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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.

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

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

1.1. Terminology

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

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

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

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

- o configuration data
- o state data

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

1.2. Tree diagram

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

1.3. Prefixes in Data Node Names

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

Prefix	YANG module	Reference
optical-imp-topo	ietf-optical-impairment-topology	[RFCXXXX]
layer0-types	ietf-layer0-types	[L0-Types]
nw	ietf-network	[RFC8345]
nt	ietf-network-topology	[RFC8345]

tet	ietf-te-topology	[TE-TOPO]	
+-----+	+-----+	+-----+	+-----+

Table 1: Prefixes and corresponding YANG modules

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

2. Reference Architecture

2.1. Control Plane Architecture

Figure 1 shows the control plane architecture.

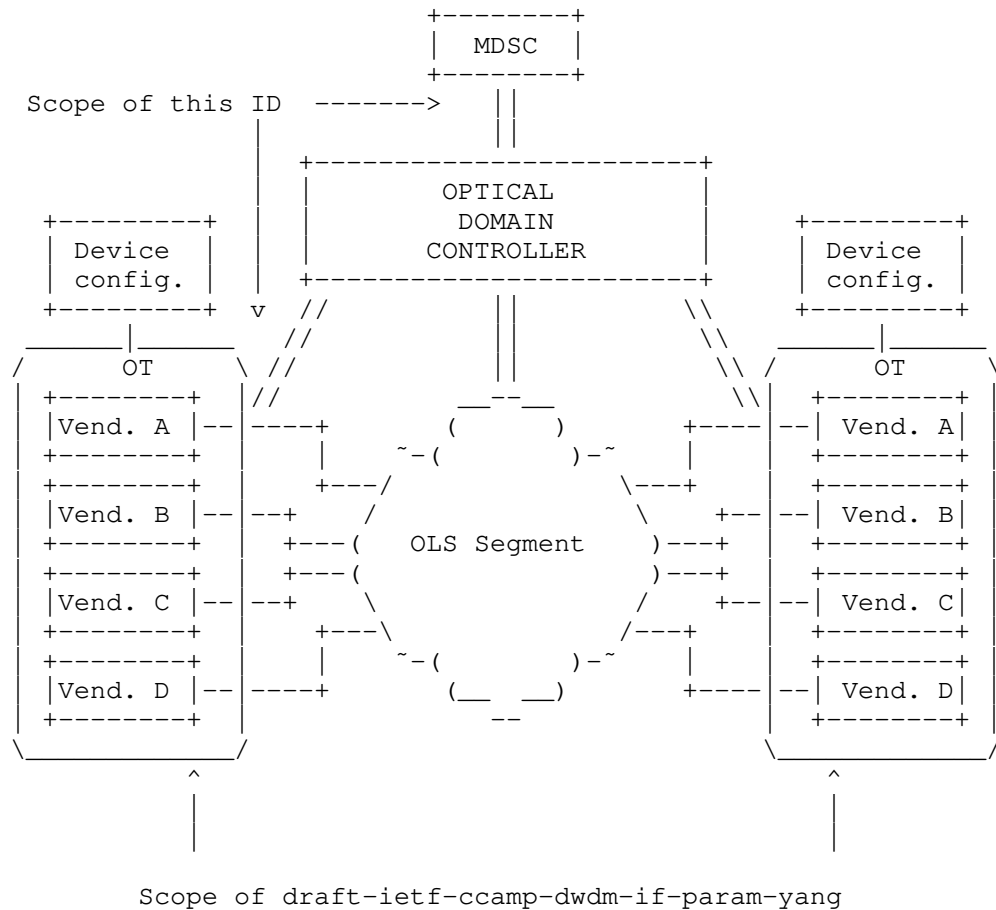


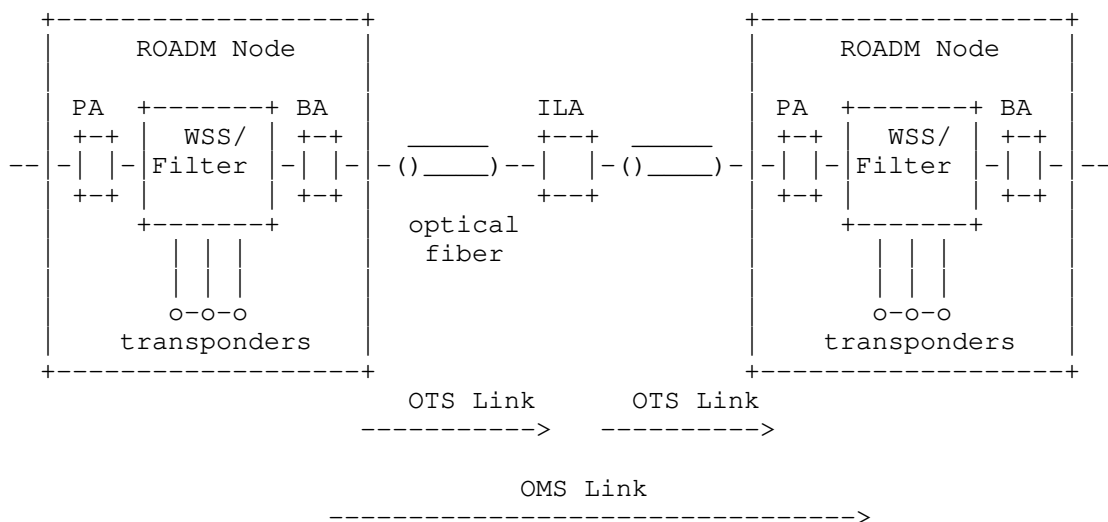
Figure 1. Control Plane Architecture

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

2.2. Transport Data Plane

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

Figure 2 shows the reference architecture.



PA: Pre-Amplifier
 BA: Booster Amplifier
 ILA: In-Line Amplifier

Figure 2. Reference Architecture for Optical Transport Network

BA (on the left side ROADM) is the ingress Amplifier and PA (on the right side ROADM) is the egress amplifier for the OMS link shown in the Figure.

2.3. OMS Media Links

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

OTS Media Link represents a media link:

- (i) between ROADM's BA and ILA;
- (ii) between a pair of ILAs;
- (iii) between ILA and ROADM's PA.

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

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

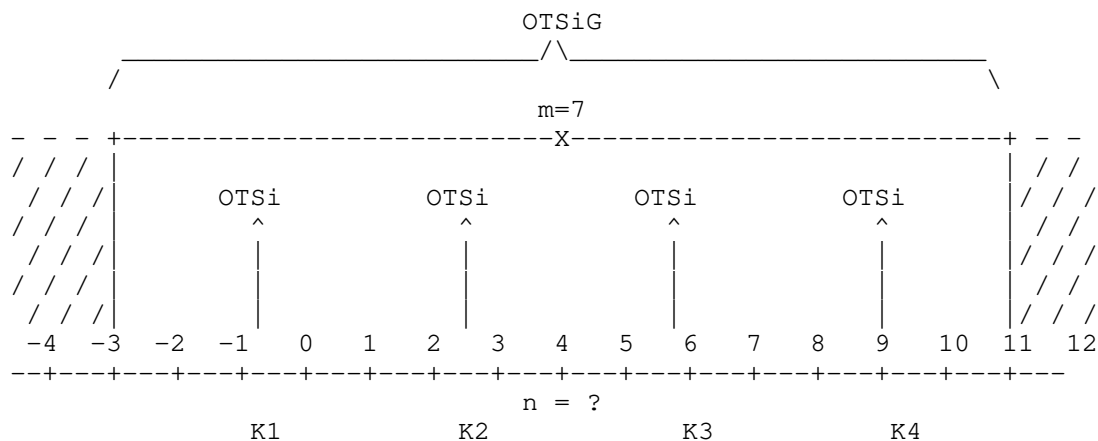
2.3.1. Optical Tributary Signal (OTSi)

