WG Web:  http://tools.ietf.org/wg/ccamp/
    WG List:  <mailto:ccamp@ietf.org>
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  description
    "This YANG module defines a data model for the configuration
    of a FlexE network.";

  revision "2022-03-03" {
    description "the second version";
    reference
      "draft-wang-ccamp-flexex-yang-cm-02: YANG Data Model for FlexE
      Management";
  }
}
```

```
typedef negotiation-mode-type {
  type enumeration {
    enum "dynamic" {
      value 1;
      description
        "Dynamic mode.";
    }
    enum "static" {
      value 2;
      description
        "Static mode.";
    }
  }
  description
    "Negotiation mode of a FlexE group.";
}

container flexex {
  description
    "Specify FlexE configuration information.";
  container flexex-groups {
    description
      "List of FlexE groups.";
    list flexex-group {
      key "index";
      description
        "Configure FlexE group.";
      leaf index {
        type uint32 {
          range "1..65535";
        }
        description
          "FlexE group index.";
      }
      leaf group-num {
        type uint32 {
          range "1..1048574";
        }
        description
          "FlexE group number, as specified in OIF FlexE 2.1.";
      }
      leaf negotiation-mode {
        type negotiation-mode-type;
        default "dynamic";
        description
          "FlexE group calendar negotiation mode.";
      }
      leaf total-bandwidth {
```

```
    type string {
      length "1..9";
    }
    config false;
    description
      "FlexE group total bandwidth in Gbit/s, such as 10.";
  }
  leaf free-bandwidth {
    type string {
      length "1..9";
    }
    config false;
    description
      "FlexE group free bandwidth in Gbit/s, such as 100.";
  }
  leaf sync-phy-number {
    type uint32 {
      range "1..254";
    }
    config false;
    description
      "The FlexE PHY number used for synchronization management
      channel in a FlexE group, which is one of the PHY number
      value in a FlexE group.";
  }
  container flexe-phys {
    description
      "List of physical port information in a FlexE Group.";
    list flexe-phy {
      key "port-name";
      description
        "FlexE PHY port name.";
      leaf port-name {
        type if:interface-ref;
        description
          "Physical port name. ";
      }
      leaf flexe-phy-number {
        type uint32 {
          range "1..254";
        }
        description
          "Number of a FlexE physical port. The PHY number of
          a 100G port is an integer ranging from 1 to 254.
          The PHY number of a 50G port is an integer ranging
          from 1 to 126.";
      }
      leaf free-timeslot-list {
```



```
organization "IETF CCAMP Working Group";
contact
  "WG Web:    http://tools.ietf.org/wg/ccamp/
  WG List:    <mailto:ccamp@ietf.org>
  Author:     Minxue Wang
               <mailto:wangminxue@chinamobile.com>
  Author:     Liuyan Han
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  Author:     Fan Yang
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  Author:     Luis M. Contreras
               <mailto:luismiguel.contrerasmurillo@telefonica.com>
  Author:     Xufeng Liu
               <mailto:xufeng.liu.ietf@gmail.com>";
description
  "This YANG module defines a data model for the configuration
  of a FlexE client.";

revision "2022-03-03" {
  description "the second version";
  reference
    "draft-wang-ccamp-flexex-yang-cm-02: YANG Data Model for FlexE
    Management";
}

augment "/if:interfaces/if:interface" {
  when "if:type = 'ianaif:flexEclient'" {
    description "Applies to FlexE client interfaces";
  }

  description
    "Augment interface model with FlexE client interface specific
    configuration nodes. Each flexe client interface represents a
    FlexE client configured in a device.";

  container flexe-client {
    description
      "FlexE client.";
    leaf client-index {
      type uint32 {
        range "1..65535";
      }
      description
        "FlexE client index.";
    }
    leaf group-index {
      type leafref {
        path "/flexe-cm:flexe/flexe-cm:flexe-groups/flexe-cm:flexe-group"
```


4. Security Considerations

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

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

There are a number of data nodes defined in the YANG data modules in this document are writable, and the involved subtrees that are sensitive include:

- o /flexex/flexex-groups/flexex-group
- o /flexex/flexex-groups/flexex-group/flexex-phys/flexex-phy-list
- o /flexex-client/timeslot-lists

Write operations (e.g., edit-config) to these data nodes without proper protection can have a negative effect on network operations. Specifically, an inappropriate configuration of them may cause an interrupt of a FlexE client flow, drop of all Ethernet frames of a FlexE client, or even break down of a whole FlexE group interface.

5. IANA Considerations

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

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

URI: urn:ietf:params:xml:ns:yang:ietf-interfaces-flexex-client
Registrant Contact: The IESG
XML: N/A; the requested URI is an XML namespace

It is proposed that IANA register the following YANG module in the "YANG Module Names" registry:

Name: ietf-flexex
Namespace:
Prefix: flexex
Reference: this document

It is proposed that IANA register the following YANG module in the "YANG Module Names" registry:

Name: ietf-interfaces-flexex-client
Namespace: urn:ietf:params:xml:ns:yang:ietf-interfaces-flexex-client
Prefix: flexexcl
Reference: this document

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

6. References

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A YANG Data Model for Client Signal Performance Monitoring
draft-zheng-ccamp-client-pm-yang-05

Abstract

A transport network is a server-layer network to provide connectivity services to its client. Given the client signal is configured, the followup function for performance monitoring, such as latency and bit error rate, would be needed for network operation.

This document describes the data model to support the performance monitoring functionalities.

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1. Introduction

Client-layer network and server-layer network have been respectively modeled to allow the tunnels carrying the client traffic. Server-layers are modeled as tunnels with various switching technologies, such as OTN in [I-D.ietf-ccamp-otn-tunnel-model] and WSON in [I-D.ietf-ccamp-wson-tunnel-model]. Client-layers are modeled as client signals according to the client-signal identities specified in [I-D.ietf-ccamp-layer1-types]. These client signals can be configured to existing tunnels via the client signal configuration model specified in [I-D.ietf-ccamp-client-signal-yang].

In the network operation, the operator is interested in monitoring their instantiated client signal over tunnels. The objective of such monitoring is to complete timely adjustment once there is abnormal statistic which may result in failure of the client signal. The parameters specified in the performance monitoring model can be collected for the operation need. The OAM mechanism, can be configured together with the performance monitoring model.

2. Terminology and Notations

A simplified graphical representation of the data model is used in this document. The meaning of the symbols in the YANG data tree presented later in this 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.

3. Model Relationship

[I-D.ietf-ccamp-client-signal-yang] has specified the two models for the client signal configuration, module ietf-trans-client-service for transparent client service and module ietf-eth-tran-service for Ethernet service. Basically the client signal types in this document is consistent with ietf-eth-tran-types, and focus on different functionality. On the perspective of operator, the modules in [I-D.ietf-ccamp-client-signal-yang] can be used to configure the service given any underlay tunnels, while the operation about monitoring the performance on given service can be achieved by using the model in this document.

Consideration on Key Performance Information (KPI) monitoring for Virtual Network (VN) and tunnels has been specified in [I-D.ietf-teas-actn-pm-telemetry-autonomics]. Usually the monitoring on the tunnels are the VNs should be separately deployed for the network operation, but it is possible to have common parameters that are both needed for the VN/TE and the configured services. Common types are imported in both modules.

VPN-level parameters and their monitoring have been defined in [I-D.www-bess-yang-vpn-service-pm]. This module focus on the performance on the topology at different layer or the overlay topology between VPN sites. On the other hand, this document is focusing on the performance of the service configured between Customer Ends (CE).

4. Consideration on Monitoring Parameters

There can be multiple groups of parameters for monitoring, such as latency, bit error rate (BER). Some of these parameters are layer-dependent, for example, packet loss is only applicable in packet networks are won't be needed for layer 1 OTN and layer 0 WSON.

This document starts with the specification of the latency measurement for both Ethernet service and client signal service. In the future version additional parameters would be added into the data model in the same approach as the latency in the current version. A candidate list of parameters to be monitored include: Latency, Packet Loss, Bit Error Rate (BER), Jitter, Bandwidth, Byte/Packet number and so on.

5. OAM Configuration

The operation, administration and maintenance protocols and data models have been specified in [RFC8531] for the connection-oriented network. The model is referenced in this work to develop an Ethernet-specific OAM models, which is augmenting the service performance monitoring data model.

The definitions of OAM terminologies, such as maintenance Maintenance Domain (MD), Maintenance Association (MA), and Maintenance End Points (MEP), can be found in [RFC8531] as well.

6. YANG Model for Performance Monitoring

6.1. YANG Tree for Performance Monitoring

