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

Abstract

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

The Yang model defined in this memo can be used for Optical Parameters monitoring and/or configuration of the endpoints of a multi-vendor IaDI optical link.

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1. Introduction

This memo defines a Yang model that translates and obsolete the SNMP mib module defined in draft-galikunze-ccamp-dwdm-if-snmp-mib for managing single channel optical interface parameters of DWDM applications, using the approach specified in G.698.2. This model

supports parameters to characterize coherent transceivers found in current implementations to specify the mode of operation. As application identifiers like those specified in ITU-T G.874.1 [ITU.G874.1] are not 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 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 read-only 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].

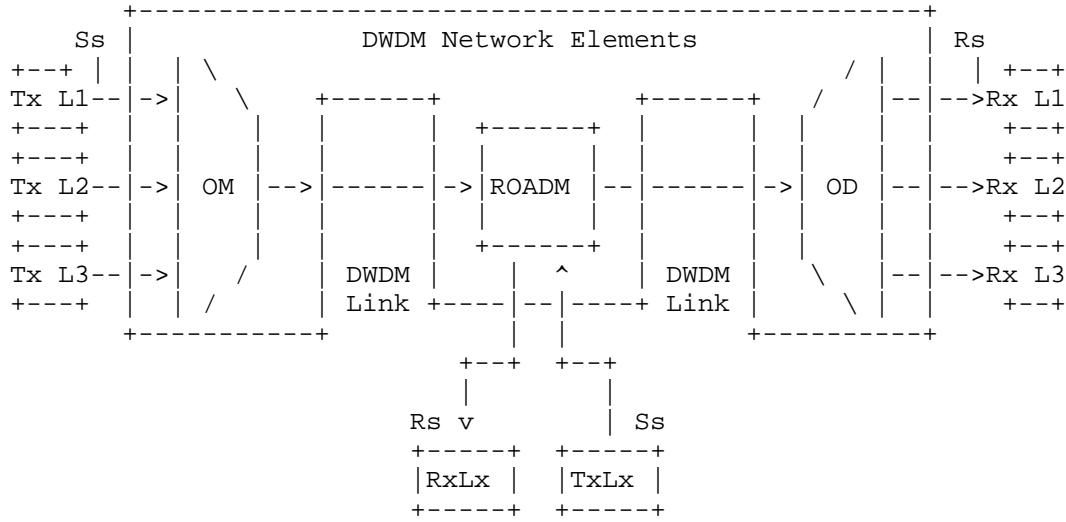
This memo specifies a Yang model for optical interfaces.

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 min-central-frequency? uint32
      | +--ro max-central-frequency? uint32
      | +--ro min-input-power?       dbm-t
      | +--ro max-input-power?       dbm-t
      | +--ro min-output-power?      dbm-t
      | +--ro max-output-power?      dbm-t
      | +--ro osnr-margin?           int32
      | +--ro q-margin?              int32
      | +--ro fec-info?              string

```

```

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

```

```

|      +--ro max-diff-group-delay?          int32
|      +--ro modulation-format?            string
|      +--ro bits-per-symbol?              uint32
|      +--ro num-symbols-in-alphabet?      uint32
|      +--ro symbols-index?                uint32
|      +--ro i-center?                     int32
|      +--ro q-center?                     int32
|      +--ro i-noise-variance?             int32
|      +--ro q-noise-variance?             int32
|      +--ro a-noise-variance?             int32
|      +--ro p-noise-variance?             int32
+--rw current-opt-if-och-mode-params
  +--rw mode-id?                           string
  +--ro osnr-margin?                       int32
  +--ro q-margin?                          int32
  +--rw central-frequency?                  uint32
  +--rw output-power?                      int32
  +--ro input-power?                       int32
  +--rw min-fec-ber-mantissa-threshold?    uint32
  +--rw min-fec-ber-exponent-threshold?    int32
  +--rw max-fec-ber-mantissa-threshold?    uint32
  +--rw max-fec-ber-exponent-threshold?    int32
  +--rw number-of-tcas-supported?          uint32
  +--rw mode-list* [tca-type]
    |   +--rw tca-type                      opt-if-och-tca-types
    |   +--rw min-threshold?                int32
    |   +--rw max-threshold?                int32
  +--ro cur-osnr?                          int32
  +--ro cur-q-factor?                      int32
  +--ro uncorrected-words?                  uint64
  +--ro fec-ber-mantissa?                   uint32
  +--ro fec-ber-exponent?                   int32

notifications:
+---n opt-if-och-central-frequency-change
|   +--ro if-name?    -> /if:interfaces/interface/name
|   +--ro new-opt-if-och-central-frequency
|       +--ro central-frequency?          uint32
+---n opt-if-och-mode-change
|   +--ro if-name?    -> /if:interfaces/interface/name
|   +--ro mode-id?    string
+---n opt-if-och-min-tca
  +--ro if-name?    -> /if:interfaces/interface/name
  +--ro tca-type?   opt-if-och-tca-types

```

5. Structure of the Yang Module

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

6. Yang Module

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

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

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

  import ietf-interfaces {
    prefix if;
  }

  organization
    "IETF CCAMP
     Working Group";

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

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

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

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     BSD License set forth in Section 4.c of the IETF Trust's
     Legal Provisions Relating to IETF Documents
     (http://trustee.ietf.org/license-info).";
```



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

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

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

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

typedef opt-if-och-tca-types {

    type enumeration {
        enum max-laser-linewdt {
            description " The maximum laser linewidth";
        }
        enum min-tx-power-tca {
            description " The min tx power tca";
        }
        enum max-tx-power-tca {
            description " The min tx power tca";
        }
        enum min-rx-power-tca{
            description " The min tx power tca";
        }
        enum max-rx-power-tca{
            description " The min tx power tca";
        }
    }
}
```

```

    enum max-pol-power-diff-tca{
        description " The power diff. between polariz. tca";
    }
    enum max-pol-skew-diff-tca{
        description " The Skew between the two polariz. tca";
    }
    enum min-frequency-offset-tca{
        description " Min Frequency offset tca";
    }
    enum max-frequency-offset-tca{
        description " Max Frequency offset tca";
    }
    enum min-osnr-tca{
        description " Min OSNR tca";
    }
    enum max-osnr-tca{
        description " Max OSNR tca";
    }
    enum min-laser-temperature-tca{
        description " The min tx power tca";
    }
    enum max-laser-temperature-tca{
        description " Temperature tca";
    }
    enum min-fec-ber-tca{
        description " Min Pre Fec BER tca";
    }
    enum max-fec-ber-tca{
        description " Max Pre Fec BER tca";
    }
    enum min-q-tca{
        description "Min Q tca";
    }
    enum max-q-tca {
        description "Max Q tca";
    }
}
description " The different types of TCA's";
}

```

```

grouping opt-if-och-power {
    description "Interface optical Power";
    leaf output-power {
        type int32;
        units ".01dbm";
        description "The output power for this interface
            in .01 dBm.
    }
}

```

```

        The setting of the output power is
        optional";
    }

    leaf input-power {
        type int32;
        units ".01dbm";
        config false;
        description "The current input power of this
            interface";
    }
}

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

grouping opt-if-och-fec {
    description "Fec info";
    leaf fec-info {
        type string {
            length "1..255";
        }
        config false;
        description
            "Fec Type - eg GFEC";
    }
    leaf fec-bitrate {
        type string {
            length "1..255";
        }
        config false;
        description

```

```
        "Fec Overhead rate ";
    }
    leaf fec-gain {
        type string {
            length "1..255";
        }
        config false;
        description
            "Fec Overhead rate ";
    }
    leaf fec-ber-mantissa-threshold {
        type uint32;
        description " Mantissa of the FEC BER threshold";
    }
    leaf fec-ber-exponent-threshold {
        type int32;
        description " Exponent of the FEC BER threshold";
    }
}

grouping opt-if-och-central-frequency {
    description "Interface Central Frequency";
    leaf central-frequency {
        type uint32;
        description " This parameter indicates the frequency
            of this interface ";
    }
}

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

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

grouping opt-if-och-modulation-params {
    description "Optical modulation parameters for the lane";
    leaf modulation-format {
        type string {
            length "1..255";
        }
        config false;
        description
            "Modulation format for this mode";
    }
    leaf bits-per-symbol {
        type uint32;
        description " This parameter the bits per symbol for
                     this mode.";
    }
    leaf num-symbols-in-alphabet {
        type uint32;
        description " This parameter the bits per symbol for
                     this mode.";
    }
}
```

```
    }
    leaf symbols-index {
      type uint32;
      description " This parameter is the symbol index this
                  mode.";
    }
    uses opt-if-och-constellation;
  }

  grouping opt-if-och-lane-param {
    description "Optical parameters for the lane";
    leaf number-of-lanes {
      type uint32;
      config false;
      description
        "Number of optical lanes of this interface";
    }
    leaf min-laser-temperature {
      type int32;
      units ".01C";
      config false;
      description
        "Minimum Laser Temperature of this mode for
         this interface";
    }
    leaf max-laser-temperature {
      type int32;
      units ".01C";
      config false;
      description
        "Maximum Laser Temperature of this mode for
         this interface";
    }
    leaf min-rx-optical-power {
      type dbm-t;
      config false;
      description
        "Minimum rx optical power of this mode for
         this interface";
    }
    leaf max-rx-optical-power {
      type dbm-t;
      config false;
      description
        "Maximum rx optical power of this mode for
         this interface";
    }
  }
```

```
    }
    leaf min-chromatic-dispersion {
        type int32;
        config false;
        description
            "Minimum chromatic dispersion of this mode
             for this interface";
    }
    leaf max-chromatic-dispersion {
        type int32;
        config false;
        description
            "Maximum chromatic dispersion of this
             mode for this interface";
    }
    leaf min-diff-group-delay {
        type int32;
        config false;
        description
            "Minimum Differential group delay of this
             mode for this interface";
    }
    leaf max-diff-group-delay {
        type int32;
        config false;
        description
            "Maximum Differential group delay of this
             mode for this interface";
    }
    uses opt-if-och-modulation-params;
}

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

```
grouping opt-if-och-fec-tca-thresholds {
  description "Pre FEC BER Thresholds for TCA's";
  leaf min-fec-ber-mantissa-threshold {
    type uint32;
    description " Min Mantissa of the FEC BER threshold";
  }
  leaf min-fec-ber-exponent-threshold {
    type int32;
    description " Min Exponent of the FEC BER threshold";
  }
  leaf max-fec-ber-mantissa-threshold {
    type uint32;
    description " Max Mantissa of the FEC BER threshold";
  }
  leaf max-fec-ber-exponent-threshold {
    type int32;
    description " Max Exponent of the FEC BER threshold";
  }
}
```

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



```
        uses opt-if-och-fec-tca-thresholds;
        uses opt-if-och-tca-list;
    }

    grouping opt-if-och-statistics {
        description "OCh statistics.";
        leaf cur-osnr {
            type int32;
            units "dB";
            config false;
            description " OSNR margin to FEC threshold";
        }
        leaf cur-q-factor {
            type int32;
            units "dB";
            config false;
            description " Q-Factor of the interface";
        }
        leaf uncorrected-words {
            type uint64;
            config false;
            description " Post FEC errored words";
        }
        leaf fec-ber-mantissa {
            type uint32;
            config false;
            description " Pre fec FEC errored words mantissa";
        }
        leaf fec-ber-exponent {
            type int32;
            config false;
            description " Pre fec FEC errored words exponent";
        }
    }

    grouping opt-if-och-mode {
        description "OCh mode template.";
        leaf mode-id {
            type string {
                length "1..255";
            }
            config false;
            description
                "Id for the OCh mode template";
        }
        leaf min-central-frequency {
            type uint32;
        }
    }
}
```

```
        config false;
        description "This parameter indicates the minimum
                    frequency for this template ";
    }
    leaf max-central-frequency {
        type uint32;
        config false;
        description "This parameter indicates the minimum
                    frequency for this template ";
    }
    leaf min-input-power {
        type dbm-t;
        config false;
        description "The minimum input power of this
                    interface";
    }
    leaf max-input-power {
        type dbm-t;
        config false;
        description "The maximum input power of this
                    interface";
    }
    leaf min-output-power {
        type dbm-t;
        config false;
        description "The minimum output power of this
                    interface";
    }
    leaf max-output-power {
        type dbm-t;
        config false;
        description "The maximum output power of this
                    interface";
    }
    leaf osnr-margin {
        type int32;
        units "dB";
        config false;
        description "OSNR margin to FEC threshold";
    }
    leaf q-margin {
        type int32;
        units "dB";
        config false;
        description "Q-Factor margin to FEC threshold";
    }
    uses opt-if-och-fec;
    uses opt-if-och-lane-param;
```

```
    }

    grouping opt-if-och-mode-list {
        description "List of Mode list group.";
        leaf number-of-modes-supported {
            type uint32;
            description "Number of modes
                        supported by this interface";
        }
        list mode-list {
            key "mode-id";
            description "List of the modes ";
            uses opt-if-och-mode;
        }
    }

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

    notification opt-if-och-mode-change {
        description "A change of Mode Template has been
                    detected.";
        leaf "if-name" {
            type leafref {
                path "/if:interfaces/if:interface/if:name";
            }
            description "Interface name";
        }
        leaf mode-id {
            type string {
                length "1..255";
            }
        }
    }
}
```

```

    }
    description "Id for the OCh mode template";
  }
}

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

augment "/if:interfaces/if:interface" {
  description "Parameters for an optical interface";
  container optIfOChRsSs {
    description "RsSs path configuration for an interface";
    container if-current-mode {
      description "Current mode template of the
        interface";
      uses opt-if-och-mode;
    }

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

```

<CODE ENDS>

7. Security Considerations

The YANG module defined in this memo is designed to be accessed via the NETCONF protocol [RFC6241]. 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.

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

Abstract

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

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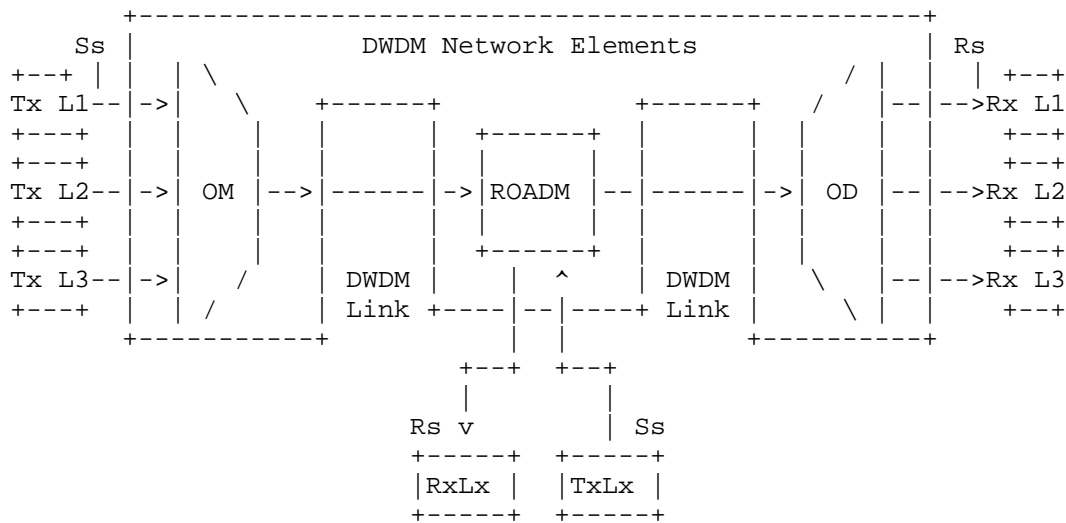
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1. Introduction

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

2. DWDM line system

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

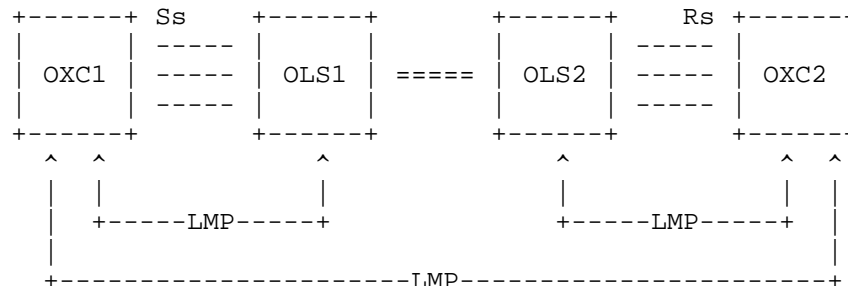


Ss = Sender reference point at the DWDM network element tributary output
 Rs = Receiver reference point at the DWDM network element tributary input
 Lx = Lambda x
 OM = Optical Mux
 OD = Optical Demux
 ROADM = Reconfigurable Optical Add Drop Mux

from Fig. 5.1/G.698.2

Figure 1: Linear Single Channel approach

Figure 2 Extended LMP Model (from [RFC4209])