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

2.3.2. Optical Tributary Signal Group (OTSiG)

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

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

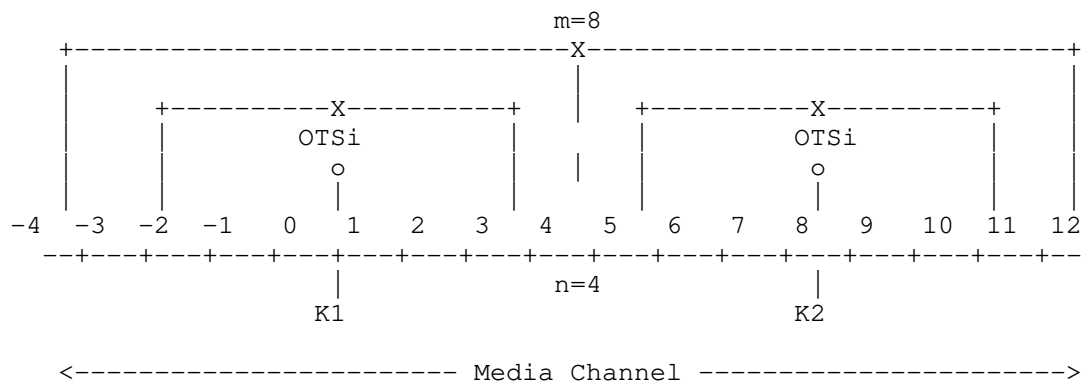


2.3.3 Media Channel (MC)

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

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

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

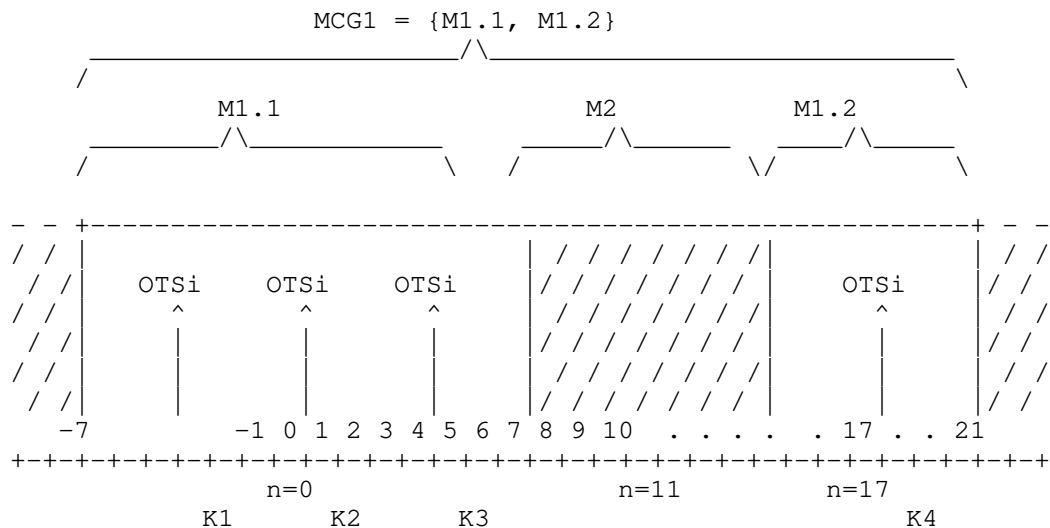


The frequency slot of the MC is defined by the n value defining the central frequency of the MC and the m value that defines the width of the MC following the flexible grid definition in ITU-T Recommendation G.694.1 [G.694.1]. In this model, the effective frequency slot as defined in ITU-T draft Recommendation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

2.3.3. Media Channel Group (MCG)

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

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



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

2.4. Amplifiers

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

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

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

2.5. Transponders

A Transponder is the element that sends and receives the optical signal from a fiber. A transponder is typically characterized by its data rate and the maximum distance the signal can travel. Channel frequency, per channel input power, FEC and Modulation are also associated with a transponder. From a path computation point of view, the selection of the compatible source and destination transponders is an important factor for optical signal to traverse through the fiber. There are three main approaches to determine optical signal compatibility. Application Code based on G.698.2 is one approach that only checks the code at both ends of the link. Another approach is organization codes that are specific to an organization or a vendor. The third approach is specify all the

relevant parameters explicitly, e.g., FEC type, Modulation type, etc.