```

module: ietf-service-pm
  +--rw performance-monitoring
    +--rw service-pm* [service-name]
      +--rw service-name          union
      +--rw task-pm-enable?       boolean
      +--rw granularity?          identityref
      +--rw performance-data-config* [parameter-name]
        | +--rw parameter-name    identityref
        | +--rw measure-method?   identityref
      +--ro service-pm-state
        +--ro oam-state
          | +--ro cc-state        enumeration
          | +--ro lm-state?       enumeration
          | +--ro dm-state?       enumeration
        +--ro performance-data* [parameter-name]
          | +--ro parameter-name    identityref
          | +--ro parameter-value* [index]
          |   +--ro index            uint64
          |   +--ro value            performance-parameter-value
          |   +--ro value-unit       string
          |   +--ro value-description? string
          |   +--ro start-time?      yang:date-and-time
          |   +--ro end-time?        yang:date-and-time
        +--ro monitor-state        identityref
        +--ro error-info
          | +--ro error-code?       uint32
          | +--ro error-message?    string
        +--ro alarm
          +--ro status?             identityref

```

6.2. YANG Tree for OAM Configuration

```

module: ietf-eth-service-oam
augment /svc-pm:performance-monitoring/svc-pm:service-pm:
  +--rw oam-config
    +--rw source
      +--rw md-name?      string
      +--rw ma-name?      string
      +--rw ma-level?     string
      +--rw meg-id?       string
      +--rw meg-level?    string
      +--rw mep-id?       uint8
      +--rw remote-mep-id? uint8
    +--rw destination
      +--rw md-name?      string
      +--rw ma-name?      string
      +--rw ma-level?     string
      +--rw meg-id?       string
      +--rw meg-level?    string
      +--rw mep-id?       uint8
      +--rw remote-mep-id? uint8
    +--rw cc-interval?    identityref
    +--rw lm-interval?    identityref
    +--rw dm-interval?    identityref

```

7. YANG Code for Performance Monitoring

7.1. The Performance Monitoring YANG Code

```

<CODE BEGINS> file "ietf-service-pm@2021-07-07.yang"
module ietf-service-pm {
  yang-version 1.1;

  namespace "urn:ietf:params:xml:ns:yang:ietf-service-pm";
  prefix "svc-pm";

  import ietf-eth-tran-service {
    prefix "ethtsvc";
  }

  import ietf-yang-types {
    prefix "yang";
  }

  import ietf-trans-client-service {
    prefix "clntsvc";
  }

  organization

```

```
"Internet Engineering Task Force (IETF) CCAMP WG";
contact
"
  WG List: <mailto:ccamp@ietf.org>
  ID-draft editor:
    Haomian Zheng (zhenghaomian@huawei.com);
    Italo Busi (italo.busi@huawei.com);
    Yanlei Zheng (zhengyanlei@chinaunicom.cn);
    Victor Lopez (victor.lopez@nokia.com);
    Oscar Gonzalez de Dios (oscar.gonzalezdedios@telefonica.com);
";

description
  "This module defines the performance monitoring for Ethernet
  services. The model fully conforms to the Network Management
  Datastore Architecture (NMDA).

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  Relating to IETF Documents
  (https://trustee.ietf.org/license-info).
  This version of this YANG module is part of RFC XXXX; see
  the RFC itself for full legal notices."

revision 2021-07-07 {
  description
    "Initial version";
  reference
    "ADD REFERENCE HERE";
}

typedef performance-parameter-value {
  type union {
    type uint32;
    type uint64;
    type decimal64 {
      fraction-digits 6;
    }
    type string;
  }
  description
    "A performance parameter value."
}
```

```
grouping service-performance-monitor-set{
  description "the set of parameter name, value and description.";
  leaf parameter-name{
    type identityref {
      base performance-parameter-type;
    }
    description
      "The name of parameters to be monitored.
       For example, latency, Bit Error Rate, Bandwidth and so on.";
  }
  list parameter-value {
    key index;
    description
      "The table of values of the performance and
       their descriptions.";
    leaf index {
      type uint64;
      description
        "Used for list index";
    }
    leaf value {
      type performance-parameter-value;
      mandatory true;
      description
        "The value of the parameter. ";
    }
    leaf value-unit {
      type string;
      mandatory true;
      description
        "The value unit of the parameter.
         For example, second, minute and so on.";
    }
    leaf value-description{
      type string;
      description
        "The description of previous value. ";
    }
  }
  leaf start-time {
    type yang:date-and-time;
    description
      "The time stamp when the parameter is started.";
  }
  leaf end-time {
    type yang:date-and-time;
    description
      "The time stamp when the parameter is ended.";
  }
}
```