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

Figure 2: Extended LMP Model

3. Use Cases

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

4. Extensions to LMP-WDM Protocol

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

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

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

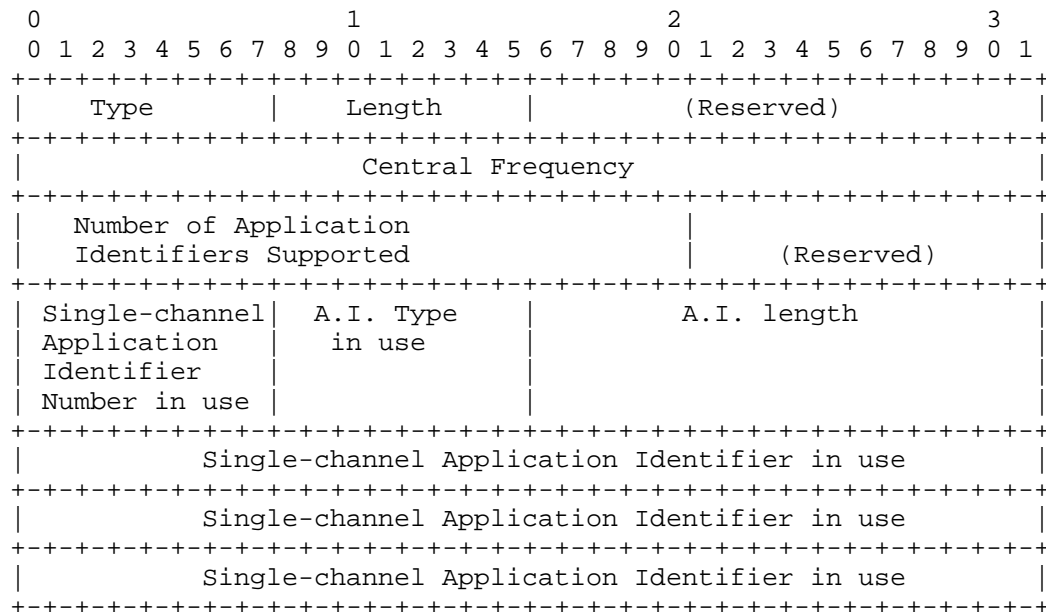
5. General Parameters - OCh_General

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

The general parameters are

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

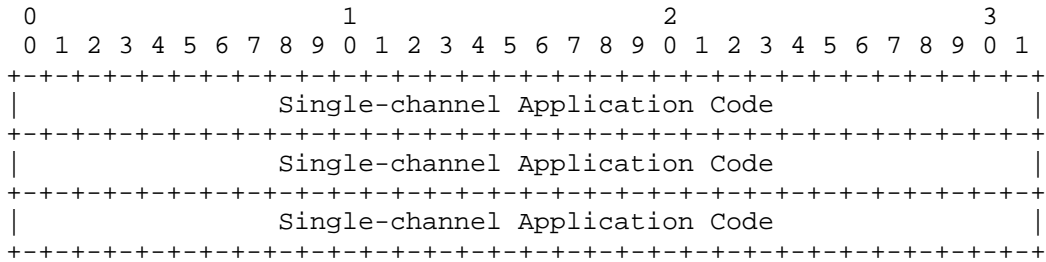
Figure 3: The format of the this sub-object (Type = TBA, Length = TBA) is as follows:



A.I. Type in use: STANDARD, PROPRIETARY

A.I. Type in use: STANDARD

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



A.I. Type in use: PROPRIETARY

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

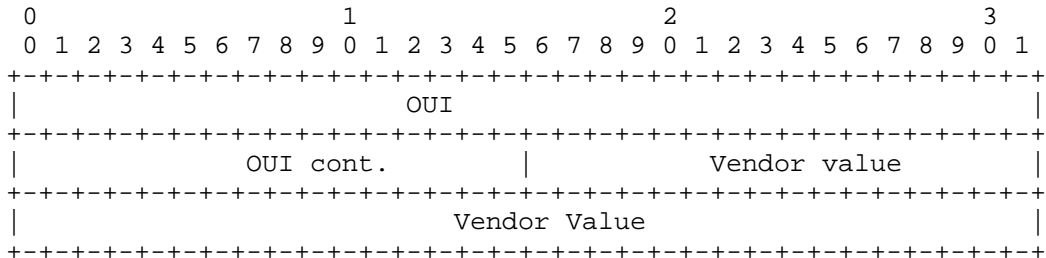


Figure 3: OCh_General

6. ApplicationIdentifier - OCh_ApplicationIdentifier

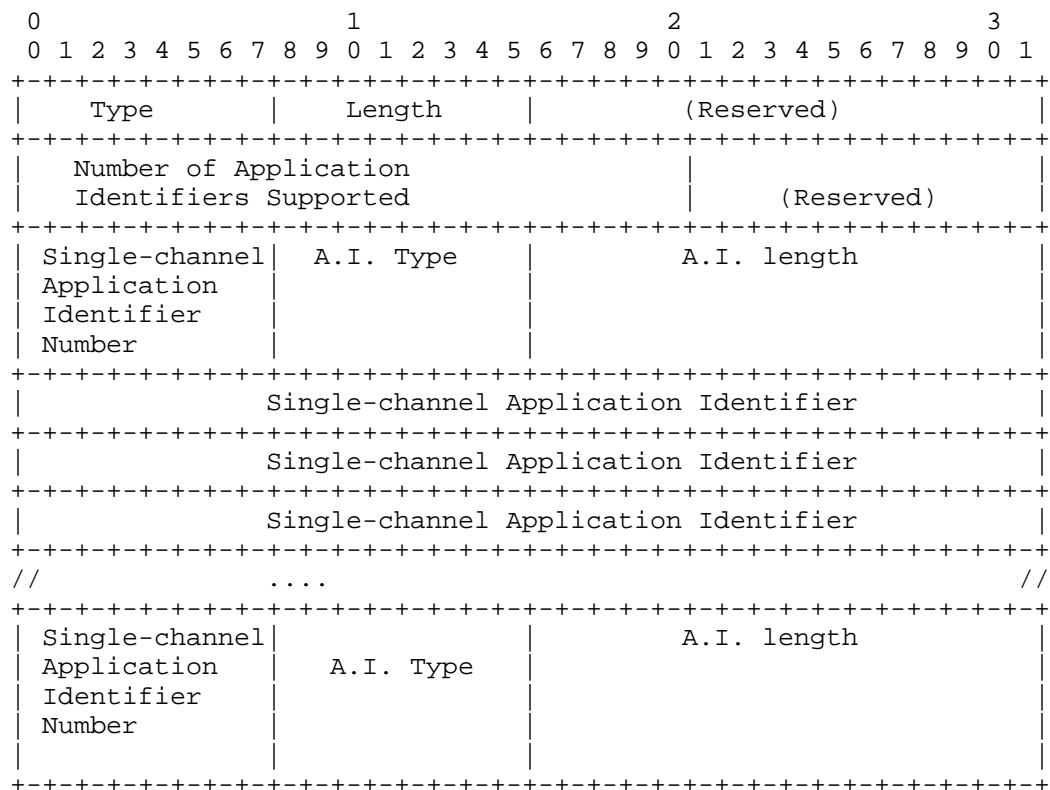
This message is to exchange the application identifiers supported as described in [G698.2]. There can be more than one Application Identifier supported by the transmitter/receiver in the OXC. The number of application identifiers supported is exchanged in the "OCh_General" message. (from [G698.1]/[G698.2]/[G959.1]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

The parameters are

1. Number of Application Identifiers (A.I.) Supported
2. Single-channel application identifier Number
uniquely identifies this entry - 8 bits
3. Application Identifier Type (A.I.) (STANDARD/PROPRIETARY)
4. Single-channel application identifier -- 96 bits
(from [G698.1]/[G698.2]/[G959.1])

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

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



```

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

```

A.I. Type in use: STANDARD, PROPRIETARY

A.I. Type in use: STANDARD

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

```

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

```

A.I. Type in use: PROPRIETARY

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

```

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

```

Figure 4: OCh_ApplicationIdentifier

7. OCh_Ss - OCh transmit parameters

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

1. Output power

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

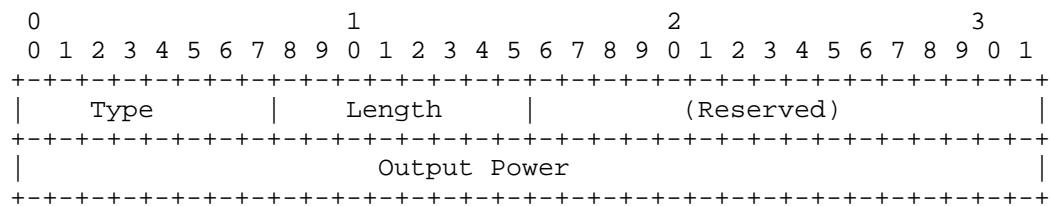


Figure 5: OCh_Ss transmit parameters

8. OCh_Rs - receive parameters

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

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

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

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

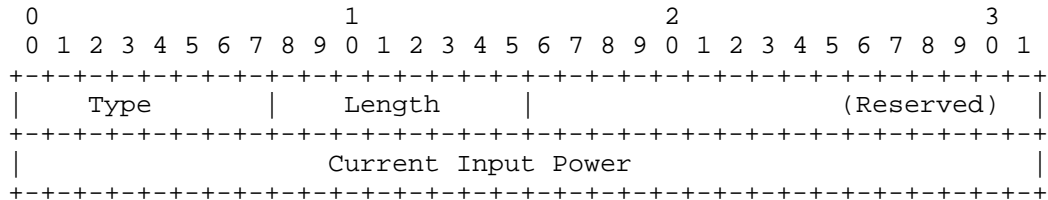


Figure 6: OCh_Rs receive parameters

9. Security Considerations

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

10. IANA Considerations

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

- LMP Message Type
 - LMP Object Class
 - LMP Object Class type (C-Type) unique within the Object Class
 - LMP Sub-object Class type (Type) unique within the Object Class
- This memo introduces the following new assignments:

LMP Sub-Object Class names:

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

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

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June 25, 2018

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

Abstract

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

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

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1. Introduction

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

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

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

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

2. The Internet-Standard Management Framework

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

This memo specifies a Yang model for optical interfaces.

3. Conventions

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

4. Definition

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

5. Applicability

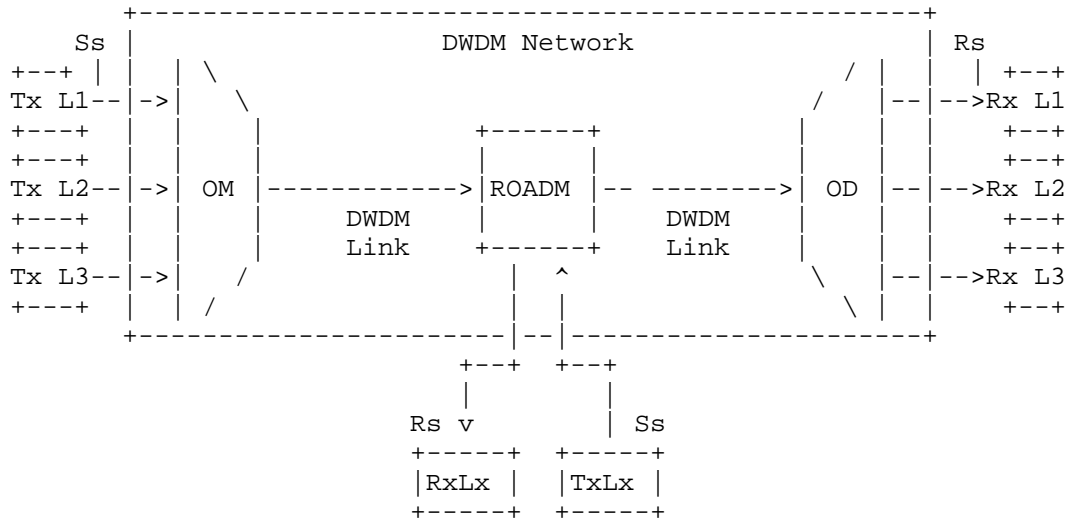
This document targets at Scenario C defined in [RFC6566] section 4.1.1. as approximate impairment estimation. The Approximate concept refers to the fact that this Information Model covers information mainly provided by [ITU.G680] Computational Model. Although the [RFC6566] provides no or little approximation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

6. Properties

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

7. Overview

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



Ss = 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

7.1. Optical Parameters Description

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

The definitions of the optical parameters are provided below to increase the readability of the document, where the definition is

ended by (R) the parameter can be retrieve with a read, when (W) it can be provisioned by a write, (R,W) can be either read or written.

7.1.1.1. Optical path from point Ss to Rs

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

Maximum and minimum (residual) chromatic dispersion:

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

Minimum optical return loss at Ss:

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

Maximum discrete reflectance between Ss and Rs:

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

Maximum differential group delay:

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

Maximum polarization dependent loss:

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

Maximum inter-channel crosstalk:

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

Maximum interferometric crosstalk:

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

Maximum optical path OSNR penalty:

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

Maximum ripple:

Although is defined in G.698.2 (R).

7.1.2. Rs and Ss Configuration

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

7.1.3. Table of Application Codes

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

7.2. Use Cases

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

7.3. Optical Parameters for impairment validation in a WDM network

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

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

```

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

```

8. Structure of the Yang Module

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

9. Yang Module

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

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

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

```
  
  import ietf-interfaces {  
    prefix if;  
  }
```

```
  
  import iana-if-type {  
    prefix ianaift;  
  }
```

```
  
  organization  
    "IETF CCAMP  
    Working Group";
```

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

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

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

```
  
    Copyright (c) 2016 IETF Trust and the persons identified  
    as authors of the code.  All rights reserved.
```

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

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

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

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

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

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

typedef dbm-t {
```

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

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

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

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

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

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

    leaf opwr-min-clear {
```

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

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

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

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

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

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

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

```
}

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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



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

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

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

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

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

    leaf offset {
```

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

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

  leaf tilt-calibration {
    type tilt-t;
    description "Amplifier Tilt tuning";
  }
}

container opwr-threshold-warning {
  description "Optical power threshold warning";
  uses opwr-threshold-warning-grp;
}

container gain-degrade-alarm {
  description "Gain degrade alarm";
  uses gain-degrade-alarm-grp;
}

container power-degrade-high-alarm {
  description "Power degrade high alarm";
  uses power-degrade-high-alarm-grp;
}

container power-degrade-low-alarm {
  description "Power degrade low alarm";
  uses power-degrade-low-alarm-grp;
}

container noise {
  description "Channel Noise feasibility";
  uses noise-grp;
}

container noise-sigma {
  description "Channel Noise sigma feasibility";
  uses noise-sigma-grp;
}