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

2.6. WSS/Filter

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

2.7. Optical Fiber

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

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

3. YANG Model (Tree Structure)

```
module: ietf-optical-impairment-topology
  augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
    +--rw optical-impairment-topology!
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes:
    +--ro OMS-attributes
      +--ro generalized-snr?                decimal64
      +--ro equalization-mode                identityref
      +--ro (power-param)?
        |   +--:(channel-power)
        |   |   +--ro nominal-channel-power?    decimal64
        |   +--:(power-spectral-density)
        |   |   +--ro nominal-power-spectral-density?    decimal64
      +--ro media-channel-group* [i]
```

```

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

```

```

    +---ro OTSiG-container
      +---ro OTSi* [OTSi-carrier-id]
        +---ro OTSi-carrier-id          int16
        +---ro OTSi-carrier-frequency?   decimal64
        +---ro OTSi-signal-width?        decimal64
        +---ro channel-delta-power?      decimal64
+---ro transponders-list* [transponder-id]
  +---ro transponder-id                uint32
  +---ro (mode)?
    +---: (G.692.2)
      +---ro standard_mode?             layer0-types:standard-mode
    +---: (organizational_mode)
      +---ro operational-mode?           layer0-types:operational-mode
      |
      +---ro organization-identifier?    layer0-types:vendor-identifier
    +---: (explicit_mode)
      +---ro available-modulation*       identityref
      +---ro modulation-type?            identityref
      +---ro available-baud-rates*       uint32
      +---ro configured-baud-rate?       uint32
      +---ro available-FEC*              identityref
      +---ro FEC-type?                   identityref
      +---ro FEC-code-rate?              decimal64
      +---ro FEC-threshold?              decimal64
  +---ro power?                         int32
  +---ro power-min?                     int32
  +---ro power-max?                     int32
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point:
    +---ro transponder-list* [carrier-id]
      +---ro carrier-id                uint32

```

4. Optical Impairment Topology YANG Model

```

<CODE BEGINS> file ietf-optical-impairment-topology@2018-05-22.yang
module ietf-optical-impairment-topology {
  yang-version 1.1;

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

  prefix "optical-imp-topo";

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

```

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

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

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

organization
  "IETF CCAMP Working Group";

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

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revision 2019-05-22 {
  description
```

```
    "Initial Version";
  reference
    "RFC XXXX: A Yang Data Model for Impairment-aware
      Optical Networks";
}

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

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

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

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

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

identity DP_QAM8 {
  base modulation;
  description
    "DP-QAM8 (Dual Polarization Quadrature Amplitude Modulation)";
}

identity DC_DP_QAM8 {
  base modulation;
  description
    "DC DP-QAM8 (Dual Polarization Quadrature Amplitude Modulation)";
}

identity DP_QAM16 {
  base modulation;
  description
    "DP-QAM16 (Dual Polarization Quadrature Amplitude Modulation)";
}

identity DC_DP_QAM16 {
  base modulation;
```



```
    description
      "DC DP-QAM16 (Dual Polarization Quadrature Amplitude Modulation)";
  }

  identity FEC {
    description
      "Enumeration that defines the type of
      Forward Error Correction";
  }
  identity reed-solomon {
    base FEC;
    description
      "Reed-Solomon error correction";
  }
  identity hamming-code {
    base FEC;
    description
      "Hamming Code error correction";
  }
  identity golay {
    base FEC;
    description "Golay error correction";
  }

  typedef fiber-type {
    type enumeration {
      enum G.652 {
        description "G.652 Standard Singlemode Fiber";
      }
      enum G.654 {
        description "G.654 Cutoff Shifted Fiber";
      }
      enum G.653 {
        description "G.653 Dispersion Shifted Fiber";
      }
      enum G.655 {
        description "G.655 Non-Zero Dispersion Shifted Fiber";
      }
      enum G.656 {
        description "G.656 Non-Zero Dispersion for Wideband
          Optical Transport";
      }
      enum G.657 {
        description "G.657 Bend-Insensitive Fiber";
      }
    }
    description
      "ITU-T based fiber-types";
  }
```