```
    }  
  }  
  
  identity performance-parameter-type {  
    description  
      "Base type of the performance parameter being monitored.";  
  }  
  
  identity near-frame-loss {  
    base performance-parameter-type;  
    description  
      "Near frame loss, using one-way eth loss measure,  
       the sampling point is the MEP.";  
  }  
  
  identity far-frame-loss {  
    base performance-parameter-type;  
    description  
      "Far frame loss, using one-way eth loss measure,  
       the sampling point is the MEP.";  
  }  
  
  identity one-way-delay {  
    base performance-parameter-type;  
    description  
      "One way delay.";  
  }  
  
  identity two-way-delay {  
    base performance-parameter-type;  
    description  
      "Two way delay.";  
  }  
  
  identity receive-packets {  
    base performance-parameter-type;  
    description  
      "Total number of received packets.";  
  }  
  
  identity transmit-packets {  
    base performance-parameter-type;  
    description  
      "Total number of transmitted packets.";  
  }  
  
  identity ingress-bandwidth {  
    base performance-parameter-type;
```

```
    description
      "Current bandwidth usage of the ingress traffic.";
  }

  identity egress-bandwidth {
    base performance-parameter-type;
    description
      "Current bandwidth usage of the egress traffic.";
  }

  identity alarm-status {
    description "indicates whether there is alarm or not";
  }
  identity alarm {
    base alarm-status;
    description "There is one or multiple alarms from the monitor. ";
  }

  identity no-alarm {
    base alarm-status;
    description "There is no alarms from the monitor. ";
  }

  identity monitoring-state {
    description
      "The state of performance monitoring. ";
  }

  identity monitoring {
    base monitoring-state;
    description "The Ethernet client signal is under monitoring. ";
  }

  identity monitor-finished {
    base monitoring-state;
    description
      "The monitoring of Ethernet client signal is finished. ";
  }

  identity monitor-failed {
    base monitoring-state;
    description
      "The monitoring of Ethernet client signal is failed. ";
  }

  identity granularity-type {
    description
      "Monitoring granularity";
  }
```



```
    }

    identity granularity-1min {
      base granularity-type;
      description
        "1 minute";
    }

    identity granularity-15min {
      base granularity-type;
      description
        "15 minutes";
    }
    identity granularity-24h {
      base granularity-type;
      description
        "24 hours";
    }

    identity measure-method {
      description "Measure method.";
    }

    identity measure-by-loopback {
      base measure-method;
      description "Loopback measure method.";
    }

    identity measure-at-ingress {
      base measure-method;
      description "Ingress measure method.";
    }

    container performance-monitoring {
      description
        "This part is for performance monitoring. ";
      list service-pm {
        key "service-name";
        description
          "The list of service to be monitored.";
        leaf service-name {
          type union {
            type leafref {
              path "/ethtsvc:etht-svc/ethtsvc:etht-svc-instances"
                + "/ethtsvc:etht-svc-name";
            }
            type leafref {
              path "/clntsvc:client-svc/clntsvc:client-svc-instances"
```

```
        + "/clntsvc:client-svc-name";
    }
}
mandatory true;
description "The name of service.";
}

leaf task-pm-enable {
    type boolean;
    description
        "Indicate whether the performance monitoring
         is enable or not.";
}

leaf granularity {
    type identityref {
        base granularity-type;
    }
    description
        "Monitoring granularity";
}

list performance-data-config {
    key parameter-name;
    description
        "Specify the performance parameters to be queried";

    leaf parameter-name {
        type identityref {
            base performance-parameter-type;
        }
        description
            "The name of parameters to be monitored.
             For example, latency, BER, Bandwidth and so on.";
    }
    leaf measure-method {
        type identityref {
            base measure-method;
        }
        description "Measure Methods.";
    }
}

container service-pm-state {
    config false;
    description
        "The state of service performance monitoring.";
```

```
container oam-state {
  description "the state of OAM. ";
  leaf cc-state {
    type enumeration {
      enum up {
        description "up";
      }
      enum down {
        description "down";
      }
    }
    mandatory true;
    description
      "The state of continuity check.";
  }
  leaf lm-state {
    type enumeration {
      enum up {
        description "up";
      }
      enum down {
        description "down";
      }
    }
    description
      "The state of loss measurement.";
  }
  leaf dm-state {
    type enumeration {
      enum up {
        description "up";
      }
      enum down {
        description "down";
      }
    }
    description
      "The state of delay measurement.";
  }
}

list performance-data {
  key parameter-name;
  description "The list of performance under monitor.";
  uses service-performance-monitor-set;
}

leaf monitor-state {
```

```

    type identityref {
        base monitoring-state;
    }
    mandatory true;
    description "The status of performance monitoring. ";
}

container error-info {
    description
        "Describe the error message.";
    leaf error-code {
        type uint32;
        description
            "The code of error.";
    }
    leaf error-message {
        type string;
        description
            "The message of error.";
    }
}

container alarm {
    description
        "To retrieve the Alarm during performance Monitoring.";
    leaf status {
        type identityref {
            base alarm-status;
        }
        description "The status of the alarm. ";
    }
}
}
}
}
}
<CODE ENDS>
```

7.2. The OAM Configuration YANG Code

```
<CODE BEGINS> file "ietf-eth-service-oam@2021-07-10.yang"
module ietf-eth-service-oam {
  yang-version 1.1;

  namespace "urn:ietf:params:xml:ns:yang:ietf-eth-service-oam";
  prefix "eth-oam";
```

```
import ietf-eth-tran-service {
  prefix "ethtsvc";
}

import ietf-service-pm {
  prefix "svc-pm";
}

import ietf-trans-client-service {
  prefix "clntsvc";
}

import ietf-network {
  prefix nw;
}

organization
  "Internet Engineering Task Force (IETF) CCAMP WG";
contact
  "
    WG List: <mailto:ccamp@ietf.org>
    ID-draft editor:
      Haomian Zheng (zhenghaomian@huawei.com);
      Italo Busi (italo.busi@huawei.com);
      Yanlei Zheng (zhengyanlei@chinaunicom.cn);
      Victor Lopez (victor.lopez@nokia.com);
      Oscar Gonzalez de Dios (oscar.gonzalezdedios@telefonica.com);
  ";

description
  "This module defines the performance monitoring for Ethernet
  services OAM. 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.
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  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 2021-07-10 {
  description
    "Initial version";
```

```
    reference
      "ADD REFERENCE HERE";
  }

  identity interval-type {
    description "Time interval";
  }

  identity interval-3p33ms {
    base interval-type;
    description "3.33 milliseconds";
  }

  identity interval-10ms {
    base interval-type;
    description "10 milliseconds";
  }

  identity interval-100ms {
    base interval-type;
    description "100 milliseconds";
  }

  identity interval-1s {
    base interval-type;
    description "1 second";
  }

  identity interval-10s {
    base interval-type;
    description "10 seconds";
  }

  identity interval-1m {
    base interval-type;
    description "1 minute";
  }

  identity interval-10m {
    base interval-type;
    description "10 minutes";
  }

  grouping eth-service-oam-config {
    container source {
      uses mep-config;
      description "OAM MEP configuration on source node.";
    }
  }
```