container chromatic-dispersion {
  description "Chromatic Dispersion";
  uses noise-sigma-grp;
}
```

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

<CODE ENDS>

10. Security Considerations

The YANG module defined in this memo is designed to be accessed via the NETCONF protocol [RFC6241]. 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.

11. IANA Considerations

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

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

Registrant Contact: The IESG.

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

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

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

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

12. Acknowledgements

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14. References

14.1. Normative References

- [ITU.G694.1]
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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

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June 25, 2018

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

Abstract

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

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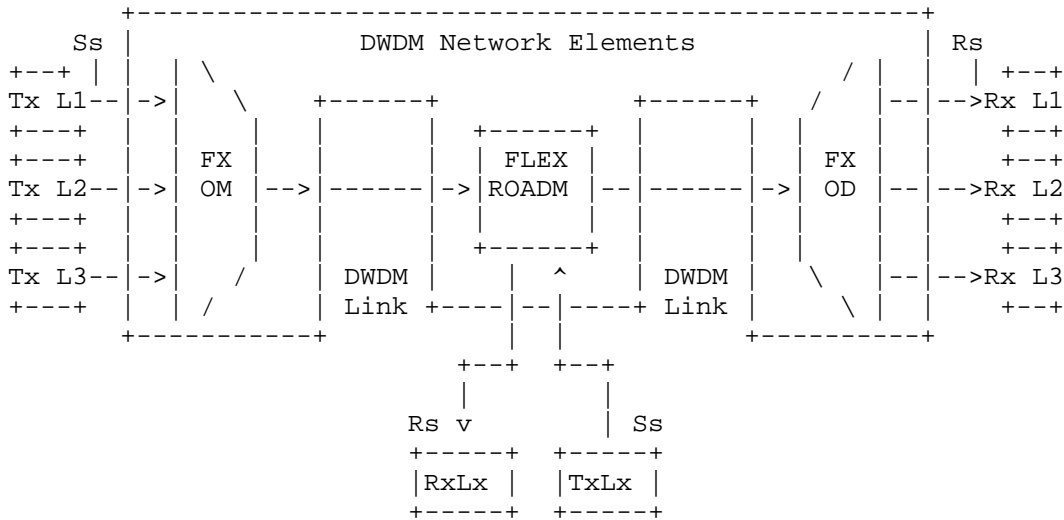
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1. Introduction

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

2. DWDM line system

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



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

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

FX OM = Flex-Spectrum Optical Mux

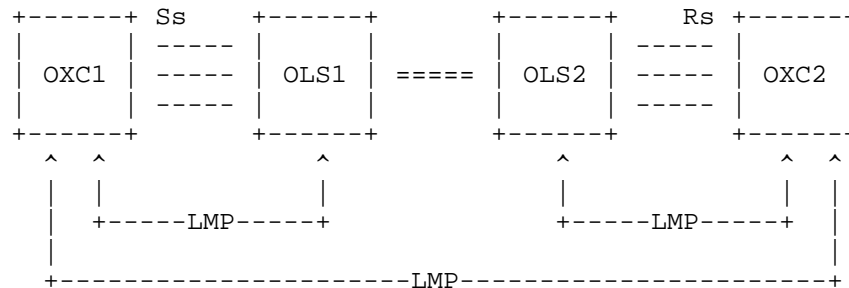
FX OD = Flex-Spectrum Optical Demux

Flex ROADM = Flex-Spectrum Optical Add Drop Mux (reconfigurable)

extending Fig. 5.1/G.698.2

Figure 1: Linear Single Channel approach

Figure 2 Extended LMP Model (from [RFC4209])



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

Figure 2: Extended LMP Model

3. Use Cases

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

4. Extensions to LMP-WDM Protocol

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

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

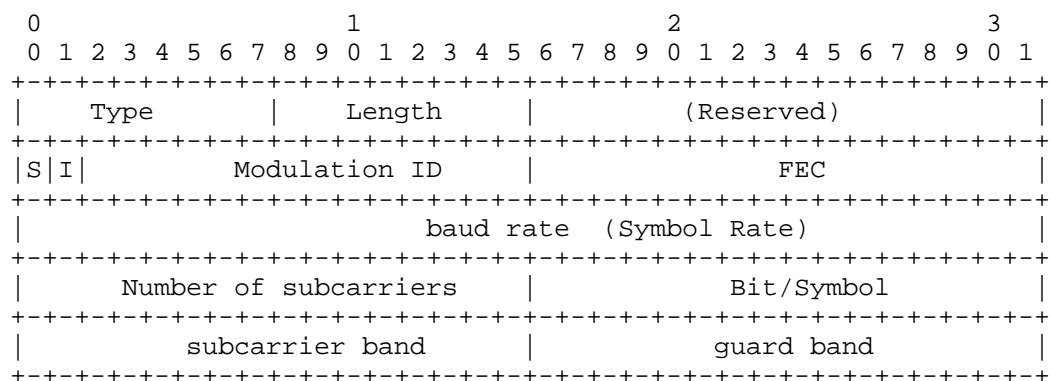
5. Multi carrier Transceiver

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

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

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

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