```
}

grouping transponder-attributes {
  description "Configuration of an optical transponder";

  leaf-list available-modulation {
    type identityref {
      base modulation;
    }
    config false;
  }
  description
    "List determining all the available modulations";
}

leaf modulation-type {
  type identityref {
    base modulation;
  }
  config false;
  description
    "Modulation configured for the transponder";
}

leaf-list available-baud-rates {
  type uint32;
  units Bd;
  config false;
  description
    "list of available baud-rates. Baud-rate is the unit for
    symbol rate or modulation rate in symbols per second or
    pulses per second. It is the number of distinct symbol
    changes (signaling events) made to the transmission medium
    per second in a digitally modulated signal or a line code";
}

leaf configured-baud-rate {
  type uint32;
  units Bd;
  config false;
  description "configured baud-rate";
}

leaf-list available-FEC {
  type identityref {
    base FEC;
  }
  config false;
  description "List determining all the available FEC";
}
```

```
leaf FEC-type {
  type identityref {
    base FEC;
  }
  config false;
description
  "FEC type configured for the transponder";
}

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

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

}

grouping sliceable-transponder-attributes {
  description
    "Configuration of a sliceable transponder.";
  list transponder-list {
    key "carrier-id";
    config false;
    description "List of carriers";
    leaf carrier-id {
      type uint32;
      config false;
      description "Identifier of the carrier";
    }
  }
}

grouping optical-fiber-data {
  description
    "optical link (fiber) attributes with impairment data";
```

```
leaf fiber-type {
    type fiber-type;
    config false;
    description "fiber-type";
}

leaf span-length {
    type decimal64 {
        fraction-digits 2;
    }
    units "km";
    config false;
    description "the lenght of the fiber span in km";
}

leaf input-power {
    type decimal64 {
        fraction-digits 2;
    }
    units "dBm";
    config false;
    description
        "Average input power level estimated at the receiver
         of the link";
}

leaf output-power {
    type decimal64 {
        fraction-digits 2;
    }
    units "dBm";
    description
        "Mean launched power at the transmitter of the link";
}

leaf pmd {
    type decimal64 {
        fraction-digits 8;
        range "0..max";
    }
    units "ps/(km)^0.5";
    config false;
    description
        "Polarization Mode Dispersion";
}

leaf cd {
    type decimal64 {
        fraction-digits 5;
    }
}
```

```
    }
    units "ps/nm/km";
    config false;
    description
      "Cromatic Dispersion";
  }

  leaf osnr {
    type decimal64 {
      fraction-digits 5;
    }
    units "dB";
    config false;
    description
      "Optical Signal-to-Noise Ratio (OSNR) estimated
       at the receiver";
  }

  leaf sigma {
    type decimal64 {
      fraction-digits 5;
    }
    units "dB";
    config false;
    description
      "sigma in the Gaussian Noise Model";
  }
}

grouping optical-channel-data {
  description
    "optical impairment data per channel/wavelength";
  leaf bit-rate {
    type decimal64 {
      fraction-digits 8;
      range "0..max";
    }
    units "Gbit/s";
    config false;
    description
      "Gross bit rate";
  }

  leaf BER {
    type decimal64 {
      fraction-digits 18;
      range "0..max";
    }
    config false;
  }
}
```