```
    container destination {
      uses mep-config;
      description "OAM MEP configuration on destination node.";
    }
    uses interval-config;
    description "OAM configuration on Eth services.";
  }

  grouping interval-config {
    description "OAM Interval Configuration.";
    leaf cc-interval {
      type identityref {
        base interval-type;
      }
      description "Continuity check interval.";
    }

    leaf lm-interval {
      type identityref {
        base interval-type;
      }
      description "Loss measurement interval.";
    }

    leaf dm-interval {
      type identityref {
        base interval-type;
      }
      description "Delay measurement interval.";
    }
  }

  grouping mep-config {
    description "OAM MEP Configuration.";
    leaf md-name {
      type string;
      description
        "Name of Maintenance Domain.";
    }
    leaf ma-name {
      type string;
      description
        "Name of Maintenance Domain.
        An maintenance association(MA) is a part of an MD.
        An MD can be divided into one or more MAs. ";
    }

    leaf ma-level {
```

```
        type string;
        description
            "Maintenance Association Level.";
    }

    leaf meg-id {
        type string;
        description
            "Comply with Y.1731 term, mapping with 802.lag MA name.";
    }
    leaf meg-level {
        type string;
        description "Mapping with 802.lag MA level.";
    }

    leaf mep-id {
        type uint8;
        description "0 if Abnormal";
    }

    leaf remote-mep-id {
        type uint8;
        description "The remote MEP ID must be specified.";
    }
}

augment "/svc-pm:performance-monitoring/svc-pm:service-pm" {
    description
        "Augment with additional parameters required for Ethernet OAM";

    container oam-config {
        description "OAM configuration container.";
        uses eth-service-oam-config;
    }
}

grouping errors {
    description "The grouping of error information.";
    leaf error-code {
        type uint32;
        description "The error code.";
    }

    leaf error-message {
        type string;
        description "The error message.";
    }
}
```



```
    }

    /*
     * Operations
     */
    rpc configure-oam {
        description "Deliver OAM configurations. ";

        input {
            list oam-config-list {
                key "service-name";
                description
                    "The request list of service oam to be configured.";
                leaf service-name {
                    type union {
                        type leafref {
                            path "/ethtsvc:ethht-svc/ethtsvc:ethht-svc-instances"
                                + "/ethtsvc:ethht-svc-name";
                        }
                        type leafref {
                            path "/clntsvc:client-svc/clntsvc:client-svc-instances"
                                + "/clntsvc:client-svc-name";
                        }
                    }
                    mandatory true;
                    description "The name of service.";
                }
                uses eth-service-oam-config;
            }
        }

        output {
            list oam-config-list {
                key "service-name";
                description "The OAM configuration list. ";
                leaf service-name {
                    type union {
                        type leafref {
                            path "/ethtsvc:ethht-svc/ethtsvc:ethht-svc-instances"
                                + "/ethtsvc:ethht-svc-name";
                        }
                        type leafref {
                            path "/clntsvc:client-svc/clntsvc:client-svc-instances"
                                + "/clntsvc:client-svc-name";
                        }
                    }
                    mandatory true;
                }
            }
        }
    }
}
```

```
        description "The name of service.";
    }
}
leaf result {
    type enumeration {
        enum success {
            description "success";
        }
        enum failure {
            description "failure";
        }
    }
    description "Result of OAM configuration.";
}
uses errors;
}
}

rpc delete-oam-configurations {
    description "Delete OAM configurations. ";
    input {
        list service-list {
            key "service-name";
            leaf service-name {
                type union {
                    type leafref {
                        path "/ethtsvc:etht-svc/ethtsvc:etht-svc-instances"
                        + "/ethtsvc:etht-svc-name";
                    }
                    type leafref {
                        path "/clntsvc:client-svc/clntsvc:client-svc-instances"
                        + "/clntsvc:client-svc-name";
                    }
                }
            }
            mandatory true;
            description "The name of service.";
        }
        description "The list of service.";
    }
}

output {
    list oam-config-list {
        key "service-name";
        leaf service-name {
            type union {
                type leafref {
```

```
        path "/ethtsvc:etht-svc/ethtsvc:etht-svc-instances"
          + "/ethtsvc:etht-svc-name";
      }
      type leafref {
        path "/clntsvc:client-svc/clntsvc:client-svc-instances"
          + "/clntsvc:client-svc-name";
      }
    }
    mandatory true;
    description "The name of service.";
  }

  leaf result {
    type enumeration {
      enum success {
        description "success";
      }
      enum failure {
        description "failure";
      }
    }
    description "The result of OAM deletion.";
  }

  uses errors;
  description "The list of service.";
}

}

rpc get-node-eth-oam-configurations {
  description "Get the Eth node OAM configuration info.";
  input {
    leaf-list te-node-list {
      type leafref {
        path "/nw:networks/nw:network/nw:node/nw:node-id";
      }
    }
    description
      "Node identifier. Must be same in the topology.";
  }
}

output {
  list oam-list {
    leaf node-id {
      type leafref {
        path "/nw:networks/nw:network/nw:node/nw:node-id";
      }
    }
  }
}
```