```

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

```

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

Figure 3: Multi carrier Transceiver

6. Security Considerations

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

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

7. IANA Considerations

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

- LMP Message Type
 - LMP Object Class
 - LMP Object Class type (C-Type) unique within the Object Class
 - LMP Sub-object Class type (Type) unique within the Object Class
- This memo introduces the following new assignments:

LMP Sub-Object Class names:

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

- Multi carrier Transceiver (sub-object Type = TBA)

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Signaling extensions for Media Channel sub-carriers configuration in
Spectrum Switched Optical Networks (SSON) in Lambda Switch Capable (LSC)
Optical Line Systems.
draft-ggalimbe-ccamp-flexigrid-carrier-label-04

Abstract

This memo defines the signaling extensions for managing Spectrum Switched Optical Network (SSON) parameters shared between the Client and the Network and inside the Network in accordance to the model described in RFC 7698. The extensions are in accordance and extending the parameters defined in ITU-T Recommendation G.694.1.[ITU.G694.1] and its extensions and G.872.[ITU.G872].

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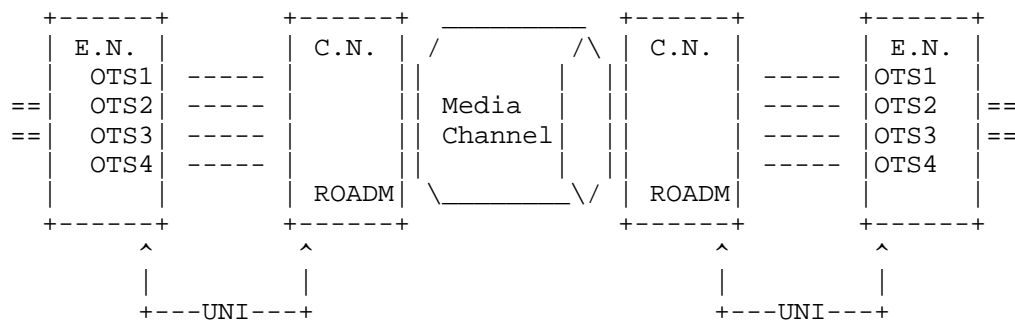
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1. Introduction

Generalised Multiprotocol Label Switched (GMPLS) is widely used in Wavelength Switched Optical Network (WSO) to support the optical circuits set-up through the signalling between Core Nodes and Edge Nodes. This extension addresses the use cases described by [RFC7698] Ch.3.3 and supports the information, needed in Spectrum Switched Optical Network (SSO), to signal a Media Channel and the associated carriers set request. The new set of parameters is related to the Media Channel and the carrier(s) routed with it and keep the backward compatibility with the WSO signalling. In particular this memo wants to address the use cases where the SSO LSP (the Media Channel in RFC7698) carries multiple carrier (OTSi) containing same Payload. The set of the carriers can be seen as single Logical circuit. This

memo can be considered as the extension of [RFC7792]. The contents and the parameters reflect the experimental activity on IP over SSON recently done by some vendors and research consortia.

Figure 1 shows how the multiple carrier are mapped into a Media Channel. A set of parameters must be shared on the UNI to allow the GMPLS to do the proper routing and Spectrum Assignment and decide the carrier position.



E.N. = Edge Node - UNI Client
 C.N. = Core Node - UNI Network
 ROADM = Lambda/Spectrum switch
 Media Channel = the optical circuit
 OTSi = Carriers belonging to the same Network Media Channel (or Super Channel)
 UNI = Signalig interface

Figure 1: Multi carrier LSP

2. Client interface parameters

The Edge Node interface can have one or multiple carriers (OTSi). All the carrier have the same characteristics and are provisionable in terms of:

Number of subcarriers:

This parameter indicates the number of subcarriers available for the super-channel in case the Transceiver can support multiple carrier circuits.

Central frequency (see G.694.1 Table 1):

This parameter indicates the Central frequency value that Ss and Rs will be set to work (in THz). See the details in Section 6/

G.694.1 or based on "n" value explanation and the following "k" values definition in case of multicarrier transceivers.

Central frequency granularity:

This parameter indicates the Central frequency granularity supported by the transceiver, this value is combined with k and n value to calculate the central frequency of the carrier or sub-carriers.

Minimum channel spacing:

This is the minimum nominal difference in frequency (in GHz) between two adjacent channels (or carriers) depending on the Transceiver characteristics.

Bit rate / Baud rate of optical tributary signals:

Optical Tributary Signal bit (for NRZ signals) rate or Symbol (for Multiple bit per symbol) rate .

FEC Coding:

This parameter indicate what Forward Error Correction (FEC) code is used at Ss and Rs (R/W) (not mentioned in G.698.2). .

Wavelength Range (see G.694.1): [ITU.G694.1]

This parameter indicate minimum and maximum wavelength spectrum in a definite wavelength Band (L, C and S).

Modulation format:

This parameter indicates the list of supported Modulation Formats and the provisioned Modulation Format..

Inter carrier skew:

This parameter indicates, in case of multi-carrier transceivers the maximum skew between the sub-carriers supported by the transceiver.

Laser Output power:

This parameter provisions the Transceiver Output power, it can be either a setting and measured value.

receiver input power:

This parameter provisions the Min and MAX input power supported by the Transceiver, i.e. Receiver Sensitivity.

The above parameters are related to the Edge Node Transceiver and are used by the Core Network GMPLS in order to calculate the optical feasibility and the spectrum allocation. The parameters can be shared between the Client and the Network via LMP or provisioned to the Network by an EMS or an operator OSS.

3. Use Cases

The use cases are described in draft-ietf-ccamp-dwdm-if-mng-ctrl-fwk and [RFC7698]

4. Signalling Extensions

Some of the above parameters can be applied to RFC7792 (SENDER_TSPEC/FLOWSPEC). The above parameters could be applied to [RFC4208] scenarios but they are valid also in case of non UNI scenarios. The [RFC6205] parameters remain valid.

4.1. New LSP set-up parameters

When the E.N. wants to request to the C.N. a new circuit set-up request or the GMPLS wants to signal in the SSON network the Optical Interface characteristics the following parameters will be provided to the C.N.:

Number of available subcarriers (c):

This parameter is an integer and identifies the number of Client ports connected to the Core ports available to support the requested circuit

Total bandwidth request:

e.g. 200Gb, 400Gb, 1Tb - it is the bandwidth (payload) to be carried by the multiple carrier circuit

Policy (strict/loose):

Strict/loose referred to B/W and subcarrier number. This is to give some flexibility to the GMPLS in order to commit client request.

Subcarrier bandwidth tunability:

(optional) e.g. 34Ghz, 48GHz.

The TLV define the resource constraints for the requested Media Channel.

The format of the this sub-object is as follows:

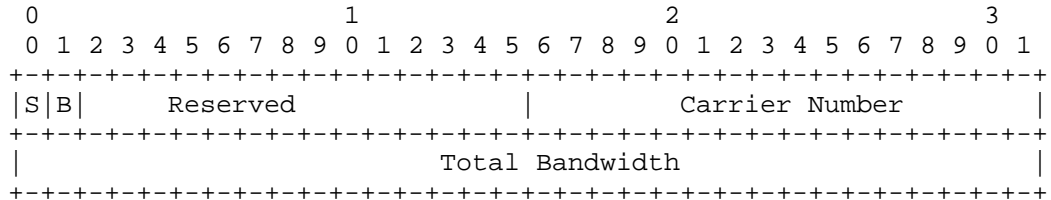


Figure 2: SSON LSP set-up request

Carrier Number: number of carrier to be allocated for the requested channel (16-bit unsigned integer)

If Carrier Number == 0 no constraint set on the number of carriers to be used

S strict number of subcarrier

- S = 0 the number of requested carriers is the maximum number that can be allocated (a lower value can be allocated if the requested bandwidth is satisfied)
- S = 1 the number of requested carriers is strict (must be > 0)

Total Bandwidth: the requested total bandwidth to be supported by the Media Channel (32-bit IEEE float, bytes/s)

If Total Bandwidth == 0: no bandwidth constraint is defined (B must be 0)

B Bandwidth constraints

- B = 0: the value is the maximum requested bandwidth (a lower value can be allocated if resources are not available)
- B = 1: the requested bandwidth is the minimum value to be allocated (a higher value can be allocated if requested by the physical constraints of the ports)

Reserved: unused bit (for future use, should be 0)

Note: bandwidth unit is defined in accordance to RFC 3471
chap. 3.1.2 Bandwidth Encoding specification. Bandwidth higher
than 40Gb/s values must be defined (e.g. 100Gb/s, 150Gb/s
400Gb/s, etc.)

TLV Usage:

Head UNI-C PATH: requested traffic constraints, the Head UNI-N node
must satisfy when reserving the optical resources and defining
the carriers configuration

The TLV can be omitted: no traffic constraints is defined (resources
allocated by UNI-N based on a local policy)

4.2. Extension to LSP set-up reservation

Once the GMPLS has calculated the Media Channel path, the Spectrum
Allocation, the Sub-carrier number and frequency, the modulation
format, the FEC and the Transmit power, sends back to the E.N. the
path set-up confirmation providing the values of the calculated
parameters:

Media Channel:

(Grid, C.S., Identifier m and n). as indicated in RFC7699
Section 4.1

Modulation format:

This parameter indicates the Modulation Formats to be set in the
Transceivers.

FEC Coding:

This parameter indicate what Forward Error Correction (FEC) code
must be used by the Transceivers (not mentioned in G.698). .

Bit rate / Baud rate of optical tributary signals:

Optical tributary signal bit (for NRZ signals) rate or Symbol (for
Multiple bit per symbol) rate.

List of subcarriers:

This parameter indicates the subcarriers to be used for the super-
channel in case the Transceiver can support multiple carrier
Circuits.

Central frequency granularity (J):

This parameter indicates the Central frequency granularity
supported by the transceiver, this value is combined with K and n
value to calculate the central frequency on the carrier or sub-
carriers.

Central frequency (see G.694.1 Table 1):

Grid, Identifiers, central frequency and granularity.

Laser Output power:

This parameter provisions the Transceiver Output power, it can be either a setting and measured value.

Circuit Path, RRO, etc:

All these info are defined in [RFC4208].

Path Error:

e.g. no path exist, all the path error defined in [RFC4208].

The TLV defines the carriers signal configuration.

All carriers in a Media Channel MUST have the same configuration.

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

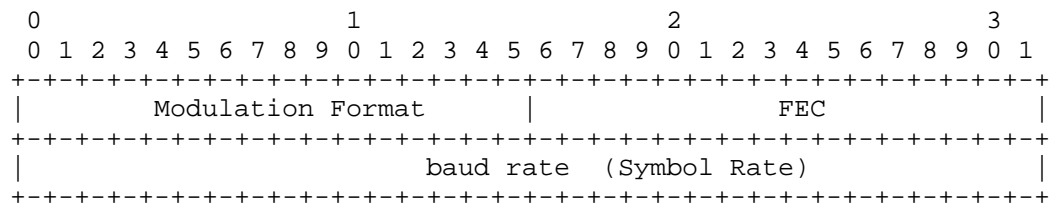


Figure 3: OCh_General

Traffic Type

- Modulation Format: is the modulation type:
 - BPSK, DC DP BPSK, QPSK, DP QPSK, 8QAM, 16QAM, 64QAM, Hybrid, etc.
 - <TBD> (ITU-T reference)
 - value > 32768 (first bit is 1): custom defined values
 - Value 0 is reserved to be used if no value is defined
- FEC: the signal Forward Error Corrections type (16-bit unsigned integer), the defined values are:
 - <TBD> (ITU-T reference)
 - 32768 (first bit is 1): custom defined values
 - Value 0 is reserved to be used if no value is defined
- Baud Rate: the signal symbol rate (IEEE 32-bit float, in bauds/s)
 - Value 0 is reserved to be used if no value is defined

Notes:

- The PATH request from the Head UNI-C node can specify all or only a subset of the parameters (e.g. the Modulation and the baud rate as required but not the FEC) setting to 0 for the undefined parameters.
When forwarding the PATH message, the UNI-N will set the undefined parameters based on the optical impairment calculation and the constraints giveng by the UNI-C
- Custom codes (values > 0x8000) interpretation is a local installation matter.

TLV Usage:

- Head UNI-C PATH: used to force specific transponder configurations
- Head UNI-N RESV: set selected configuration on head node
- Tail UNI-N PATH: set selected configuration on tail node

4.2.1. Sub-carrier list content

For Each carrier inside the Media Channel the TLV is used.

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

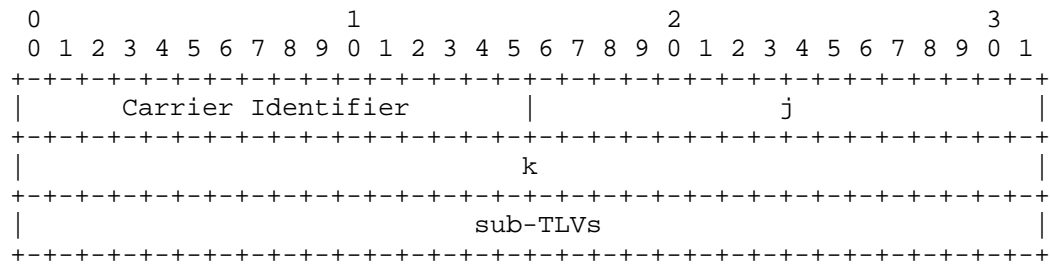
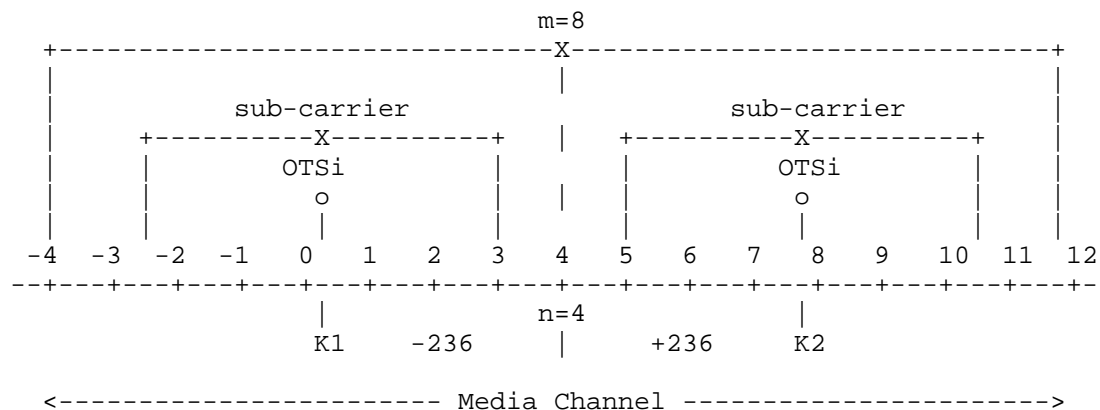


Figure 4: Sub-Carrier parameters

Carrier set-up:

- Carrier identifier field: sub-carrier identifier inside the mediachannel. Identifies the carrier position inside the Media Channel (16-bit unsigned integer) The Carrier Identifier is the logical circuit sub-lane position, a TLV for each value from 1 to the number of allocated carriers must be present.
- J field: granularity of the channel spacing, can be a multiple of 0.01GHz. - default value is 0.1GHz.
- K field: positive or negative integer (including 0) to multiply by J and identify the Carrier Position inside the Media Channel, offset from media Channel Central frequency
- sub-TLVs: additional information related to carriers if needed and the ports associated to the carrier.

In summary Carrier Frequency = MC-C.F. (in THz) + K * J GHz.



4.2.2. Sub-carrier sub-TLV

The defined sub-TLVs are Port Identifiers and Carrier Power

Source Port Identifier

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

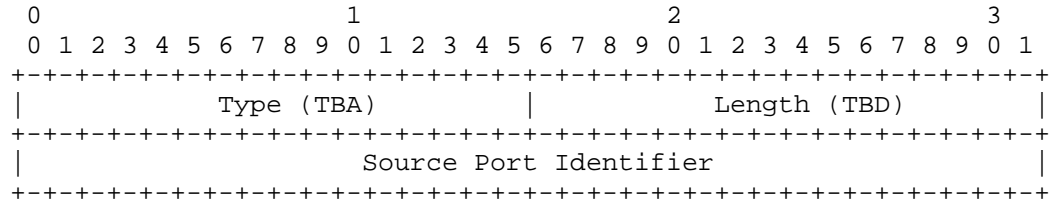


Figure 5: Source Port Identifier

Source Port Identifier: the HEAD UNI-C optical logical source end point identifier (32-bits integer, ifindex)

TLV Usage:

- Head UNI-C PATH: used to force specific carrier ports [optional use, e.g. with external PCE scenario]
- Tail UNI-N PATH: report selected carrier head ports to tail UNI-C
- RESV: report selected configuration to HEAD UNI-C node

Destination Port Identifier

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

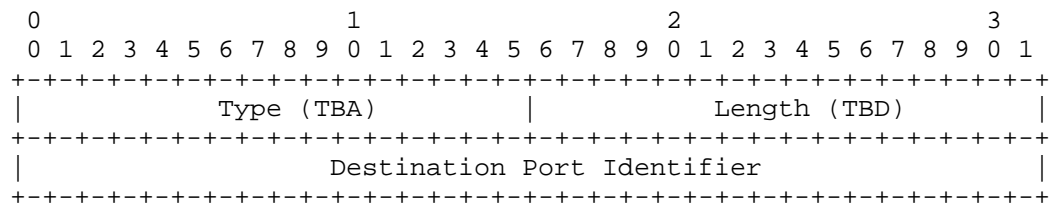


Figure 6: Destination Port Identifiers

Destination Port Identifier: the local upstream optical logical destination end point identifier (32-bits integer, ifindex)

TLV Usage:

- Head UNI-C PATH: used to force specific carrier ports [optional use, e.g. with external PCE scenario]
- Tail UNI-N PATH: set selected configuration on tail node
- RESV: report selected configuration to HEAD UNI-C node

Carrier Power

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

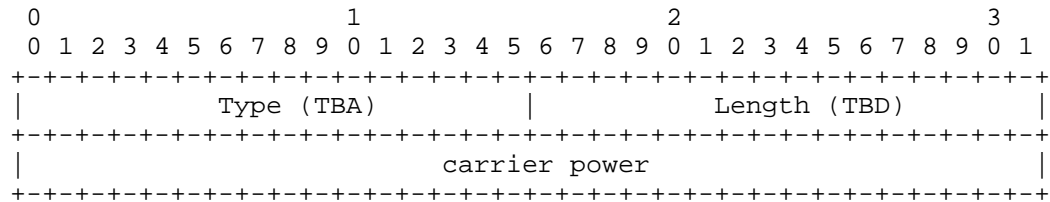


Figure 7: Carrier Power

Carrier Power: the requested carrier transmit power (32-bits IEEE Float, dBm), optionally used to notify the configured power (in UNI client side) or force the power to the to the UNI client).

TLV Usage:

- Head UNI-C PATH: used to force specific carrier frequency/ports (optional use, e.g. with external PCE scenario)
- Head UNI-N RESV: set selected configuration on head node
- Tail UNI-N PATH: set selected configuration on tail node

4.3. RSVP Protocol Extensions considerations

The additional information described in the draft, is related to the Media Channel supported traffic. It could be encoded in the SENDER_TSPEC/FLOW_SPEC objects by extending the SSON_SENDER_TSPEC/SSON_FLOW_SPEC defined in RFC 7792 (or defining a new C-Type) with an optional TLV list or it could be encoded in a newly defined entry (new OBJECT or new LSP_ATTRIBUTES OBJECT TLV)

This solution is consistent with other technology specific extensions (e.g. SDH), but requires the explicit handling of the extensions by all nodes.

Beside this, some of the additional information defined is local to the head/tail UNI link (e.g. the carrier/port association), while the traffic spec info should be valid end-to-end.

5. Security Considerations

GMPLS message security uses IPsec, as described in xxxx. This document only defines new UNI objects that are carried in existing UNI messages, similar to the UNI objects in xxx. This document does not introduce new security considerations.

6. IANA Considerations

T.B.D.

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Abstract

ITU-T Recommendation G.808.3 [G808.3] defines the generic aspects of a shared mesh protection (SMP) mechanism, where the difference between SMP and shared mesh restoration (SMR) is also identified. ITU-T Recommendation G.873.3 [G873.3] defines the protection switching operation and associated protocol for shared mesh protection (SMP) at the optical data unit (ODU) layer.

This document updates RFC 4872 to provide the extensions to the Generalized Multi-Protocol Label Switching (GMPLS) signaling to support the control of the shared mesh protection.

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1. Introduction

RFC 4872 [RFC4872] defines extension of RSVP-TE to support shared mesh restoration (SMR) mechanism. Shared mesh restoration can be seen as a particular case of pre-planned LSP rerouting that reduces the recovery resource requirements by allowing multiple protecting LSPs to share common link and node resources. The recovery resources for the protecting LSPs are pre-reserved during the provisioning phase, and an explicit restoration signaling is required to activate (i.e., commit resource allocation at the data

plane) a specific protecting LSP instantiated during the provisioning phase.

ITU-T Recommendation G.808.3 [G808.3] defines the generic aspects of a shared mesh protection (SMP) mechanism. ITU-T Recommendation G.873.3 [G873.3] defines the protection switching operation and associated protocol for shared mesh protection (SMP) at the optical data unit (ODU) layer.

SMP differs from SMR in the activation/protection switching operation. The former activates a protecting LSP via the automatic protection switching (APS) protocol in the data plane when the working LSP fails, while the latter via the control plane signaling. It is therefore necessary to distinguish SMP from SMR during provisioning so that each node involved behaves appropriately in the recovery phase when activation of a protecting LSP is done.

This document updates RFC 4872 to provide the extensions to the Generalized Multi-Protocol Label Switching (GMPLS) signaling to support the control of the shared mesh protection.

2. 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.

In addition, the reader is assumed to be familiar with the terminology used in [RFC4872] and [RFC4426].

3. SMP Definition

ITU-T Recommendation G.808.3 [G808.3] defines the generic aspects of a shared mesh protection (SMP) mechanism. ITU-T Recommendation G.873.3 [G873.3] defines the protection switching operation and associated protocol for shared mesh protection (SMP) at the optical data unit (ODU) layer.

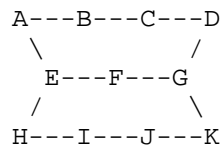
The SMP mechanism is based on pre-computed protection transport entities that are pre-configured into the network elements. Pre-configuration here means pre-reserving resources for the protecting LSPs without activating a particular protecting LSP

(e.g. in circuit networks, the cross-connects in the intermediate nodes of the protecting LSP are not pre-established). Pre-configuring but not activating the protecting LSP allows the common link and node resources in a protecting LSP to be shared by multiple working LSPs that are physically (i.e., link, node, SRLG, etc.) disjoint. Protecting LSPs are activated in response to failures of working LSPs or operator's commands by means of the APS protocol that operates in the data plane. SMP is always revertive.

SMP has a lot of similarity to SMR except that the activation in case of SMR is achieved by control plan signaling during the recovery operation while SMP is done by APS protocol in the data plane. SMP has advantages with regard to the recovery speed compared with SMR.

4. GMPLS Signaling Extension for SMP

Consider the following network topology:



The working LSPs [A,B,C,D] and [H,I,J,K] could be protected by [A,E,F,G,D] and [H,E,F,G,K], respectively. Per [RFC3209], in order to achieve resource sharing during the signaling of these protecting LSPs, they must have the same Tunnel Endpoint Address (as part of their SESSION object). However, these addresses are not the same in this example. Similar to SMR, a new LSP Protection Type of the secondary LSP is defined as "Shared Mesh Protection" (see PROTECTION object defined in [RFC4872]) to allow resource sharing along nodes E, F, and G. In this case, the protecting LSPs are not merged (which is useful since the paths diverge at G), but the resources along E, F, G can be shared.

When a failure is detected on one of the working LSPs (say working LSP [A,B,C,D]), the switching operation for the egress node (say node A) will be triggered by an Signal Degrade (SD) or Signal Fail (SF) on the working LSP. The egress node A will send a protection switching request APS message (for example SF) to its adjacent (downstream) intermediate node (say node E) to activate setting up

the corresponding protecting LSP. If the protection resource is available, Node E will send a confirmation message to the egress node A and forward the switching request APS message to its adjacent (downstream) node (say node F). When the confirmation message is received by node A and the protection resource is available, the cross-connection on node A is established. At this time the traffic is bridged to and selected from the protecting LSP at node A. The node E will wait for the confirmation message from node F, which triggers node E to set up the cross-connection for the protection transport entity being activated. If the protection resource is not available (due to failure or being used by higher priority connections), the switching will not be successful; the intermediate node may send a message to notify the end node, or keep trying until the resource is available or the switching request is cancelled. If the resource is in use by a lower priority protection entity, the lower priority service will be removed and then the intermediate node will follow the procedure as described for the case when the resource is available.

The following subsections detail how shared mesh protection can be implemented in an interoperable fashion using GMPLS RSVP-TE extensions (see [RFC3473]). This includes:

- (1) the ability to identify a "secondary protecting LSP" (hereby called the "secondary LSP") used to recover another primary working LSP (hereby called the "protected LSP")
- (2) the ability to associate the secondary LSP with the protected LSP
- (3) the capability to include information about the resources used by the protected LSP while instantiating the secondary LSP.
- (4) the capability to instantiate during the provisioning phase several secondary LSPs in an efficient manner.
- (5) the capability to support activation of a secondary LSP after failure occurrence via APS protocol in the data plane.

4.1. Identifiers

To simplify association operations, both LSPs (i.e., the protected and the secondary LSPs) belong to the same session. Thus, the SESSION object MUST be the same for both LSPs. The LSP ID, however, MUST be different to distinguish between the protected LSP carrying working traffic and the secondary LSP.

A new LSP Protection Type "Shared Mesh Protection" is introduced to the LSP Flags of PROTECTION object (see [RFC4872]) to set up the two LSPs. This LSP Protection Type value is applicable to both uni- and bidirectional LSPs.

4.2. Signaling Primary LSPs

The PROTECTION object (see [RFC4872]) is included in the Path message during signaling of the primary working LSPs, with the LSP Protection Type value set to "Shared Mesh Protection".

Primary working LSPs are signaled by setting in the PROTECTION object the S bit to 0, the P bit to 0, the N bit to 1 and in the ASSOCIATION object, the Association ID to the associated secondary protecting LSP_ID.

Note: N bit is set to indicate that the protection switching signaling is done via data plane.

4.3. Signaling Secondary LSPs

The PROTECTION object (see [RFC4872]) is included in the Path message during signaling of the secondary protecting LSPs, with the LSP Protection Type value set to "Shared Mesh Protection".

Secondary protecting LSPs are signaled by setting in the PROTECTION object the S bit and the P bit to 1, the N bit to 1 and in the ASSOCIATION object, the Association ID to the associated primary working LSP_ID, which MUST be known before signaling of the secondary LSP. Moreover, the Path message used to instantiate the secondary LSP SHOULD include at least one PRIMARY_PATH_ROUTE object (see [RFC4872]) that further allows for recovery resource sharing at each intermediate node along the secondary path.

With this setting, the resources for the secondary LSP SHOULD be pre-reserved, but not committed at the data plane level, meaning that the internals of the switch need not be established until explicit action is taken to activate this LSP. Activation of a secondary LSP and protection switching to the activated protecting LSP is done using APS protocol in the data plane.

After protection switching completes the protecting LSP SHOULD be signaled with the S bit set to 0 and O bit set to 1 in the PROTECTION object. At this point, the link and node resources must be allocated for this LSP that becomes a primary LSP (ready to carry normal traffic). The formerly working LSP MAY be signaled with the A bit set in the ADMIN_STATUS object (see [RFC3473]).

5. Updates to PROTECTION Object

GMPLS extension requirements for SMP introduce several updates to the Protection Object (see [RFC4872]).

5.1. New Protection Type

A new LSP protection type "Shared Mesh Protection" is added in the protection object. This LSP Protection Type value is applicable to both uni- and bidirectional LSPs.

LSP (Protection Type) Flags

0x11 Shared Mesh Protection

5.2. Other Updates

N bit and O bit in the Protection object as defined in [RFC4872] are also updated to include applicability to SMP.

Notification (N): 1 bit

When set to 1, this bit indicates that the control plane message exchange is only used for notification during protection switching. When set to 0 (default), it indicates that the control plane message exchanges are used for protection-switching purposes. The N bit is only applicable when the LSP Protection Type Flag is set to either 0x04 (1:N Protection with Extra-Traffic), or 0x08 (1+1 Unidirectional Protection), or 0x10 (1+1 Bidirectional Protection), or 0x11 (Shared Mesh Protection). The N bit MUST be set to 0 in any other case.

Operational (O): 1 bit

When set to 1, this bit indicates that the protecting LSP is carrying the normal traffic after protection switching. The O bit

is only applicable when the P bit is set to 1, and the LSP Protection Type Flag is set to either 0x04 (1:N Protection with Extra-Traffic), or 0x08 (1+1 Unidirectional Protection), or 0x10 (1+1 Bidirectional Protection), or 0x11 (Shared Mesh Protection). The O bit MUST be set to 0 in any other case.

6. Security Considerations

No further security considerations than [RFC4872].

7. IANA Considerations

There are no IANA actions required.

8. References

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

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Abstract

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

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1. Introduction

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

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

model (Basic Mode) and signaling and routing service model (Enhanced Mode).

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

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

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

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

1.1. Deployment Scenarios

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

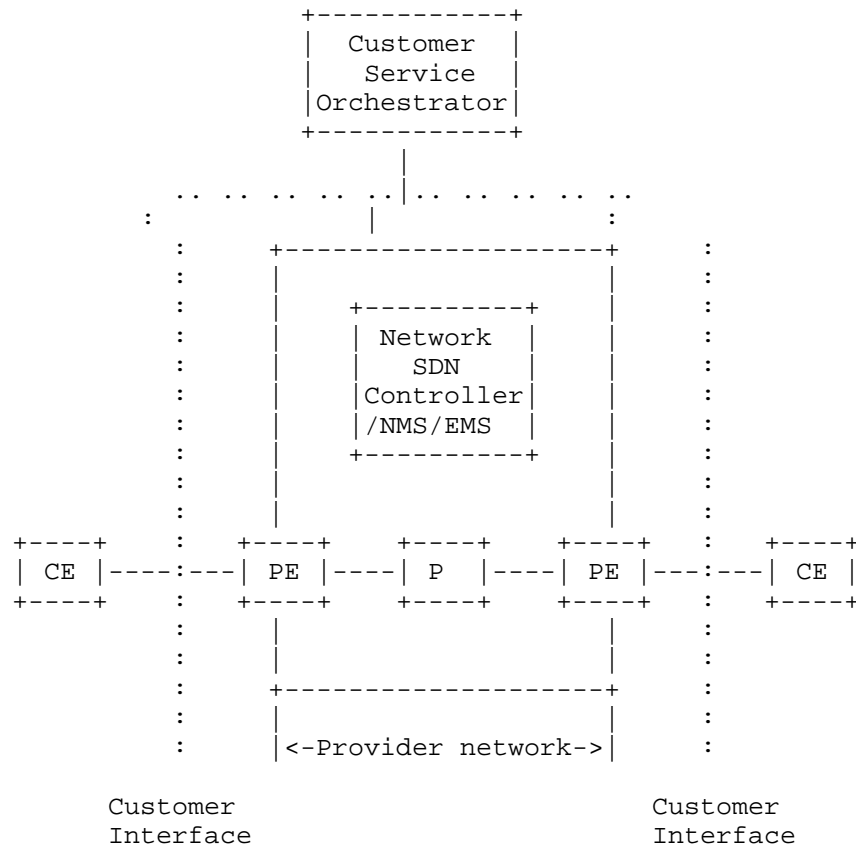


Figure 1: L1VPN SDN Controller/EMS/NMS-Based Service Model: External Customer

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

Figure 2 depicts another deployment scenario for internal customer (e.g., higher-layer service management department(s)) interfacing the layer 1 transport network department. With this scenario, a multi-service backbone is characterized such that each service

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

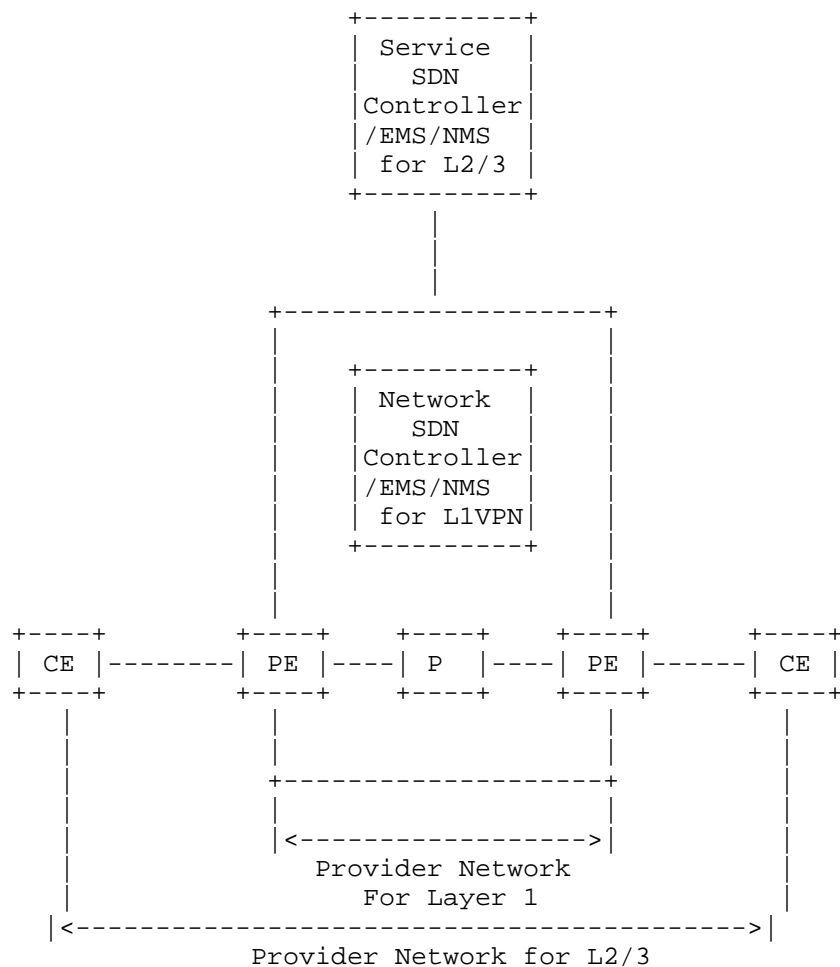


Figure 2: L1VPN SDN Controller/EMS/NMS-Based Service Model: Internal Customer

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

1.2. Terminology

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

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

- o client
- o configuration data
- o server
- o state data

The following terms are defined in [RFC6020] and are not redefined here:

- o augment
- o data model
- o data node

The terminology for describing YANG data models is found in [RFC6020].

1.3. Tree diagram

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

1.4. Prefixes in Data Node Names

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

Prefix	YANG module	Reference
llcsm	ietf-llcsm	[RFC XXXX]
ll-st	ietf-ll-mef-service-types	[RFC XXXX]
yang	ietf-yang-types	[RFC6991]

Table 1: Prefixes and corresponding YANG modules

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

2. Definitions

L1VC Layer 1 Virtual Connection

SLS Service Level Specification

UNI User Network Interface

PE Provider Edge

CE Customer Edge

EP End Point

P Protocol

C Coding

O Optical Interface

3. L1SM YANG Model (Tree Structure)