```
    description
      "BER (Bit Error Rate)";
  }

  leaf ch-input-power {
    type decimal64 {
      fraction-digits 2;
    }
    units "dBm";
    config false;
    description
      "Per channel average input power level
       estimated at the receiver of the link";
  }

  leaf ch-pmd {
    type decimal64 {
      fraction-digits 8;
      range "0..max";
    }
    units "ps/(km)^0.5";
    config false;
    description
      "per channel Polarization Mode Dispersion";
  }

  leaf ch-cd {
    type decimal64 {
      fraction-digits 5;
    }
    units "ps/nm/km";
    config false;
    description
      "per channel Chromatic Dispersion";
  }

  leaf ch-osnr {
    type decimal64 {
      fraction-digits 5;
    }
    units "dB";
    config false;
    description
      "per channel Optical Signal-to-Noise Ratio
       (OSNR) estimated at the receiver";
  }

  leaf q-factor {
    type decimal64 {
```

```
        fraction-digits 5;
    }
    units "dB";
    config false;
    description
        "q-factor estimated at the receiver";
}
}

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

    leaf standard_mode {
        type layer0-types:standard-mode;
        config false;
        description
            "G.698.2 standard mode";
    }
}

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

    leaf operational-mode {
        type layer0-types:operational-mode;
        config false;
        description
            "configured organization- or vendor-specific
            application identifiers (AI) supported by the transponder";
    }

    leaf organization-identifier {
        type layer0-types:vendor-identifier;
        config false;
        description
            "organization identifier that uses organizational
            mode";
    }
}

/*
* Identities
```

```
    */
    identity type-element {
        description
            "Base identity for element type";
    }

    identity Fiber {
        base type-element;
        description
            "Fiber element";
    }

    identity Roadm {
        base type-element;
        description
            "Roadm element";
    }

    identity Edfa {
        base type-element;
        description
            "Edfa element";
    }

    identity Concentratedloss {
        base type-element;
        description
            "Concentratedloss element";
    }

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

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

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

    /*
    * Groupings
```



```
*/
grouping amplifier-params {
  description "describes parameters for an amplifier";
  container amplifier {
    description "amplifier type, operational parameters are described";
    leaf type_variety {
      type string ;
      mandatory true ;
      description
        "String identifier of amplifier type referencing
         a specification in a separate equipment catalog";
    }
    container operational {
      description "amplifier operational parameters";
      leaf actual-gain {
        type decimal64 {
          fraction-digits 2;
        }
        units dB ;
        mandatory true ;
        description "..";
      }
      leaf tilt-target {
        type decimal64 {
          fraction-digits 2;
        }
        mandatory true ;
        description "..";
      }
      leaf out-voa {
        type decimal64 {
          fraction-digits 2;
        }
        units dB;
        mandatory true;
        description "..";
      }
      leaf in-voa {
        type decimal64 {
          fraction-digits 2;
        }
        units dB;
        mandatory true;
        description "..";
      }
      uses power-param;
    }
  }
}
```

```
grouping fiber-params {
  description "String identifier of fiber type referencing a specification in
a
separate equipment catalog";
  container fiber {
    description "fiber characteristics";
    leaf type_variety {
      type string ;
    mandatory true ;
    description "fiber type";
  }
  leaf length {
    type decimal64 {
      fraction-digits 2;
    }
    units km;
    mandatory true ;
    description "length of fiber";
  }
  leaf loss_coef {
    type decimal64 {
      fraction-digits 2;
    }
    units dB/km;
    mandatory true ;
    description "loss coefficient of the fiber";
  }
  leaf total_loss {
    type decimal64 {
      fraction-digits 2;
    }
    units dB;
    mandatory true ;
    description
      "includes all losses: fiber loss and conn_in and conn_out losses";
  }
  leaf pmd{
    type decimal64 {
      fraction-digits 2;
    }
    units sqrt(ps);
    description "pmd of the fiber";
  }
  leaf conn_in{
    type decimal64 {
      fraction-digits 2;
    }
    units dB;
    description "connector-in";
  }
}
```