```
        description "The node identifier.";
    }
    list mep-config-list {
        key "md-name ma-name meg-id mep-id";
        uses mep-config;
        description "The list of MEP configuration.";
    }
    description "The list of OAM.";
}
}
}
}
<CODE ENDS>
```

8. IANA Considerations

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

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

URI: urn:ietf:params:xml:ns:yang:ietf-eth-service-oam
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-service-pm
namespace:	urn:ietf:params:xml:ns:yang:ietf-service-pm
prefix:	svc-pm
reference:	RFC XXXX (This document)

name:	ietf-eth-service-oam
namespace:	urn:ietf:params:xml:ns:yang:ietf-eth-service-oam
prefix:	eth-oam
reference:	RFC XXXX (This document)

9. Manageability Considerations

TBD.

10. Security Considerations

The data following the model defined in this document is exchanged via, for example, the interface between an orchestrator and a transport network controller. The security concerns mentioned in [I-D.ietf-ccamp-client-signal-yang] also applies to this document.

The YANG module defined in this document can be accessed via the RESTCONF protocol defined in [RFC8040], or maybe via the NETCONF protocol [RFC6241].

11. Contributors

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Framework and Data Model for OTN Network Slicing
draft-zheng-ccamp-yang-otn-slicing-03

Abstract

The requirement of slicing network resources with desired quality of service is emerging at every network technology, including the Optical Transport Networks (OTN). As a part of the transport network, OTN can provide hard pipes with guaranteed data isolation and deterministic low latency, which are highly demanded in the Service Level Agreement (SLA).

This document describes a framework for OTN network slicing and a YANG data model augmentation of the OTN topology model. Additional YANG data model augmentations will be defined in a future version of this draft.

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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.

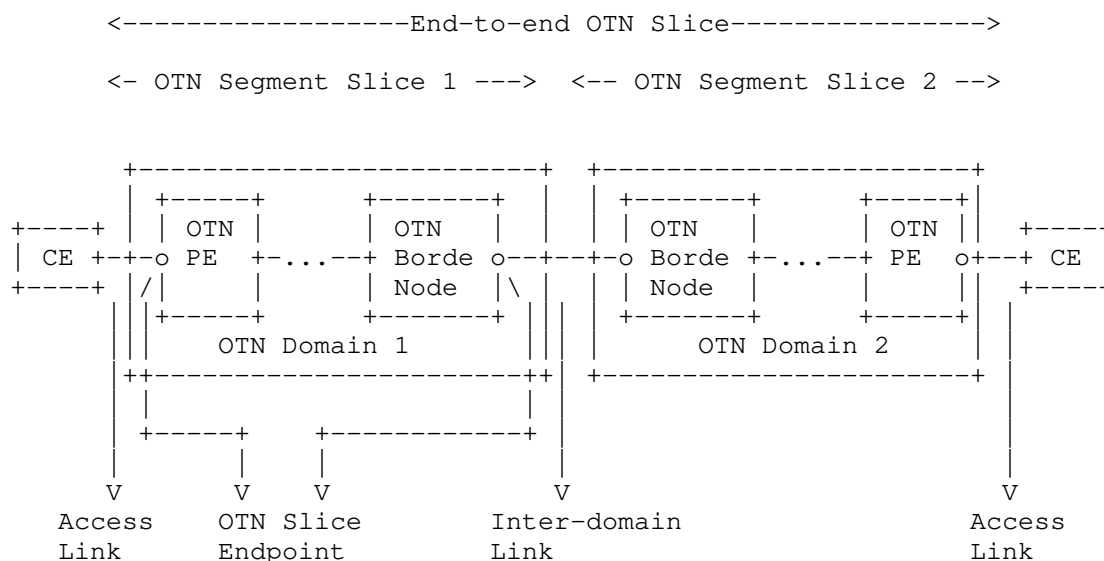


Figure 1: OTN Slice

OTN slices may be pre-configured by the management plane and presented to the customer via the northbound interface (NBI), or be dynamically provisioned by a higher layer slice controller, e.g. an IETF network slice controller (IETF NSC) through the NBI. The OTN slice is provided by a service provider to a customer to be used as though it was part of the customer's own networks.

2. Use Cases for OTN Network Slicing

2.1. Leased Line Services with OTN

For end business customers (like OTT or enterprises), leased lines have the advantage of providing high-speed connections with low costs. On the other hand, the traffic control of leased lines is very challenging due to rapid changes in service demands. Carriers are recommended to provide network-level slicing capabilities to meet this demand. Based on such capabilities, private network users have full control over the sliced resources which have been allocated to them and which could be used to support their leased lines, when needed. Users may formulate policies based on the demand for services and time to schedule the resources from the entire network's perspective flexibly. For example, the bandwidth between any two points may be established or released based on the time or monitored traffic characteristics. The routing and bandwidth may be adjusted at a specific time interval to maximize network resource utilization efficiency.

2.2. Co-construction and Sharing

Co-construction and sharing of a network are becoming a popular means among service providers to reduce networking building CAPEX. For Co-construction and sharing case, there are typically multiple co-founders for the same network. For example, one founder may provide optical fibres and another founder may provide OTN equipment, while each occupies a certain percentage of the usage rights of the network resources. In this scenario, the network O&M is performed by a certain founder in each region, where the same founder usually deploys an independent management and control system. The other founders of the network use each other's management and control system to provision services remotely. In this scenario, different founders' network resources need to be automatically (associated) divided, isolated, and visualized. All founders may share or have independent O&M capabilities, and should be able to perform service-level provisioning in their respective slices.

2.3. Wholesale of optical resources

In the optical resource wholesale market, smaller, local carriers and wireless carriers may rent resources from larger carriers, or infrastructure carriers instead of building their networks. Likewise, international carriers may rent resources from respective local carriers and local carriers may lease their owned networks to each other to achieve better network utilization efficiency. From the perspective of a resource provider, it is crucial that a network slice is timely configured to meet traffic matrix requirements requested by its tenants. The support for multi-tenancy within the resource provider's network demands that the network slices are qualitatively isolated from each other to meet the requirements for transparency, non-interference, and security. Typically, a resource purchaser expects to use the leased network resources flexibly, just like they are self-constructed. Therefore, the purchaser is not only provided with a network slice, but also the full set of functionalities for operating and maintaining the network slice. The purchaser also expects to, flexibly and independently, schedule and maintain physical resources to support their own end-to-end automation using both leased and self-constructed network resources.

2.4. Vertical dedicated network with OTN

Vertical industry slicing is an emerging category of network slicing due to the high demand for private high-speed network interconnects for industrial applications. In this scenario, the biggest challenge is to implement differentiated optical network slices based on the requirements from different industries. For example, in the financial industry, to support high-frequency transactions, the slice

must ensure to provide the minimum latency along with the mechanism for latency management. For the healthcare industry, online diagnosis network and software capabilities to ensure the delivery of HD video without frame loss. For bulk data migration in data centers, the network needs to support on-demand, large-bandwidth allocation. In each of the aforementioned vertical industry scenarios, the bandwidth shall be adjusted as required to ensure flexible and efficient network resource usage.