```

module: ietf-llcsm
  +--rw llcs
    +--rw access
      | +--rw uni-list* [UNI-ID]

```

```

    |      +--rw UNI-ID                string
    |      +--rw protocol?             identityref
    |      +--rw coding?               identityref
    |      +--rw optical_interface?    identityref
+--rw service
  +--rw service-list* [subscriber-llvc-id]
  +--rw subscriber-llvc-id            string
  +--rw service-config
    +--rw subscriber-llvc-id?         string
    +--rw subscriber-llvc-ep-id-1?    string
    +--rw subscriber-llvc-ep-id-2?    string
    +--rw subscriber-llvc-ep-UNI-1?   -> /llcs/access/uni-list/UNI-I
D
    +--rw subscriber-llvc-ep-UNI-2?   -> /llcs/access/uni-list/UNI-I
D
    +--rw time-start?                 yang:date-and-time
    +--rw time-interval?              int16
    +--rw performance-metric?         Identityref

```

4. L1SM YANG Code

The YANG code is as follows:

<CODE BEGINS> file "ietf-llcsm@2018-07-02.yang"

```

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

  prefix "llcsm";
  import ietf-yang-types {
    prefix "yang";
  }

  import ietf-ll-mef-service-types {
    prefix "ll-st";
  }

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

  contact
    "Editor: G. Fioccola (giuseppe.fioccola@telecomitalia.it)
    Editor: K. Lee (kwangkoog.lee@kt.com)
    Editor: Y. Lee (leeyoung@huawei.com)
    Editor: D. Dhody (dhruv.ietf@gmail.com)
    Editor: O. G. de-Dios (oscar.gonzalezdedios@telefonica.com)

```

Editor: D. Ceccarelli (daniele.ceccarelli@ericsson.com);

description

"this module describes Layer 1 connectivity service model for subscriber Layer 1 Connectivity Services and Attributes. Refer to 'MEF x.y.x Technical Specification Working Draft v0.09 5, December 13, 2017' for all terms and the original references used in the module.

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

revision 2018-07-02 {

description

"updated version to incorporate MEF comments";
reference "to add the draft name";

}

revision 2018-06-20 {

description

"updated version to incorporate MEF comments";
reference "to add the draft name";

}

revision 2018-04-11 {

description

"Initial revision.";
reference "to add the draft name";

}

grouping protocol-coding-optical_interface {

description

"describes <p,c,o> where p:protocol type; c:coding function; o:optical interface function";

leaf protocol {

type identityref {
base "l1-st:protocol-type";

}

```
        description
            "List of physical layer L1VC clientprotocol";
    }
    leaf coding {
        type identityref {
            base "l1-st:coding-func";
        }
        description "coding function";
    }
    leaf optical_interface {
        type identityref {
            base "l1-st:optical-interface-func";
        }
        description "optical-interface-function";
    }
}

grouping uni-attributes {
    description
        "uni-service-attributes";

    leaf UNI-ID {
        type string;
        description "the UNI id of UNI Service Attributes";
    }

    uses protocol-coding-optical_interface;
}

grouping subscriber-l1vc-sls-service-attribute {
    description
        "The value of the Subscriber L1VC SLS (Service Level
        Specification) Service Attribute expressed in a 3-tuple
        <p,c,o> of the form.";

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

    leaf time-interval {
        type int16;
        units seconds;
        description "a time interval (e.g., 2,419,200 seconds
            which is 28 days) that is used in
            conjunction with time-start to specify a
            contiguous sequence of time intervals T for
```

```
        determining when performance objectives are
        met.";
    }

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

grouping subscriber-l1vc-service-attributes {
    description
        "subscriber layer 1 connection service service level";

    leaf subscriber-l1vc-id {
        type string;
        description "subscriber L1VC identifier";
    }

    leaf subscriber-l1vc-ep-id-1 {
        type string;
        description "subscriber end point ID of one end";
    }

    leaf subscriber-l1vc-ep-id-2 {
        type string;
        description "subscriber end point ID of the other end";
    }

    leaf subscriber-l1vc-ep-UNI-1 {
        type leafref {
            path "/l1cs/access/uni-list/UNI-ID";
        }
        description "this is one end of subscriber L1VC end point
            ID value = UNI-1";
    }

    leaf subscriber-l1vc-ep-UNI-2 {
        type leafref {
            path "/l1cs/access/uni-list/UNI-ID";
        }
        description "this is the other end of subscriber L1VC end
            point ID value = UNI-2";
    }

    uses subscriber-l1vc-sls-service-attribute;
}
```



```
grouping subscriber-attributes {
  description
    "subscriber attributes";

  uses subscriber-llvc-service-attributes;
}

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

  container access {
    description "UNI configurations";

    list uni-list {
      key "UNI-ID";
      description "uni identifier";
      uses uni-attributes {
        description "UNI attributes information";
      }
    }
  }

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

      leaf subscriber-llvc-id {
        type string;
        description "a unique service identifier for
          L1VC.";
      }
      container service-config {
        description "service-config container";
        uses subscriber-attributes;
      } //end of service-config
    } //end of service list
  } //end of service container
} //service top container

}

<CODE ENDS>

<CODE BEGINS> file "ietf-l1-mef-service-types@2018-7-02.yang"
```

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

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

    Editor: G. Fioccola(giuseppe.fioccola@telecomitalia.it)
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    Editor: D. Dhody (dhruv.ietf@gmail.com)
    Editor: O. G. de-Dios(oscar.gonzalezdedios@telefonica.com)
    Editor: D. Ceccarelli(daniele.ceccarelli@ericsson.com);

  description
    "This module defines L1 service types based on MEF
    subscriber Layer 1 Connectivity Service Attribute. Refer to
    'MEF x.y.x Technical Specification Working Draft v0.09 5,
    December 13, 2017' for all terms and the original references
    used in the module.

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

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

  revision "2018-07-02" {
    description
      "Revision 0.2";
    reference "TBD";
  }

  revision "2018-06-20" {
    description
      "Revision 0.2";
    reference "TBD";
  }
```

```
}

revision "2018-04-11" {
    description
        "Revision 0.1";
    reference "TBD";
}

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

identity aGigE {
    base "protocol-type";
    description
        "GigE protocol type";
}

identity a10GigE_WAN {
    base "protocol-type";
    description
        "10GigE-WAN protocol type";
}

identity a10GigE_LAN {
    base "protocol-type";
    description
        "10GigE-LAN protocol type";
}

identity a40GigE {
    base "protocol-type";
    description
        "40GigE protocol type";
}

identity a100GigE {
    base "protocol-type";
    description
        "100GigE protocol type";
}

identity FC-100 {
    base "protocol-type";
    description
        "Fiber Channel - 100 protocol type";
}
```

```
identity FC-200 {
    base "protocol-type";
    description
        "Fiber Channel - 200 protocol type";
}

identity FC-400 {
    base "protocol-type";
    description
        "Fiber Channel - 400 protocol type";
}

identity FC-800 {
    base "protocol-type";
    description
        "Fiber Channel - 800 protocol type";
}

identity FC-1200 {
    base "protocol-type";
    description
        "Fiber Channel - 1200 protocol type";
}

identity FC-1600 {
    base "protocol-type";
    description
        "Fiber Channel - 1600 protocol type";
}

identity FC-3200 {
    base "protocol-type";
    description
        "Fiber Channel - 3200 protocol type";
}

identity STM-1 {
    base "protocol-type";
    description
        "SDH STM-1 protocol type";
}

identity STM-4 {
    base "protocol-type";
    description
        "SDH STM-4 protocol type";
}

identity STM-16 {
```

```
        base "protocol-type";
        description
            "SDH STM-16 protocol type";
    }

    identity STM-64 {
        base "protocol-type";
        description
            "SDH STM-64 protocol type";
    }

    identity STM-256 {
        base "protocol-type";
        description
            "SDH STM-256 protocol type";
    }

    identity OC-3 {
        base "protocol-type";
        description
            "SONET OC-3 protocol type";
    }

    identity OC-12 {
        base "protocol-type";
        description
            "SONET OC-12 protocol type";
    }

    identity OC-48 {
        base "protocol-type";
        description
            "SONET OC-48 protocol type";
    }

    identity OC-192 {
        base "protocol-type";
        description
            "SONET OC-192 protocol type";
    }

    identity OC-768 {
        base "protocol-type";
        description
            "SONET OC-768 protocol type";
    }

    identity coding-func {
        description
```

```

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

identity a1000X-PCS-36 {
    base "coding-func";
    description
        "PCS clause 36 coding function that corresponds to 1000BASE-X";
}

identity a10GW-PCS-49-WIS-50 {
    base "coding-func";
    description
        "PCS clause 49 and WIS clause 50 coding func that corresponds to
10GBASE-W (WAN PHY)";
}

identity a10GR-PCS-49 {
    base "coding-func";
    description
        "PCS clause 49 coding function that corresponds to 10GBASE-R (LAN
PHY)";
}

identity a40GR-PCS-82 {
    base "coding-func";
    description
        "PCS clause 82 coding function that corresponds to 40GBASE-R";
}

identity a100GR-PCS-82 {
    base "coding-func";
    description
        "PCS clause 82 coding function that corresponds to 100GBASE-R";
}

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

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

identity SX-PMD-clause-38 {
    base "optical-interface-func";
    description
        "SX-PMD-clause-38 Optical Interface function for 1000BASE-X PCS-3
6";
}

```

```
identity LX-PMD-clause-38 {
    base "optical-interface-func";
    description
        "LX-PMD-clause-38 Optical Interface function for 1000BASE-X PCS-3
6";
}

identity LX10-PMD-clause-59 {
    base "optical-interface-func";
    description
        "LX10-PMD-clause-59 Optical Interface function for 1000BASE-X PCS
-
36";
}

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

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

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

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

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

identity LR4-PMD-clause-87 {
    base "optical-interface-func";
    description
```

```

        "LR4-PMD-clause-87 Optical Interface function for 40GBASE-R PCS-8
2";
    }

    identity ER4-PMD-clause-87 {
        base "optical-interface-func";
        description
            "ER4-PMD-clause-87 Optical Interface function for 40GBASE-R PCS-8
2";
    }

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

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

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

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

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

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

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

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