```
    }
    leaf conn_out{
        type decimal64 {
            fraction-digits 2;
        }
        units dB;
        description "connector-out";
    }
}

grouping roadm-params{
    description "roadm parameters description";
    container roadm{
        description "roadm parameters";
        leaf type_variety {
            type string ;
            mandatory true ;
            description "String identifier of roadm type referencing a specification
in a
separate equipment catalog";
        }
        leaf loss {
            type decimal64 {
                fraction-digits 2;
            }
            units dB ;
            description "..";
        }
    }
}

grouping concentratedloss-params{
    description "concentrated loss";
    container concentratedloss{
        description "concentrated loss";
        leaf loss {
            type decimal64 {
                fraction-digits 2;
            }
            units dB ;
            description "..";
        }
    }
}

grouping power-param{
    description
        "optical power or PSD after the ROADM or after the out-voa";
    choice power-param {
```

```

    description
        "select the mode: channel power or power spectral density";
    case channel-power {
/*      when "equalization-mode='channel-power'"; */
        leaf nominal-channel-power{
            type decimal64 {
                fraction-digits 1;
            }
            units dBm ;
            description
                " Reference channel power after the ROADM or after the out-voa. ";
        }
    }
    case power-spectral-density{
/*      when "equalization-mode='power-spectral-density'"; */
        leaf nominal-power-spectral-density{
            type decimal64 {
                fraction-digits 16;
            }
            units W/Hz ;
            description
                " Reference power spectral density after the ROADM or after the out-voa.
                Typical value : 3.9 E-14, resolution 0.1nW/MHz";
        }
    }
}

grouping oms-general-optical-params {
    description "OMS link optical parameters";
    leaf generalized-snr {
        type decimal64 {
            fraction-digits 5;
        }
        units "dB@0.1nm";
        description "generalized snr";
    }
    leaf equalization-mode{
        type identityref {
            base type-power-mode;
        }
        mandatory true;
        description "equalization mode";
    }
    uses power-param;
}

grouping OTSiG {

```

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

```
container OTSiG-container {
  config false;
  description
    "the container contains the related list of OTSi.
    The list could also be of only 1 element";
  list OTSi {
    key "OTSi-carrier-id";
    description
      "list of OTSi's under OTSi-G";
    leaf OTSi-carrier-id {
      type int16;
      description "OTSi carrier-id";
    }
    leaf OTSi-carrier-frequency {
      type decimal64 {
        fraction-digits 3;
      }
      units GHz;
      config false;
      description
        "OTSi carrier frequency";
    }
    leaf OTSi-signal-width {
      type decimal64 {
        fraction-digits 3;
      }
      units GHz;
      config false;
      description
        "OTSi signal width";
    }
    leaf channel-delta-power {
      type decimal64 {
        fraction-digits 2;
      }
      units dB;
      config false;
      description
        "optional ; delta power to ref channel input-power applied
        to this media channel";
    }
  }
} // OTSiG container
} // OTSiG grouping
```

```

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

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

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

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

```

```

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

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

/* Data nodes */

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

```

```
}

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

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

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

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

  list transponders-list {
    key "transponder-id";
    config false;
    description "list of transponders";
    leaf transponder-id {
```



```
type uint32;
description "transponder identifier";
}

choice mode {
  description "standard mode, organizational mode or explicit mode";

  case G.692.2 {
    uses standard_mode;
  }

  case organizational_mode {
    uses organizational_mode;
  }

  case explicit_mode {
    uses transponder-attributes;
  }
}

leaf power {
  type int32;
  units "dBm";
  config false;
  description "per channel power";
}

leaf power-min {
  type int32;
  units "dBm";
  config false;
  description "minimum power of the transponder";
}

leaf power-max {
  type int32;
  units "dBm";
  config false;
  description "maximum power of the transponder";
}
}
}

augment "/nw:networks/nw:network/nw:node/tet:te"
+ "/tet:tunnel-termination-point" {
  when "/nw:networks/nw:network/nw:network-types"
  + "/tet:te-topology/optical-imp-topo:optical-impairment-topology" {
    description
      "This augment is only valid for optical impairment with sliceable
```