2.5. End-to-end network slicing

In an end-to-end network slicing scenario such as 5G network slicing [TS.28.530-3GPP], an IETF network slice [I-D.ietf-teas-ietf-network-slices] provides the required connectivity between other different segments of an end-to-end network slice, such as the Radio Access Network (RAN) and the Core Network (CN) segments, with a specific performance commitment. An IETF network slice could be composed of network slices from multiple technological and administrative domains. An IETF network slice can be realized by using or combining multiple underlying OTN slices with OTN resources, e.g. ODU time slots or ODU containers, to achieve end-to-end slicing across the transport domain.

3. Framework for OTN slicing

OTN slices may be abstracted differently depending on the requirement contained in the configuration provided by the slice customer. Whereas the customer requests an OTN slice to provide connectivities between specified endpoints, an OTN slice can be abstracted as a set of endpoint-to-endpoint links, with each link formed by an end-to-end tunnel across the underlying OTN networks. The resources associated with each link of the slice is reserved and commissioned in the underlying physical network upon the completion of configuring the OTN slice and all the links are active.

An OTN slice can also be abstracted as an abstract topology when the customer requests the slice to share resources between multiple endpoints and to use the resources on demand. The abstract topology may consist of virtual nodes and virtual links, whose associated resources are reserved but not commissioned across the underlying OTN networks. The customer can later commission resources within the slice dynamically using the NBI provided by the service provider. An OTN slice could use abstract topology to connect endpoints with shared resources to optimize the resource utilization, and connections can be activated within the slice as needed.

It is worth noting that those means to abstract an OTN slice are similar to the Virtual Network (VN) abstraction defined for higher-level interfaces in [RFC8453], in which context a connectivity-based slice corresponds to Type 1 VN and a resource-based slice corresponds to Type 2 VN, respectively.

A particular resource in an OTN network, such as a port or link, may be sliced with one of the two granularity levels:

- * Link-based slicing, in which a link and its associated link termination points (LTPs) are dedicatedly allocated to a particular OTN slice.
- * Tributary-slot based slicing, in which multiple OTN slices share the same link by allocating different OTN tributary slots in different granularities.

Furthermore, an OTN switch is typically fully non-blockable switching at the lowest ODU container granularity, it is desirable to specify just the total number of ODU containers in the lowest granularity (e.g. ODU0), when configuring tributary-slot based slicing on links and ports internal to an OTN network. In multi-domain OTN network scenarios where separate OTN slices are created on each of the OTN networks and are stitched at inter-domain OTN links, it is necessary to specify matching tributary slots at the endpoints of the inter-domain links. In some real network scenarios, OTN network resources including tributary slots are managed explicitly by network operators for network maintenance considerations. Therefore an OTN slice controller shall support configuring an OTN slice with both options.

An OTN slice controller (OTN-SC) is a logical function responsible for the life-cycle management of OTN slices instantiated within the corresponding OTN network domains. The OTN-SC provides technology-specific interfaces at its northbound (OTN-SC NBI) to allow a higher-layer slice controller, such as an IETF network slice controller (NSC), or an orchestrator, to request OTN slices with OTN-specific requirements. The OTN-SC interfaces at the southbound using the MDSC-to-PNC interface (MPI) with a Physical Network Controller (PNC) or Multi-Domain Service Orchestrator (MDSC), as defined in the ACTN control framework [RFC8453]. The logical function within the OTN-SC is responsible for translating the OTN slice requests into concrete slice realization which can be understood and provisioned at the southbound by the PNC or MDSC.

When realizing OTN slices, the OTN-SC may translate a connectivity-based OTN slice into a set of end-to-end tunnels using the Traffic-engineering(TE) tunnel interface defined in [I-D.ietf-teas-yang-te]. For a resource-based OTN slice, the OTN-SC may translate the abstract topology representing the slice into a colored graph on an abstract TE topology using the TE topology interface defined in [RFC8795].

The OTN-SC NBI is technology-specific, while the IETF NSC-NBI is technology-agnostic. An IETF NSC may translate its customer's technology-agnostic slice request into an OTN slice request and utilize the OTN-SC NBI to realize the IETF network slice. Alternatively, the IETF NSC may translate the slicing request into tunnel or topology configuration commands and communicate directly with the underlying PNC or MDSC to provision the IETF network slice.

Figure 2 illustrates the OTN slicing control hierarchy and the positioning of the OTN slicing interfaces.

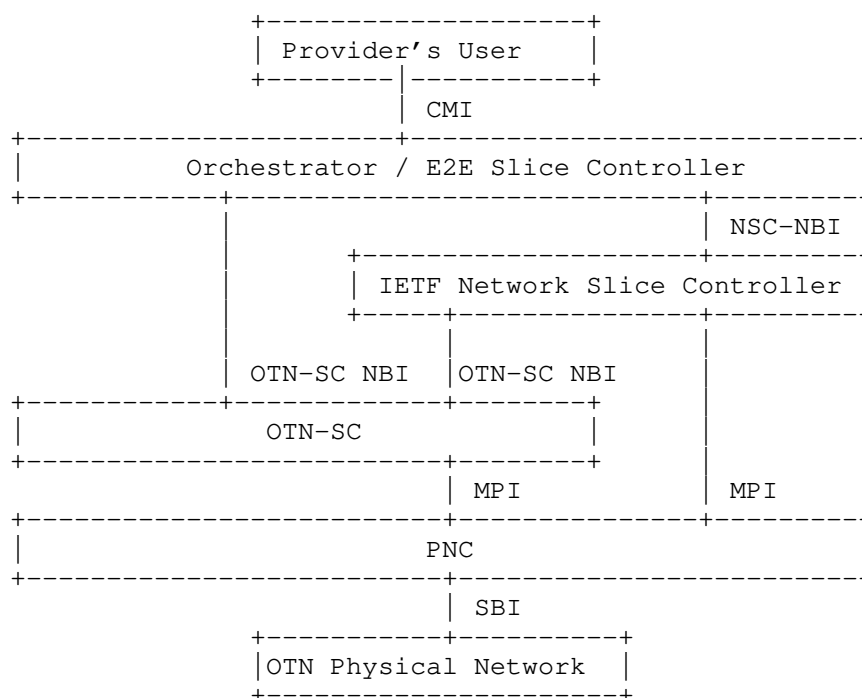


Figure 2: Positioning of OTN Slicing Interfaces

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.

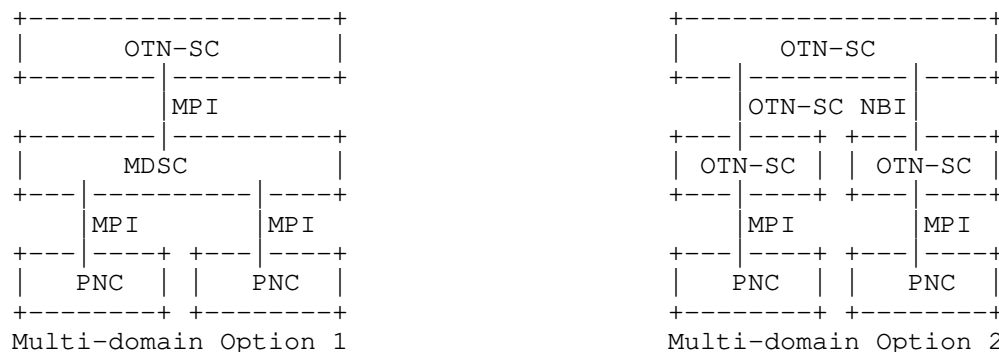


Figure 3: OTN-SC for multi-domain

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;
  namespace "urn:ietf:params:xml:ns:yang:ietf-otn-slice";
  prefix "otnslice";

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

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

  import ietf-te-topology {
```

```
    prefix "tet";
    reference
      "RFC8795: YANG Data Model for Traffic Engineering
      (TE) Topologies";
  }

  import ietf-otn-topology {
    prefix "otntopo";
    reference
      "I-D.ietf-ccamp-otn-topo-yang: A YANG Data Model
      for Optical Transport Network Topology";
  }

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

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

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

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

    Editor: Aihua Guo
           <mailto:aihuaguo.ietf@gmail.com>

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

  description
    "This module defines a YANG data model to configure an OTN
    network slice realization.

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

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    identified as authors of the code. All rights reserved."
```