```



```
    }

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

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

<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] 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 [RFC5246].

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

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

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

Service-Config:

- subscriber-llvc-id
- subscriber-llvc-ep-id-1
- subscriber-llvc-ep-id-2
- subscriber-llvc-ep-UNI-1
- subscriber-llvc-ep-UNI-2

- time-start
- time-interval
- performance-metric

6. IANA Considerations

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

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

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

This document registers the following YANG modules in the YANG Module

Names registry [RFC7950]:

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

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

7. Acknowledgments

The authors would like to thank Tom Petch and Italo Busi for their helpful comments and valuable contributions.

8. References

8.1. Normative References

- [MEF-L1CS] "Subscriber Layer 1 Connectivity Service Attributes", Working Draft (WD) v0.09 December 13, 2017.
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A YANG Data Model for Optical Transport Network Topology
draft-ietf-ccamp-otn-topo-yang-03

Abstract

A transport network is a server-layer network designed to provide connectivity services for a client-layer network to carry the client traffic transparently across the server-layer network resources. A transport network can be constructed from equipments utilizing any of a number of different transport technologies such as the evolving Optical Transport Networks (OTN) or packet transport as provided by the MPLS-Transport Profile (MPLS-TP).

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

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1. Introduction

A transport network is a server-layer network designed to provide connectivity services for a client-layer network to carry the client traffic transparently across the server-layer network resources. A

transport network can be constructed of equipments utilizing any of a number of different transport technologies such as the Optical Transport Networks (OTN) or packet transport as provided by the MPLS-Transport Profile (MPLS-TP).

This document defines a data model of an OTN network topology, using YANG [RFC7950]. The model can be used by an application exposing to a transport controller via a REST interface. Furthermore, it can be used by an application for the following purposes (but not limited to):

- o To obtain a whole view of the network topology information of its interest;
- o To receive notifications with regard to the information change of the OTN topology;
- o To enforce the establishment and update of a network topology with the characteristic specified in the data model, e.g., by a client controller;

The YANG model defined in this document is independent of control plane protocols and captures topology related information pertaining to an Optical Transport Networks (OTN)-electrical layer, as the scope specified by [RFC7062] and [RFC7138]. Furthermore, it is not a stand-alone model, but augmenting from the TE topology YANG model defined in [I-D.ietf-teas-yang-te-topo]. Following TE topology YANG model, the YANG model defined in this document is interface independent. The applicability of models to interfaces is described in [I-D.ietf-teas-actn-yang].

Optical network technologies, including fixed Dense Wavelength Switched Optical Network (WSON) and flexible optical networks (a.k.a., flexi-grid networks), are covered in [I-D.ietf-ccamp-wson-yang] and [I-D.ietf-ccamp-flexigrid-yang], respectively.

2. Terminology and Notations

A simplified graphical representation of the data model is used in this document. The meaning of the symbols in the YANG data tree presented later in this document is defined in [I-D.ietf-netmod-yang-tree-diagrams]. They are provided below for reference.

- o Brackets "[" and "]" enclose list keys.

- o Abbreviations before data node names: "rw" means configuration (read-write) and "ro" state data (read-only).
- o Symbols after data node names: "?" means an optional node, "!" means a presence container, and "*" denotes a list and leaf-list.
- o Parentheses enclose choice and case nodes, and case nodes are also marked with a colon (":").
- o Ellipsis ("...") stands for contents of subtrees that are not shown.

3. YANG Data Model for OTN Topology

3.1. OTN Topology Data Model Overview

As can be seen, from the data tree shown in Section 3.1, 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.yang` as specified in [I-D.ietf-teas-yang-te-topo]. In section 6 of [I-D.ietf-teas-yang-te-topo], the guideline for augmenting TE topology model was provided, and in this draft we respectively augment the OTN attributes, TE bandwidth and TE label.

The entities and TE attributes, such as node, termination points and links, are still applicable for describing an OTN topology and the model presented in this document only specifies with technology-specific attributes/information. In OTN attributes augmentation, mainly OTN-specific parameters are included such as Tributary Slot Granularity (TSG), payload type and so on.

For different order of ODU in OTN technology, the `te-bandwidth` is augmented to allow specifying the type of ODU container and the number a link can support per priority level. For example, for a ODU3 link, it may advertise 32*ODU0, 16*ODU1, 4*ODU2 available, assuming only a single priority level is supported. If one of ODU2 resource is taken to establish a ODU path, then the availability of this ODU link is updated as 24*ODU0, 12*ODU1, 3*ODU2 available. If there are equipment hardware limitations, then a subset of potential ODU type SHALL be advertised. For instance, an ODU3 link may only support 4*ODU2.

The types of OTN label can be divided into the tributary ports and the tributary slots, represented by TPN or TS list respectively. In the TE-label augmentation, two optional label formats are available for label representation.

Note the model in this document re-uses some attributes defined in `ietf-otn-types.yang`, which is specified in [I-D.ietf-ccamp-otn-tunnel-model].

3.2. YANG Tree for OTN topology

The following OTN specific attributes have been augmented to TE topology models.

```
module: ietf-otn-topology
  augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
    +--rw otn-topology!
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes:
    +--rw tsg?          identityref
    +--rw distance?     uint32
  augment /nw:networks/nw:network/nw:node/nt:termination-point/tet:te:
    +--rw supported-payload-types* [index]
    |   +--rw index          uint16
    |   +--rw payload-type?  string
    +--rw client-facing?          boolean
```

The technology specific TE bandwidth for OTN topology can be specified using the following augment statements:

```
augment /nw:networks/nw:network/nw:node/nt:termination-point/tet:te
  /tet:interface-switching-capability/tet:max-lsp-bandwidth
  /tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--rw odu-type?  identityref
  augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
    /tet:connectivity-matrices/tet:path-constraints
    /tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--rw odulist* [odu-type]
    +--rw odu-type  identityref
    +--rw number?   uint16
  augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
    /tet:connectivity-matrices/tet:connectivity-matrix
    /tet:path-constraints/tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--rw odulist* [odu-type]
    +--rw odu-type  identityref
    +--rw number?   uint16
  augment /nw:networks/nw:network/nw:node/tet:te
    /tet:information-source-entry/tet:connectivity-matrices
    /tet:path-constraints/tet:te-bandwidth/tet:technology:
```

```

+--:(otn)
  +--ro odulist* [odu-type]
    +--ro odu-type    identityref
    +--ro number?     uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:path-constraints
  /tet:te-bandwidth/tet:technology:
+--:(otn)
  +--ro odulist* [odu-type]
    +--ro odu-type    identityref
    +--ro number?     uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point/tet:client-layer-adaptation
  /tet:switching-capability/tet:te-bandwidth/tet:technology:
+--:(otn)
  +--rw odulist* [odu-type]
    +--rw odu-type    identityref
    +--rw number?     uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point/tet:local-link-connectivities
  /tet:path-constraints/tet:te-bandwidth/tet:technology:
+--:(otn)
  +--rw odulist* [odu-type]
    +--rw odu-type    identityref
    +--rw number?     uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point/tet:local-link-connectivities
  /tet:local-link-connectivity/tet:path-constraints
  /tet:te-bandwidth/tet:technology:
+--:(otn)
  +--rw odulist* [odu-type]
    +--rw odu-type    identityref
    +--rw number?     uint16
augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes
  /tet:interface-switching-capability/tet:max-lsp-bandwidth
  /tet:te-bandwidth/tet:technology:
+--:(otn)
  +--rw odu-type?    identityref
augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes
  /tet:max-link-bandwidth/tet:te-bandwidth/tet:technology:
+--:(otn)
  +--rw odulist* [odu-type]
    +--rw odu-type    identityref
    +--rw number?     uint16
augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes
  /tet:max-resv-link-bandwidth/tet:te-bandwidth/tet:technology:
+--:(otn)

```

```

    +--rw odulist* [odu-type]
      +--rw odu-type    identityref
      +--rw number?     uint16
augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes
      /tet:unreserved-bandwidth/tet:te-bandwidth/tet:technology:
+--:(otn)
  +--rw odulist* [odu-type]
    +--rw odu-type    identityref
    +--rw number?     uint16
augment /nw:networks/nw:network/nt:link/tet:te
      /tet:information-source-entry
      /tet:interface-switching-capability/tet:max-lsp-bandwidth
      /tet:te-bandwidth/tet:technology:
+--:(otn)
  +--ro odu-type?     identityref
augment /nw:networks/nw:network/nt:link/tet:te
      /tet:information-source-entry/tet:max-link-bandwidth
      /tet:te-bandwidth/tet:technology:
+--:(otn)
  +--ro odulist* [odu-type]
    +--ro odu-type    identityref
    +--ro number?     uint16
augment /nw:networks/nw:network/nt:link/tet:te
      /tet:information-source-entry/tet:max-resv-link-bandwidth
      /tet:te-bandwidth/tet:technology:
+--:(otn)
  +--ro odulist* [odu-type]
    +--ro odu-type    identityref
    +--ro number?     uint16
augment /nw:networks/nw:network/nt:link/tet:te
      /tet:information-source-entry/tet:unreserved-bandwidth
      /tet:te-bandwidth/tet:technology:
+--:(otn)
  +--ro odulist* [odu-type]
    +--ro odu-type    identityref
    +--ro number?     uint16
augment /nw:networks/tet:te/tet:templates/tet:link-template
      /tet:te-link-attributes/tet:interface-switching-capability
      /tet:max-lsp-bandwidth/tet:te-bandwidth/tet:technology:
+--:(otn)
  +--rw odu-type?     identityref
augment /nw:networks/tet:te/tet:templates/tet:link-template
      /tet:te-link-attributes/tet:max-link-bandwidth
      /tet:te-bandwidth/tet:technology:
+--:(otn)
  +--rw odulist* [odu-type]
    +--rw odu-type    identityref
    +--rw number?     uint16

```

```

augment /nw:networks/tet:te/tet:templates/tet:link-template
  /tet:te-link-attributes/tet:max-resv-link-bandwidth
  /tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--rw odulist* [odu-type]
      +--rw odu-type identityref
      +--rw number? uint16
augment /nw:networks/tet:te/tet:templates/tet:link-template
  /tet:te-link-attributes/tet:unreserved-bandwidth
  /tet:te-bandwidth/tet:technology:
  +--:(otn)
    +--rw odulist* [odu-type]
      +--rw odu-type identityref
      +--rw number? uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:te-node-attributes/tet:connectivity-matrices
  /tet:label-restriction:
  +--rw range-type? identityref
  +--rw tsg? identityref
  +--rw priority? uint8

```

The technology specific TE label for this OTN topology can be specified using the following augment statements:

```

augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
  /tet:connectivity-matrices/tet:label-restriction
  /tet:label-start/tet:te-label/tet:technology:
  +--:(otn)
    +--rw (otn-label-type)?
      +--:(tributary-port)
        | +--rw tpn? uint16
      +--:(tributary-slot)
        +--rw ts? uint16
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
  /tet:connectivity-matrices/tet:label-restriction
  /tet:label-end/tet:te-label/tet:technology:
  +--:(otn)
    +--rw (otn-label-type)?
      +--:(tributary-port)
        | +--rw tpn? uint16
      +--:(tributary-slot)
        +--rw ts? uint16
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
  /tet:connectivity-matrices/tet:underlay/tet:primary-path
  /tet:path-element/tet:type/tet:label/tet:label-hop
  /tet:te-label/tet:technology:
  +--:(otn)
    +--rw tpn? uint16

```

```

    +---rw tsg?          identityref
    +---rw ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
    /tet:connectivity-matrices/tet:underlay/tet:backup-path
    /tet:path-element/tet:type/tet:label/tet:label-hop
    /tet:te-label/tet:technology:
+--:(otn)
    +---rw tpn?          uint16
    +---rw tsg?          identityref
    +---rw ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
    /tet:connectivity-matrices/tet:optimizations/tet:algorithm
    /tet:metric/tet:optimization-metric
    /tet:explicit-route-exclude-objects
    /tet:route-object-exclude-object/tet:type/tet:label
    /tet:label-hop/tet:te-label/tet:technology:
+--:(otn)
    +---rw tpn?          uint16
    +---rw tsg?          identityref
    +---rw ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
    /tet:connectivity-matrices/tet:optimizations/tet:algorithm
    /tet:metric/tet:optimization-metric
    /tet:explicit-route-include-objects
    /tet:route-object-include-object/tet:type/tet:label
    /tet:label-hop/tet:te-label/tet:technology:
+--:(otn)
    +---rw tpn?          uint16
    +---rw tsg?          identityref
    +---rw ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
    /tet:connectivity-matrices/tet:path-properties
    /tet:path-route-objects/tet:path-route-object/tet:type
    /tet:label/tet:label-hop/tet:te-label/tet:technology:
+--:(otn)
    +---ro tpn?          uint16
    +---ro tsg?          identityref
    +---ro ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
    /tet:connectivity-matrices/tet:connectivity-matrix
    /tet:from/tet:label-restriction:
    +---rw range-type?   identityref
    +---rw tsg?          identityref
    +---rw priority?     uint8
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
    /tet:connectivity-matrices/tet:connectivity-matrix/tet:from
    /tet:label-restriction/tet:label-start/tet:te-label/tet:technology:
+--:(otn)

```

```

    +--rw (otn-label-type)?
      +--:(tributary-port)
        | +--rw tpn?    uint16
      +--:(tributary-slot)
        +--rw ts?      uint16
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
      /tet:connectivity-matrices/tet:connectivity-matrix/tet:from
      /tet:label-restriction/tet:label-end/tet:te-label/tet:technology:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
      | +--rw tpn?    uint16
    +--:(tributary-slot)
      +--rw ts?      uint16
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
      /tet:connectivity-matrices/tet:connectivity-matrix/tet:to
      /tet:label-restriction:
  +--rw range-type?    identityref
  +--rw tsg?            identityref
  +--rw priority?      uint8
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
      /tet:connectivity-matrices/tet:connectivity-matrix/tet:to
      /tet:label-restriction/tet:label-start/tet:te-label
      /tet:technology:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
      | +--rw tpn?    uint16
    +--:(tributary-slot)
      +--rw ts?      uint16
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
      /tet:connectivity-matrices/tet:connectivity-matrix/tet:to
      /tet:label-restriction/tet:label-end/tet:te-label
      /tet:technology:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
      | +--rw tpn?    uint16
    +--:(tributary-slot)
      +--rw ts?      uint16
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
      /tet:connectivity-matrices/tet:connectivity-matrix
      /tet:underlay/tet:primary-path/tet:path-element/tet:type
      /tet:label/tet:label-hop/tet:te-label/tet:technology:
+--:(otn)
  +--rw tpn?          uint16
  +--rw tsg?          identityref
  +--rw ts-list?      string

```



```

augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
  /tet:connectivity-matrices/tet:connectivity-matrix
  /tet:underlay/tet:backup-path/tet:path-element/tet:type
  /tet:label/tet:label-hop/tet:te-label/tet:technology:
+--:(otn)
  +--rw tpn?          uint16
  +--rw tsg?          identityref
  +--rw ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
  /tet:connectivity-matrices/tet:connectivity-matrix
  /tet:optimizations/tet:algorithm/tet:metric
  /tet:optimization-metric/tet:explicit-route-exclude-objects
  /tet:route-object-exclude-object/tet:type/tet:label
  /tet:label-hop/tet:te-label/tet:technology:
+--:(otn)
  +--rw tpn?          uint16
  +--rw tsg?          identityref
  +--rw ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
  /tet:connectivity-matrices/tet:connectivity-matrix
  /tet:optimizations/tet:algorithm/tet:metric
  /tet:optimization-metric/tet:explicit-route-include-objects
  /tet:route-object-include-object/tet:type/tet:label
  /tet:label-hop/tet:te-label/tet:technology:
+--:(otn)
  +--rw tpn?          uint16
  +--rw tsg?          identityref
  +--rw ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te/tet:te-node-attributes
  /tet:connectivity-matrices/tet:connectivity-matrix
  /tet:path-properties/tet:path-route-objects
  /tet:path-route-object/tet:type/tet:label/tet:label-hop
  /tet:te-label/tet:technology:
+--:(otn)
  +--ro tpn?          uint16
  +--ro tsg?          identityref
  +--ro ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:label-restriction:
+--ro range-type?    identityref
+--ro tsg?            identityref
+--ro priority?      uint8
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:label-restriction/tet:label-start/tet:te-label
  /tet:technology:
+--:(otn)

```

```

    +---ro (otn-label-type)?
      +---:(tributary-port)
        | +---ro tpn?      uint16
      +---:(tributary-slot)
        +---ro ts?        uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:label-restriction/tet:label-end/tet:te-label
  /tet:technology:
+---:(otn)
  +---ro (otn-label-type)?
    +---:(tributary-port)
      | +---ro tpn?      uint16
    +---:(tributary-slot)
      +---ro ts?        uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:underlay/tet:primary-path/tet:path-element/tet:type
  /tet:label/tet:label-hop/tet:te-label/tet:technology:
+---:(otn)
  +---ro tpn?            uint16
  +---ro tsg?            identityref
  +---ro ts-list?       string
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:underlay/tet:backup-path/tet:path-element/tet:type
  /tet:label/tet:label-hop/tet:te-label/tet:technology:
+---:(otn)
  +---ro tpn?            uint16
  +---ro tsg?            identityref
  +---ro ts-list?       string
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:optimizations/tet:algorithm/tet:metric
  /tet:optimization-metric/tet:explicit-route-exclude-objects
  /tet:route-object-exclude-object/tet:type/tet:label
  /tet:label-hop/tet:te-label/tet:technology:
+---:(otn)
  +---ro tpn?            uint16
  +---ro tsg?            identityref
  +---ro ts-list?       string
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:optimizations/tet:algorithm/tet:metric
  /tet:optimization-metric/tet:explicit-route-include-objects
  /tet:route-object-include-object/tet:type/tet:label
  /tet:label-hop/tet:te-label/tet:technology:
+---:(otn)

```

```

    +--ro tpn?          uint16
    +--ro tsg?          identityref
    +--ro ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:information-source-entry/tet:connectivity-matrices
    /tet:path-properties/tet:path-route-objects
    /tet:path-route-object/tet:type/tet:label/tet:label-hop
    /tet:te-label/tet:technology:
+--:(otn)
    +--ro tpn?          uint16
    +--ro tsg?          identityref
    +--ro ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:information-source-entry/tet:connectivity-matrices
    /tet:connectivity-matrix/tet:from/tet:label-restriction:
    +--ro range-type?   identityref
    +--ro tsg?          identityref
    +--ro priority?     uint8
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:information-source-entry/tet:connectivity-matrices
    /tet:connectivity-matrix/tet:from/tet:label-restriction
    /tet:label-start/tet:te-label/tet:technology:
+--:(otn)
    +--ro (otn-label-type)?
        +--:(tributary-port)
            | +--ro tpn?   uint16
        +--:(tributary-slot)
            +--ro ts?     uint16
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:information-source-entry/tet:connectivity-matrices
    /tet:connectivity-matrix/tet:from/tet:label-restriction
    /tet:label-end/tet:te-label/tet:technology:
+--:(otn)
    +--ro (otn-label-type)?
        +--:(tributary-port)
            | +--ro tpn?   uint16
        +--:(tributary-slot)
            +--ro ts?     uint16
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:information-source-entry/tet:connectivity-matrices
    /tet:connectivity-matrix/tet:to/tet:label-restriction:
    +--ro range-type?   identityref
    +--ro tsg?          identityref
    +--ro priority?     uint8
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:information-source-entry/tet:connectivity-matrices
    /tet:connectivity-matrix/tet:to/tet:label-restriction
    /tet:label-start/tet:te-label/tet:technology:

```