```
        transponder model";
    }
    description
        "Tunnel termination point augmentation for sliceable transponder model.";
    uses sliceable-transponder-attributes;
}
}
<CODE ENDS>
```

5. Security Considerations

The configuration, state, and action data defined in this document are designed to be accessed via a management protocol with a secure transport layer, such as NETCONF [RFC6241]. The NETCONF access control model [RFC6536] provides the means to restrict access for particular NETCONF users to a preconfigured subset of all available NETCONF protocol operations and content.

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

6. IANA Considerations

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

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

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

```
-----
name:      ietf-optical-impairment-topology
namespace: urn:ietf:params:xml:ns:yang:ietf-optical-impairment-
topology
-----
```

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

7. Acknowledgments

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

8. References

8.1. Normative References

- [RFC7950] Bjorklund, M., Ed., "The YANG 1.1 Data Modeling Language", RFC 7950, August 2016.
- [RFC8040] A. Bierman, M. Bjorklund, K. Watsen, "RESTCONF Protocol", RFC 8040, January 2017.
- [RFC8341] Bierman, A. and M. Bjorklund, "Network Configuration Access Control Model", RFC 8341, March 2018.

8.2. Informative References

- [RFC6241] Enns, R., Ed., Bjorklund, M., Ed., Schoenwaelder, J., Ed., and A. Bierman, Ed., "Network Configuration Protocol (NETCONF)", RFC 6241, June 2011.
- [RFC6566] Y. Lee, G. Bernstein, D. Li, G. Martinelli, "A Framework for the Control of Wavelength Switched Optical Networks (WSOs) with Impairments", RFC 6566, March 2012.
- [RFC7446] Y. Lee, G. Bernstein, D. Li, W. Imajuku, "Routing and Wavelength Assignment Information Model for Wavelength Switched Optical Networks", RFC 7446, February 2015.
- [RFC7579] G. Bernstein, Y. Lee, D. Li, W. Imajuku, "General Network Element Constraint Encoding for GMPLS Controlled Networks", RFC 7579, June 2015.
- [RFC7581] G. Bernstein, Y. Lee, D. Li, W. Imajuku, "Routing and Wavelength Assignment Information Encoding for Wavelength Switched Optical Networks", RFC 7581, June 2015.
- [RFC7698] O. Gonzalez de Dios, Ed. and R. Casellas, Ed., "Framework and Requirements for GMPLS-Based Control of Flexi-Grid Dense Wavelength Division Multiplexing (DWDM) Networks", RFC 7698, November 2015.

- [RFC8340] M. Bjorklund, L. Berger, Ed., "YANG Tree Diagrams", RFC 8340, March 2018.
- [RFC8342] Bjorklund, M., Schoenwaelder, J., Shafer, P., Watsen, K., and R. Wilton, "Network Management Datastore Architecture (NMDA)", RFC 8342, March 2018.
- [RFC8345] A. Clemm, et al, "A YANG Data Model for Network Topologies", RFC 8345, March 2018.
- [TE-TOPO] X. Liu, et al., "YANG Data Model for TE Topologies", work in progress: draft-ietf-teas-yang-te-topo.
- [RFC8453] Ceccarelli, D. and Y. Lee, "Framework for Abstraction and Control of Traffic Engineered Networks", RFC 8453, August 2018.
- [WSON-Topo] Y. Lee, Ed., "A Yang Data Model for WSON Optical Networks", draft-ietf-ccamp-wson-yang-13, work in progress.
- [L0-Types] Y. Lee, Ed., "A YANG Data Model for Layer 0 Types", draft-ietf-ccamp-layer0-types, work in progress.
- [G.807] "Draft new Recommendation ITU-T G.807 (ex G.media)", ITU-T Recommendation G.807, work in progress.
- [G.709] "Interfaces for the Optical Transport Network (OTN)", ITU-T Recommendation G.709, June 2016.
- [G.694.1] "Spectral grids for WDM applications: DWDM frequency grid", ITU-T Recommendation G.694.1, February 2012.
- [G.959.1] "Optical transport network physical layer interfaces", ITU-T Recommendation G.959.1, February 2012.
- [G.872] "Architecture of optical transport networks", ITU-T Recommendation G.872, January 2017.

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