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```
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 ll-types:otn-link-bandwidth;
                }
                case time-slots {
                    leaf otn-ts-num {
                        type uint32;
                        description
                            "Number of OTN tributary slots allocated for the
                                slice.";
                    }
                }
            }
        }
    }
}

leaf sliced-link-ref {
    type leafref {
        path "../.../.../nt:link/nt:link-id";
    }
    config false;
    description
        "Relative reference to virtual links generated from
            this TE link.";
}
}
}

/*
 * Augments
 */
augment "/nw:networks/nw:network/nt:link/tet:te/"
    + "tet:te-link-attributes" {
    when "../.../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description
            "Augmentation parameters apply only for networks with
                OTN topology type.";
    }
    description
        "Augment OTN TE link attributes with slicing profile.";
    uses otn-link-slice-profile;
}
}

```

<CODE ENDS>

Figure 5: OTN slicing YANG model

4.2. OTN Slicing YANG Model for OTN-SC NBI

4.2.1. NBI YANG Model Overview

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

The base model defines a transport network slice (TNS) with the following constructs and attributes:

- Common attributes, which include a set of common attributes like slice identifier, name, description and names of customers who use the slice.
- Endpoints, which represent conceptual points of connection from a customer device to the TNS. An endpoint is mapped to specific physical or virtual resources of the customer and provider, and such mapping is pre-negotiated and known to both the customer and provider prior to the slice configuration. The mechanism for endpoint negotiation is outside the scope of this draft.
- Network topology, which represent set of shared, reserved resources organized as a virtual topology between all of the endpoints. A customer could use such network topology to define detailed 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

```

```

+--rw slo
|   +--rw optimization-criterion?  identityref
|   +--rw delay-tolerance?         boolean
|   +--rw periodicity*             uint64
|   +--rw isolation-level?         identityref
+--rw endpoints
|   +--rw endpoint* [endpoint-id]
|       +--rw endpoint-id         string
+--rw network-topologies
|   +--rw network-topology* [topology-id]
|       +--rw topology-id         string
|       +--rw node* [node-id]
|           +--rw node-id         inet:uri
|           +--rw slo
|               +--rw isolation-level?  identityref
|           +--rw termination-point* [tp-id]
|               +--rw tp-id         inet:uri
|               +--rw endpoint-id?    leafref
+--rw link* [link-id]
|   +--rw link-id                 inet:uri
|   +--rw slo
|       +--rw delay-tolerance?      boolean
|       +--rw periodicity*          uint64
|       +--rw isolation-level?      identityref
+--rw source
|   +--rw source-node?             -> ../../../../node/node-id
|   +--rw source-tp?              leafref
+--rw destination
|   +--rw dest-node?               -> ../../../../node/node-id
|   +--rw dest-tp?                leafref
+--rw connectivity-matrices
|   +--rw connectivity-matrix* [connectivity-matrix-id]
|       +--rw connectivity-matrix-id  uint32
|       +--rw topology-id?           leafref
|       +--rw src-endpoint?
|           -> ../../../../endpoints/endpoint/endpoint-id
|       +--rw dst-endpoint?
|           -> ../../../../endpoints/endpoint/endpoint-id
|       +--rw slo
|       +--rw explicit-path* [tp-id]
|           +--rw tp-id             leafref

```

Figure 6: Tree diagram for transport network slice

4.2.3. NBI YANG Code for Transport Network Slice

```
<CODE BEGINS> file "ietf-transport-network-slice@2021-10-22.yang"
module ietf-transport-network-slice {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-transport-network-slice";
  prefix "tns";

  import ietf-inet-types {
    prefix inet;
    reference "RFC 6991";
  }

  import ietf-te-types {
    prefix "te-types";
    reference
      "RFC 8776: Traffic Engineering Common YANG Types";
  }

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

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

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           <mailto:italo.busi@huawei.com>

    Editor: Aihua Guo
           <mailto:aihuaguo.ietf@gmail.com>

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

  description
    "This module defines a YANG data model to configure an OTN
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```

```
    set forth in Section 4.c of the IETF Trust's Legal Provisions
    Relating to IETF Documents
    (https://trustee.ietf.org/license-info).
    This version of this YANG module is part of RFC XXXX; see
    the RFC itself for full legal notices.";

revision "2021-10-22" {
  description
    "Latest revision of NBI YANG model for OTN slicing.";
  reference
    "draft-zheng-ccamp-yang-otn-slicing-03: Framework and Data
    Model for OTN Network Slicing";
}

/*
 * Identities
 */
identity isolation-level {
  description
    "Base identity for the isolation-level.";
  reference
    "GSMA-NS-Template: Generic Network Slice Template,
    Version 3.0.";
}
identity no-isolation {
  base isolation-level;
  description
    "Network slices are not separated.";
}
identity physical-isolation {
  base isolation-level;
  description
    "Network slices are physically separated (e.g. different rack,
    different hardware, different location, etc.).";
}
identity logical-isolation {
  base isolation-level;
  description
    "Network slices are logically separated.";
}
identity process-isolation {
  base physical-isolation;
  description
    "Process and threads isolation.";
}
identity physical-memory-isolation {
  base physical-isolation;
  description
```



```
        "Process and threads isolation.";
    }
    identity physical-network-isolation {
        base physical-isolation;
        description
            "Process and threads isolation.";
    }
    identity virtual-resource-isolation {
        base logical-isolation;
        description
            "A network slice has access to specific range of resources
            that do not overlap with other network slices
            (e.g. VM isolation).";
    }
    identity network-functions-isolation {
        base logical-isolation;
        description
            "NF (Network Function) is dedicated to the network slice, but
            virtual resources are shared.";
    }
    identity service-isolation {
        base logical-isolation;
        description
            "NSC data are isolated from other NSCs, but virtual
            resources and NFs are shared.";
    }
}