```

+--:(otn)
  +--ro (otn-label-type)?
    +--:(tributary-port)
      | +--ro tpn?      uint16
    +--:(tributary-slot)
      +--ro ts?        uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:to/tet:label-restriction
  /tet:label-end/tet:te-label/tet:technology:
+--:(otn)
  +--ro (otn-label-type)?
    +--:(tributary-port)
      | +--ro tpn?      uint16
    +--:(tributary-slot)
      +--ro ts?        uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:underlay/tet:primary-path
  /tet:path-element/tet:type/tet:label/tet:label-hop
  /tet:te-label/tet:technology:
+--:(otn)
  +--ro tpn?          uint16
  +--ro tsg?          identityref
  +--ro ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:underlay/tet:backup-path
  /tet:path-element/tet:type/tet:label/tet:label-hop
  /tet:te-label/tet:technology:
+--:(otn)
  +--ro tpn?          uint16
  +--ro tsg?          identityref
  +--ro ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:optimizations/tet:algorithm
  /tet:metric/tet:optimization-metric
  /tet:explicit-route-exclude-objects
  /tet:route-object-exclude-object/tet:type/tet:label
  /tet:label-hop/tet:te-label/tet:technology:
+--:(otn)
  +--ro tpn?          uint16
  +--ro tsg?          identityref
  +--ro ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:optimizations/tet:algorithm

```

```

        /tet:metric/tet:optimization-metric
        /tet:explicit-route-include-objects
        /tet:route-object-include-object/tet:type/tet:label
        /tet:label-hop/tet:te-label/tet:technology:
+---:(otn)
  +---ro tpn?          uint16
  +---ro tsg?          identityref
  +---ro ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:information-source-entry/tet:connectivity-matrices
  /tet:connectivity-matrix/tet:path-properties
  /tet:path-route-objects/tet:path-route-object/tet:type
  /tet:label/tet:label-hop/tet:te-label/tet:technology:
+---:(otn)
  +---ro tpn?          uint16
  +---ro tsg?          identityref
  +---ro ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point/tet:local-link-connectivities
  /tet:label-restriction:
  +---rw range-type?   identityref
  +---rw tsg?          identityref
  +---rw priority?     uint8
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point/tet:local-link-connectivities
  /tet:label-restriction/tet:label-start/tet:te-label
  /tet:technology:
+---:(otn)
  +---rw (otn-label-type)?
  +---:(tributary-port)
  |   +---rw tpn?      uint16
  +---:(tributary-slot)
  |   +---rw ts?       uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point/tet:local-link-connectivities
  /tet:label-restriction/tet:label-end/tet:te-label
  /tet:technology:
+---:(otn)
  +---rw (otn-label-type)?
  +---:(tributary-port)
  |   +---rw tpn?      uint16
  +---:(tributary-slot)
  |   +---rw ts?       uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point/tet:local-link-connectivities
  /tet:underlay/tet:primary-path/tet:path-element/tet:type
  /tet:label/tet:label-hop/tet:te-label/tet:technology:
+---:(otn)

```

```

    +--rw tpn?          uint16
    +--rw tsg?          identityref
    +--rw ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point/tet:local-link-connectivities
    /tet:underlay/tet:backup-path/tet:path-element/tet:type
    /tet:label/tet:label-hop/tet:te-label/tet:technology:
+--:(otn)
    +--rw tpn?          uint16
    +--rw tsg?          identityref
    +--rw ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point/tet:local-link-connectivities
    /tet:optimizations/tet:algorithm/tet:metric
    /tet:optimization-metric/tet:explicit-route-exclude-objects
    /tet:route-object-exclude-object/tet:type/tet:label
    /tet:label-hop/tet:te-label/tet:technology:
+--:(otn)
    +--rw tpn?          uint16
    +--rw tsg?          identityref
    +--rw ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point/tet:local-link-connectivities
    /tet:optimizations/tet:algorithm/tet:metric
    /tet:optimization-metric/tet:explicit-route-include-objects
    /tet:route-object-include-object/tet:type/tet:label
    /tet:label-hop/tet:te-label/tet:technology:
+--:(otn)
    +--rw tpn?          uint16
    +--rw tsg?          identityref
    +--rw ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point/tet:local-link-connectivities
    /tet:path-properties/tet:path-route-objects
    /tet:path-route-object/tet:type/tet:label/tet:label-hop
    /tet:te-label/tet:technology:
+--:(otn)
    +--ro tpn?          uint16
    +--ro tsg?          identityref
    +--ro ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point/tet:local-link-connectivities
    /tet:local-link-connectivity/tet:label-restriction:
    +--rw range-type?   identityref
    +--rw tsg?          identityref
    +--rw priority?     uint8
augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point/tet:local-link-connectivities

```

```

        /tet:local-link-connectivity/tet:label-restriction
        /tet:label-start/tet:te-label/tet:technology:
+---:(otn)
  +---rw (otn-label-type)?
  +---:(tributary-port)
  |   +---rw tpn?      uint16
  +---:(tributary-slot)
  |   +---rw ts?      uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point/tet:local-link-connectivities
  /tet:local-link-connectivity/tet:label-restriction
  /tet:label-end/tet:te-label/tet:technology:
+---:(otn)
  +---rw (otn-label-type)?
  +---:(tributary-port)
  |   +---rw tpn?      uint16
  +---:(tributary-slot)
  |   +---rw ts?      uint16
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point/tet:local-link-connectivities
  /tet:local-link-connectivity/tet:underlay/tet:primary-path
  /tet:path-element/tet:type/tet:label/tet:label-hop
  /tet:te-label/tet:technology:
+---:(otn)
  +---rw tpn?          uint16
  +---rw tsg?          identityref
  +---rw ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point/tet:local-link-connectivities
  /tet:local-link-connectivity/tet:underlay/tet:backup-path
  /tet:path-element/tet:type/tet:label/tet:label-hop
  /tet:te-label/tet:technology:
+---:(otn)
  +---rw tpn?          uint16
  +---rw tsg?          identityref
  +---rw ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te
  /tet:tunnel-termination-point/tet:local-link-connectivities
  /tet:local-link-connectivity/tet:optimizations/tet:algorithm
  /tet:metric/tet:optimization-metric
  /tet:explicit-route-exclude-objects
  /tet:route-object-exclude-object/tet:type/tet:label
  /tet:label-hop/tet:te-label/tet:technology:
+---:(otn)
  +---rw tpn?          uint16
  +---rw tsg?          identityref
  +---rw ts-list?      string
augment /nw:networks/nw:network/nw:node/tet:te

```

```

    /tet:tunnel-termination-point/tet:local-link-connectivities
    /tet:local-link-connectivity/tet:optimizations/tet:algorithm
    /tet:metric/tet:optimization-metric
    /tet:explicit-route-include-objects
    /tet:route-object-include-object/tet:type/tet:label
    /tet:label-hop/tet:te-label/tet:technology:
  +--:(otn)
    +--rw tpn?          uint16
    +--rw tsg?          identityref
    +--rw ts-list?      string
  augment /nw:networks/nw:network/nw:node/tet:te
    /tet:tunnel-termination-point/tet:local-link-connectivities
    /tet:local-link-connectivity/tet:path-properties
    /tet:path-route-objects/tet:path-route-object/tet:type
    /tet:label/tet:label-hop/tet:te-label/tet:technology:
  +--:(otn)
    +--ro tpn?          uint16
    +--ro tsg?          identityref
    +--ro ts-list?      string
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes
    /tet:underlay/tet:primary-path/tet:path-element/tet:type
    /tet:label/tet:label-hop/tet:te-label/tet:technology:
  +--:(otn)
    +--rw tpn?          uint16
    +--rw tsg?          identityref
    +--rw ts-list?      string
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes
    /tet:underlay/tet:backup-path/tet:path-element/tet:type
    /tet:label/tet:label-hop/tet:te-label/tet:technology:
  +--:(otn)
    +--rw tpn?          uint16
    +--rw tsg?          identityref
    +--rw ts-list?      string
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes
    /tet:label-restriction:
    +--rw range-type?   identityref
    +--rw tsg?          identityref
    +--rw priority?     uint8
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes
    /tet:label-restriction/tet:label-start/tet:te-label
    /tet:technology:
  +--:(otn)
    +--rw (otn-label-type)?
      +--:(tributary-port)
        | +--rw tpn?    uint16
      +--:(tributary-slot)
        +--rw ts?      uint16
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes

```



```

        /tet:label-restriction/tet:label-end/tet:te-label/tet:technology:
+--:(otn)
  +--rw (otn-label-type)?
    +--:(tributary-port)
      | +--rw tpn?      uint16
    +--:(tributary-slot)
      +--rw ts?        uint16
augment /nw:networks/nw:network/nt:link/tet:te
  /tet:information-source-entry/tet:label-restriction:
+--ro range-type?      identityref
+--ro tsg?              identityref
+--ro priority?        uint8
augment /nw:networks/nw:network/nt:link/tet:te
  /tet:information-source-entry/tet:label-restriction
  /tet:label-start/tet:te-label/tet:technology:
+--:(otn)
  +--ro (otn-label-type)?
    +--:(tributary-port)
      | +--ro tpn?      uint16
    +--:(tributary-slot)
      +--ro ts?        uint16
augment /nw:networks/nw:network/nt:link/tet:te
  /tet:information-source-entry/tet:label-restriction
  /tet:label-end/tet:te-label/tet:technology:
+--:(otn)
  +--ro (otn-label-type)?
    +--:(tributary-port)
      | +--ro tpn?      uint16
    +--:(tributary-slot)
      +--ro ts?        uint16
augment /nw:networks/tet:te/tet:templates/tet:link-template
  /tet:te-link-attributes/tet:underlay/tet:primary-path
  /tet:path-element/tet:type/tet:label/tet:label-hop
  /tet:te-label/tet:technology:
+--:(otn)
  +--rw tpn?            uint16
  +--rw tsg?            identityref
  +--rw ts-list?       string
augment /nw:networks/tet:te/tet:templates/tet:link-template
  /tet:te-link-attributes/tet:underlay/tet:backup-path
  /tet:path-element/tet:type/tet:label/tet:label-hop
  /tet:te-label/tet:technology:
+--:(otn)
  +--rw tpn?            uint16
  +--rw tsg?            identityref
  +--rw ts-list?       string
augment /nw:networks/tet:te/tet:templates/tet:link-template
  /tet:te-link-attributes/tet:label-restriction:

```

```

    +--rw range-type?    identityref
    +--rw tsg?           identityref
    +--rw priority?      uint8
augment /nw:networks/tet:te/tet:templates/tet:link-template
    /tet:te-link-attributes/tet:label-restriction
    /tet:label-start/tet:te-label/tet:technology:
    +--:(otn)
        +--rw (otn-label-type)?
            +--:(tributary-port)
                | +--rw tpn?    uint16
            +--:(tributary-slot)
                +--rw ts?      uint16
augment /nw:networks/tet:te/tet:templates/tet:link-template
    /tet:te-link-attributes/tet:label-restriction/tet:label-end
    /tet:te-label/tet:technology:
    +--:(otn)
        +--rw (otn-label-type)?
            +--:(tributary-port)
                | +--rw tpn?    uint16
            +--:(tributary-slot)
                +--rw ts?      uint16

```

4. The YANG Code

<CODE BEGINS> file "ietf-otn-topology.yang"

```

module ietf-otn-topology {
  yang-version 1.1;

  namespace "urn:ietf:params:xml:ns:yang:ietf-otn-topology";
  prefix "otntopo";

  import ietf-network {
    prefix "nw";
  }

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

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

```

```
import ietf-otn-types {
  prefix "otn-types";
}

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

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

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         <mailto:aihuaguo@huawei.com>

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  Editor: Sergio Belotti
         <mailto:sergio.belotti@nokia.com>

  Editor: Yunbin Xu
         <mailto:xuyunbin@ritt.cn>

  Editor: Lei Wang
         <mailto:wangleiyj@chinamobile.com>

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

description
  "This module defines a protocol independent Layer 1/ODU topology
  data model.";

revision 2018-06-07 {
  description
    "Revision 0.6";
  reference
    "draft-ietf-ccamp-otn-topo-yang-03";
}
```

```
/*
 * Groupings
 */

grouping otn-link-attributes {
  description "link attributes for OTN";

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

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

```

/*
 * Data nodes
 */

augment "/nw:networks/nw:network/nw:network-types/"
  + "tet:te-topology" {
  container otn-topology {
    presence "indicates a topology type of Optical Transport
      Network (OTN)-electrical layer.";
    description "otn topology type";
  }
  description "augment network types to include otn network";
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:te-link-attributes" {
  when "../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment only for otn network.";
  }
  description "Augment link configuration";
  uses otn-link-attributes;
}

augment "/nw:networks/nw:network/nw:node/nt:termination-point/"
  + "tet:te" {
  when "../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment only for otn network";
  }
  description "OTN TP attributes config in ODU topology.";
  uses otn-tp-attributes;
}

/*
 * Augment TE bandwidth
 */

/* Augment maximum LSP bandwidth of link terminationpoint (LTP) */
augment "/nw:networks/nw:network/nw:node/nt:termination-point/"
  + "tet:te/"
  + "tet:interface-switching-capability/tet:max-lsp-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
  when "../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE bandwidth";
  }
  description "OTN bandwidth.";
}

```

```

    case otn {
        uses otn-types:otn-path-bandwidth;
    }
}

/* Augment bandwidth path constraints of connectivity-matrices */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:path-constraints/tet:te-bandwidth/tet:technology" {
    when "../..../..../..../..../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE bandwidth";
    }
    description "OTN bandwidth.";
    case otn {
        uses otn-types:otn-link-bandwidth;
    }
}

/* Augment bandwidth path constraints of connectivity-matrix */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/"
    + "tet:path-constraints/tet:te-bandwidth/tet:technology" {
    when "../..../..../..../..../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE bandwidth";
    }
    description "OTN bandwidth.";
    case otn {
        uses otn-types:otn-link-bandwidth;
    }
}

/* Augment bandwidth path constraints of
connectivity-matrices information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:information-source-entry/tet:connectivity-matrices/"
    + "tet:path-constraints/tet:te-bandwidth/tet:technology" {
    when "../..../..../..../..../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE bandwidth";
    }
    description "OTN bandwidth.";
    case otn {
        uses otn-types:otn-link-bandwidth;
    }
}

```

```

/* Augment bandwidth path constraints of
connectivity-matrix information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/"
  + "tet:path-constraints/tet:te-bandwidth/tet:technology" {
  when "../..../..../..../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE bandwidth";
  }
  description "OTN bandwidth.";
  case otn {
    uses otn-types:otn-link-bandwidth;
  }
}

/* Augment client bandwidth of tunnel termination point (TTP) */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:tunnel-termination-point/"
  + "tet:client-layer-adaptation/tet:switching-capability/"
  + "tet:te-bandwidth/tet:technology" {
  when "../..../..../..../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE bandwidth";
  }
  description "OTN bandwidth.";
  case otn {
    uses otn-types:otn-link-bandwidth;
  }
}

/* Augment bandwidth path constraints of local-link-connectivities */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:tunnel-termination-point/"
  + "tet:local-link-connectivities/tet:path-constraints/"
  + "tet:te-bandwidth/tet:technology" {
  when "../..../..../..../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE bandwidth";
  }
  description "OTN bandwidth.";
  case otn {
    uses otn-types:otn-link-bandwidth;
  }
}

/* Augment bandwidth path constraints of
local-link-connectivity (LLC) */

```

```

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:tunnel-termination-point/"
  + "tet:local-link-connectivities/"
  + "tet:local-link-connectivity/tet:path-constraints/"
  + "tet:te-bandwidth/tet:technology" {
  when "../..../..../..../..../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE bandwidth";
  }
  description "OTN bandwidth.";
  case otn {
    uses otn-types:otn-link-bandwidth;
  }
}

/* Augment maximum LSP bandwidth of TE link */
augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:te-link-attributes/"
  + "tet:interface-switching-capability/tet:max-lsp-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
  when "../..../..../..../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "OTN TE bandwidth.";
  }
  description "OTN bandwidth.";
  case otn {
    uses otn-types:otn-path-bandwidth;
  }
}

/* Augment maximum bandwidth of TE link */
augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:te-link-attributes/"
  + "tet:max-link-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
  when "../..../..../..../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "OTN TE bandwidth.";
  }
  description "OTN bandwidth.";
  case otn {
    uses otn-types:otn-link-bandwidth;
  }
}

/* Augment maximum reservable bandwidth of TE link */
augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:te-link-attributes/"