/*
 * Groupings
 */

grouping ns-generic-info {
    description
        "Generic configuration of a network slice";
    leaf ns-name {
        type string;
        description
            "Name of the specific network slice";
    }
    leaf ns-description {
        type string;
        description
            "Description regarding the specific network slice";
    }
    leaf-list customer-name {
        type string;
        description
            "List of customers using the slice";
    }
}
```

```
    }
  }

  grouping ns-slo {
    description
      "SLO configuration of a network slice";

    container slo {
      description
        "SLO configuration of a network slice";

      leaf optimization-criterion {
        type identityref {
          base te-types:objective-function-type;
        }
        description
          "Optimization criterion applied to this topology.";
      }
      leaf delay-tolerance {
        type boolean;
        description
          "'true' if is not too critical how long it takes to deliver
          the amount of data.";
        reference
          "GSMA-NS-Template: Generic Network Slice Template,
          Version 3.0.";
      }
      leaf-list periodicity {
        type uint64;
        units seconds;
        description
          "A list of periodicities supported by the network slice.";
        reference
          "GSMA-NS-Template: Generic Network Slice Template,
          Version 3.0.";
      }
      leaf isolation-level {
        type identityref {
          base isolation-level;
        }
        description
          "A network slice instance may be fully or partly, logically
          and/or physically, isolated from another network slice
          instance. This attribute describes different types of
          isolation:";
      }
    }
  }
}
```

```
grouping node-slo {
  description
    "Node SLO";
  container slo {
    description
      "SLO configuration of a node";
    leaf isolation-level {
      type identityref {
        base isolation-level;
      }
      description
        "A network slice instance may be fully or partly, logically
        and/or physically, isolated from another network slice
        instance. This attribute describes different types of
        isolation:";
    }
  }
}

grouping link-slo {
  description
    "Link SLO";
  container slo {
    description
      "SLO configuration of a link";
    leaf delay-tolerance {
      type boolean;
      description
        "'true' if is not too critical how long it takes to deliver
        the amount of data.";
      reference
        "GSMA-NS-Template: Generic Network Slice Template,
        Version 3.0.";
    }
    leaf-list periodicity {
      type uint64;
      units seconds;
      description
        "A list of periodicities supported by the network slice.";
      reference
        "GSMA-NS-Template: Generic Network Slice Template,
        Version 3.0.";
    }
    leaf isolation-level {
      type identityref {
        base isolation-level;
      }
      description
```

```
        "A network slice instance may be fully or partly, logically
        and/or physically, isolated from another network slice
        instance. This attribute describes different types of
        isolation:";
    }
}

grouping connectivity-matrix-slo {
  description
    "SLO configuration of a path within a network slice";

  container slo {
    description
      "Path SLO configuration";
  }
  leaf delay-tolerance {
    type boolean;
    description
      "'true' if is not too critical how long it takes to deliver
      the amount of data.";
    reference
      "GSMA-NS-Template: Generic Network Slice Template,
      Version 3.0.";
  }
  leaf-list periodicity {
    type uint64;
    units seconds;
    description
      "A list of periodicities supported by the network slice.";
    reference
      "GSMA-NS-Template: Generic Network Slice Template,
      Version 3.0.";
  }
  leaf isolation-level {
    type identityref {
      base isolation-level;
    }
    description
      "A network slice instance may be fully or partly, logically
      and/or physically, isolated from another network slice
      instance. This attribute describes different types of
      isolation:";
  }
}

grouping connectivity-matrix-entry-slo {
  description
```

```
        "SLO configuration of a connectivity matrix entry within a
        network slice";

    container slo {
        description
            "SLO configuration of a connectivity matrix entry";
    }
}

grouping explicit-path {
    description
        "Explicit path for a connectivity matrix entry";

    list explicit-path {
        key "tp-id";
        description
            "List of TPs within a network topology that form a path.";
        leaf tp-id {
            type leafref {
                path "/network-slices/network-slice[ns-id=current()+
                    '/../.../..../ns-id]/network-topologies"+
                    "/network-topology[topology-id=current()+
                    '/../.../topology-id]/node/termination-point/tp-id";
            }
            description
                "Relative reference to TP id.";
        }
    }
}

grouping network-topology-def {
    description
        "Network topology definition";
    list node {
        key "node-id";
        description
            "The inventory of nodes of this topology.";
        leaf node-id {
            type inet:uri;
            description
                "Node identifier.";
        }
    }
    uses node-slo;
    list termination-point {
        key "tp-id";
        description
            "TP identifier";
        leaf tp-id {
```

```
        type inet:uri;
        description
            "Termination point identifier.";
    }
    leaf endpoint-id {
        type leafref {
            path "/network-slices/network-slice[ns-id=current()]+
                ../../../../../../ns-id]/endpoints/endpoint/" +
                "endpoint-id";
        }
        description
            "Relative reference to TP id.";
    }
}
list link {
    key "link-id";
    description
        "Link identifier.";
    leaf link-id {
        type inet:uri;
        description
            "Link identifier.";
    }
    uses link-slo;
    container source {
        description
            "Link source node";
        leaf source-node {
            type leafref {
                path "../../../../../node/node-id";
            }
            description
                "Source node identifier, must be in same topology.";
        }
        leaf source-tp {
            type leafref {
                path "../../../../../node[node-id=current()]/../"+
                    "source-node]/termination-point/tp-id";
            }
            description
                "Termination point within source node that terminates
                the link.";
        }
    }
}
container destination {
    description
        "Link destination node";
```

```
    leaf dest-node {
      type leafref {
        path "../.../node/node-id";
      }
      description
        "Destination node identifier, must be in same topology.";
    }
    leaf dest-tp {
      type leafref {
        path "../.../node[node-id=current()/../"+
          "dest-node]/termination-point/tp-id";
      }
      description
        "Termination point within destination node that terminates
        the link.";
    }
  }
}

/*
 * Configuration data nodes
 */
container network-slices {
  description
    "Generic network slice configurations";
  list network-slice {
    key "ns-id";
    description
      "Network slice identifier";
    leaf ns-id {
      type string;
      description
        "A unique network slice identifier across a slice controller";
    }
    uses ns-generic-info;
    uses ns-slo;

    container endpoints {
      description
        "Endpoints of a network slice";

      list endpoint {
        key "endpoint-id";
        description
          "List of endpoints";
        leaf endpoint-id {
          type string;
        }
      }
    }
  }
}
```

```

        description
            "Endpoint identifier";
    }
}
}
container network-topologies {
    description
        "A network slice is described as a network topology";

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

    list connectivity-matrix {
        key "connectivity-matrix-id";
        description
            "List of connectivity matrix entities";
        leaf connectivity-matrix-id {
            type uint32;
            description
                "Connectivity matrix identifier";
        }
        leaf topology-id {
            type leafref {
                path "../../network-topologies/network-topology/topology-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

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