```



```

    + "tet:max-resv-link-bandwidth/"
    + "tet:te-bandwidth/tet:technology" {
when "../..../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "OTN TE bandwidth.";
    }
    description "OTN bandwidth.";
    case otn {
        uses otn-types:otn-link-bandwidth;
    }
}

/* Augment unreserved bandwidth of TE Link */
augment "/nw:networks/nw:network/nt:link/tet:te/"
    + "tet:te-link-attributes/"
    + "tet:unreserved-bandwidth/"
    + "tet:te-bandwidth/tet:technology" {
when "../..../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "OTN TE bandwidth.";
    }
    description "OTN bandwidth.";
    case otn {
        uses otn-types:otn-link-bandwidth;
    }
}

/* Augment maximum LSP bandwidth of TE link information-source */
augment "/nw:networks/nw:network/nt:link/tet:te/"
    + "tet:information-source-entry/"
    + "tet:interface-switching-capability/"
    + "tet:max-lsp-bandwidth/"
    + "tet:te-bandwidth/tet:technology" {
when "../..../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "OTN TE bandwidth.";
    }
    description "OTN bandwidth.";
    case otn {
        uses otn-types:otn-path-bandwidth;
    }
}

/* Augment maximum bandwidth of TE link information-source */
augment "/nw:networks/nw:network/nt:link/tet:te/"
    + "tet:information-source-entry/"
    + "tet:max-link-bandwidth/"
    + "tet:te-bandwidth/tet:technology" {

```

```
when "../../../nw:network-types/tet:te-topology/"
  + "otntopo:otn-topology" {
    description "OTN TE bandwidth.";
  }
description "OTN bandwidth.";
case otn {
  uses otn-types:otn-link-bandwidth;
}

/* Augment maximum reservable bandwidth
of TE link information-source */
augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:information-source-entry/"
  + "tet:max-resv-link-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
when "../../../nw:network-types/tet:te-topology/"
  + "otntopo:otn-topology" {
    description "OTN TE bandwidth.";
  }
description "OTN bandwidth.";
case otn {
  uses otn-types:otn-link-bandwidth;
}
}

/* Augment unreserved bandwidth of TE link information-source */
augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:information-source-entry/"
  + "tet:unreserved-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
when "../../../nw:network-types/tet:te-topology/"
  + "otntopo:otn-topology" {
    description "OTN TE bandwidth.";
  }
description "OTN bandwidth.";
case otn {
  uses otn-types:otn-link-bandwidth;
}
}

/* Augment maximum LSP bandwidth of TE link template */
augment "/nw:networks/tet:te/tet:templates/"
  + "tet:link-template/tet:te-link-attributes/"
  + "tet:interface-switching-capability/"
  + "tet:max-lsp-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
/*
```

```

    when "../../../nw:network-types/tet:te-topology/"
      + "otntopo:otn-topology" {
        description "OTN TE bandwidth.";
      }
  */
  description "OTN bandwidth.";
  case otn {
    uses otn-types:otn-path-bandwidth;
  }
}

/* Augment maximum bandwidth of TE link template */
augment "/nw:networks/tet:te/tet:templates/"
  + "tet:link-template/tet:te-link-attributes/"
  + "tet:max-link-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
  /*
    when "../../../nw:network-types/tet:te-topology/"
      + "otntopo:otn-topology" {
        description "OTN TE bandwidth.";
      }
  */
  description "OTN bandwidth.";
  case otn {
    uses otn-types:otn-link-bandwidth;
  }
}

/* Augment maximum reservable bandwidth of TE link template */
augment "/nw:networks/tet:te/tet:templates/"
  + "tet:link-template/tet:te-link-attributes/"
  + "tet:max-resv-link-bandwidth/"
  + "tet:te-bandwidth/tet:technology" {
  /*
    when "../../../nw:network-types/tet:te-topology/"
      + "otntopo:otn-topology" {
        description "OTN TE bandwidth.";
      }
  */
  description "OTN bandwidth.";
  case otn {
    uses otn-types:otn-link-bandwidth;
  }
}

/* Augment unreserved bandwidth of TE link template */
augment "/nw:networks/tet:te/tet:templates/"
  + "tet:link-template/tet:te-link-attributes/"

```

```

        + "tet:unreserved-bandwidth/"
        + "tet:te-bandwidth/tet:technology" {
/*
    when "../../../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "OTN TE bandwidth.";
    }
*/
    description "OTN bandwidth.";
    case otn {
        uses otn-types:otn-link-bandwidth;
    }
}

/*
* Augment TE label.
*/

/* Augment label restrictions of connectivity-matrices */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:label-restriction" {
    when "../../../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    uses otn-types:otn-label-restriction;
}

/* Augment label restrictions start of connectivity-matrices */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:label-restriction/tet:label-start/"
    + "tet:te-label/tet:technology" {
    when "../../../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
        uses otn-types:otn-link-label;
    }
}

/* Augment label restrictions end of connectivity-matrices */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:label-restriction/tet:label-end/"

```

```

    + "tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../.../.../.../.../.../.../..."
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses otn-types:otn-link-label;
}
}

/* Augment label hop of underlay primary path
of connectivity-matrices */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:underlay/tet:primary-path/tet:path-element/"
    + "tet:type/tet:label/tet:label-hop/"
    + "tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

/* Augment label hop of underlay backup path of
connectivity-matrices */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:underlay/tet:backup-path/tet:path-element/"
    + "tet:type/tet:label/tet:label-hop/"
    + "tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

/* Augment label hop of route-exclude of connectivity-matrices */

```

[illegible]

```

    + "otntopo:otn-topology" {
      description "Augment OTN TE label";
    }
  description "OTN label.";
  case otn {
    uses otn-types:otn-path-label;
  }
}

/* Augment ingress label restrictions of connectivity-matrix */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:te-node-attributes/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/tet:from/"
  + "tet:label-restriction" {
  when "../..../nw:network-types/tet:te-topology/"
  + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  uses otn-types:otn-label-restriction;
}

/* Augment ingress label restrictions start of connectivity-matrix */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:te-node-attributes/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/tet:from/"
  + "tet:label-restriction/tet:label-start/"
  + "tet:te-label/tet:technology" {
  when "../..../nw:network-types/tet:te-topology/"
  + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses otn-types:otn-link-label;
  }
}

/* Augment ingress label restrictions end of connectivity-matrix */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:te-node-attributes/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/tet:from/"
  + "tet:label-restriction/tet:label-end/"
  + "tet:te-label/tet:technology" {
  when "../..../nw:network-types/tet:te-topology/"
  + "otntopo:otn-topology" {

```

```

        description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
        uses otn-types:otn-link-label;
    }
}

/* Augment egress label restrictions of connectivity-matrix */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/tet:to/"
    + "tet:label-restriction" {
    when "../..../..../..../..../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    uses otn-types:otn-label-restriction;
}

/* Augment egress label restrictions start of connectivity-matrix */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/tet:to/"
    + "tet:label-restriction/tet:label-start/"
    + "tet:te-label/tet:technology" {
    when "../..../..../..../..../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
        uses otn-types:otn-link-label;
    }
}

/* Augment egress label restrictions end of connectivity-matrix */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/tet:to/"
    + "tet:label-restriction/tet:label-end/"
    + "tet:te-label/tet:technology" {
    when "../..../..../..../..../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
}

```



```

}
description "OTN label.";
case otn {
    uses otn-types:otn-link-label;
}
}

/* Augment label hop of underlay primary path of connectivity-matrix */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/"
    + "tet:underlay/tet:primary-path/tet:path-element/"
    + "tet:type/tet:label/tet:label-hop/"
    + "tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../.../.../.../.../"
    + "nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
}
}
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

/* Augment label hop of underlay backup path of connectivity-matrix */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/"
    + "tet:underlay/tet:backup-path/tet:path-element/"
    + "tet:type/tet:label/tet:label-hop/"
    + "tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../.../.../.../.../"
    + "nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
}
}
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

/* Augment label hop of route-exclude of connectivity-matrix */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/tet:optimizations/"
    + "tet:algorithm/tet:metric/tet:optimization-metric/"

```

```

    + "tet:explicit-route-exclude-objects/"
    + "tet:route-object-exclude-object/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

/* Augment label hop of route-include of connectivity-matrix */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/tet:optimizations/"
    + "tet:algorithm/tet:metric/tet:optimization-metric/"
    + "tet:explicit-route-include-objects/"
    + "tet:route-object-include-object/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

/* Augment label hop of path-route of connectivity-matrix */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:te-node-attributes/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/"
    + "tet:path-properties/tet:path-route-objects/"
    + "tet:path-route-object/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

```

```

    }
  }

  /* Augment label restrictions of
  connectivity-matrices information-source */
  augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:information-source-entry/"
    + "tet:connectivity-matrices/tet:label-restriction" {
    when "../..../nw:network-types/tet:te-topology/"
      + "otntopo:otn-topology" {
      description "Augment OTN TE label";
    }
    description "OTN label.";
    uses otn-types:otn-label-restriction;
  }

  /* Augment label restrictions start of
  connectivity-matrices information-source */
  augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:information-source-entry/"
    + "tet:connectivity-matrices/tet:label-restriction/"
    + "tet:label-start/tet:te-label/tet:technology" {
    when "../..../nw:network-types/tet:te-topology/"
      + "otntopo:otn-topology" {
      description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
      uses otn-types:otn-link-label;
    }
  }

  /* Augment label restrictions end of
  connectivity-matrices information-source */
  augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:information-source-entry/"
    + "tet:connectivity-matrices/tet:label-restriction/"
    + "tet:label-end/tet:te-label/tet:technology" {
    when "../..../nw:network-types/tet:te-topology/"
      + "otntopo:otn-topology" {
      description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
      uses otn-types:otn-link-label;
    }
  }

```

```

}

/* Augment label hop of underlay primary path of
connectivity-matrices information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:information-source-entry/tet:connectivity-matrices/"
    + "tet:underlay/tet:primary-path/tet:path-element/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
    when "...../"
        + "nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
            description "Augment OTN TE label";
        }
    description "OTN label.";
    case otn {
        uses otn-types:otn-path-label;
    }
}

/* Augment label hop of underlay backup path of
connectivity-matrices information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:information-source-entry/tet:connectivity-matrices/"
    + "tet:underlay/tet:backup-path/tet:path-element/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
    when "...../"
        + "nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
            description "Augment OTN TE label";
        }
    description "OTN label.";
    case otn {
        uses otn-types:otn-path-label;
    }
}

/* Augment label hop of route-exclude of
connectivity-matrices information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:information-source-entry/tet:connectivity-matrices/"
    + "tet:optimizations/tet:algorithm/tet:metric/"
    + "tet:optimization-metric/"
    + "tet:explicit-route-exclude-objects/"
    + "tet:route-object-exclude-object/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
    when "...../"
        + "nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {

```

```

    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses otn-types:otn-path-label;
  }
}

/* Augment label hop of route-include
of connectivity-matrices information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:optimizations/tet:algorithm/tet:metric/"
  + "tet:optimization-metric/"
  + "tet:explicit-route-include-objects/"
  + "tet:route-object-include-object/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../../../../../../../../../../../../../../../../../../../"
  + "nw:network-types/tet:te-topology/"
  + "otntopo:otn-topology" {
  description "Augment OTN TE label";
}
description "OTN label.";
case otn {
  uses otn-types:otn-path-label;
}
}

/* Augment label hop of path-route of
connectivity-matrices information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:path-properties/tet:path-route-objects/"
  + "tet:path-route-object/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../../../../../../../../../../../../../../../../../../../"
  + "nw:network-types/tet:te-topology/"
  + "otntopo:otn-topology" {
  description "Augment OTN TE label";
}
description "OTN label.";
case otn {
  uses otn-types:otn-path-label;
}
}

/* Augment ingress label restrictions
of connectivity-matrix information-source */

```

```

augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/"
  + "tet:from/tet:label-restriction" {
when "../.../.../.../.../.../.../.../.../.../.../.../.../.../.../.../..."
  + "otntopo:otn-topology" {
  description "Augment OTN TE label";
}
description "OTN label.";
uses otn-types:otn-label-restriction;
}

/* Augment ingress label restrictions start
of connectivity-matrix information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/"
  + "tet:from/tet:label-restriction/"
  + "tet:label-start/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../.../.../.../.../.../.../..."
  + "nw:network-types/tet:te-topology/"
  + "otntopo:otn-topology" {
  description "Augment OTN TE label";
}
description "OTN label.";
case otn {
  uses otn-types:otn-link-label;
}
}

/* Augment ingress label restrictions end
of connectivity-matrix information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/"
  + "tet:from/tet:label-restriction/"
  + "tet:label-end/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../.../.../.../.../.../.../..."
  + "nw:network-types/tet:te-topology/"
  + "otntopo:otn-topology" {
  description "Augment OTN TE label";
}
description "OTN label.";
case otn {
  uses otn-types:otn-link-label;
}
}

```

```

/* Augment egress label restrictions of
connectivity-matrix information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/"
  + "tet:to/tet:label-restriction" {
  when "../.../.../.../.../.../.../.../.../.../.../.../.../.../.../.../..."
  + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  uses otn-types:otn-label-restriction;
}

/* Augment egress label restrictions start
of connectivity-matrix information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/"
  + "tet:to/tet:label-restriction/"
  + "tet:label-start/tet:te-label/tet:technology" {
  when "../.../.../.../.../.../.../.../.../.../.../.../.../.../.../.../..."
  + "nw:network-types/tet:te-topology/"
  + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses otn-types:otn-link-label;
  }
}

/* Augment egress label restrictions end
of connectivity-matrix information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/"
  + "tet:to/tet:label-restriction/"
  + "tet:label-end/tet:te-label/tet:technology" {
  when "../.../.../.../.../.../.../.../.../.../.../.../.../.../.../.../..."
  + "nw:network-types/tet:te-topology/"
  + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses otn-types:otn-link-label;
  }
}

```

```

}

/* Augment label hop of underlay primary path
of connectivity-matrix information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:information-source-entry/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/"
    + "tet:underlay/tet:primary-path/tet:path-element/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when ".../.../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
}
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

/* Augment label hop of underlay backup path
of connectivity-matrix information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:information-source-entry/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/"
    + "tet:underlay/tet:backup-path/tet:path-element/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when ".../.../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
}
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

/* Augment label hop of route-exclude
of connectivity-matrix information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:information-source-entry/tet:connectivity-matrices/"
    + "tet:connectivity-matrix/"
    + "tet:optimizations/tet:algorithm/tet:metric/"
    + "tet:optimization-metric/"
    + "tet:explicit-route-exclude-objects/"
    + "tet:route-object-exclude-object/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {

```



```

    when "../../../../../../../../../../../../../../../../../../../"
      + "nw:network-types/tet:te-topology/"
      + "otntopo:otn-topology" {
        description "Augment OTN TE label";
      }
    description "OTN label.";
    case otn {
      uses otn-types:otn-path-label;
    }
  }

/* Augment label hop of route-include
of connectivity-matrix information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/"
  + "tet:optimizations/tet:algorithm/tet:metric/"
  + "tet:optimization-metric/"
  + "tet:explicit-route-include-objects/"
  + "tet:route-object-include-object/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
  when "../../../../../../../../../../../../../../../../../../../"
    + "nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
      description "Augment OTN TE label";
    }
  description "OTN label.";
  case otn {
    uses otn-types:otn-path-label;
  }
}

/* Augment label hop of path-route of
connectivity-matrix information-source */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:information-source-entry/tet:connectivity-matrices/"
  + "tet:connectivity-matrix/"
  + "tet:path-properties/tet:path-route-objects/"
  + "tet:path-route-object/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
  when "../../../../../../../../../../../../../../../../../../../"
    + "nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
      description "Augment OTN TE label";
    }
  description "OTN label.";
  case otn {
    uses otn-types:otn-path-label;
  }
}

```

```

    }
  }

/* Augment label restrictions
of local-link-connectivities */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:tunnel-termination-point/"
  + "tet:local-link-connectivities/"
  + "tet:label-restriction" {
  when "../..../nw:network-types/tet:te-topology/"
  + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  uses otn-types:otn-label-restriction;
}

/* Augment label restrictions start of local-link-connectivities */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:tunnel-termination-point/"
  + "tet:local-link-connectivities/"
  + "tet:label-restriction/tet:label-start/"
  + "tet:te-label/tet:technology" {
  when "../..../nw:network-types/tet:te-topology/"
  + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses otn-types:otn-link-label;
  }
}

/* Augment label restrictions end of local-link-connectivities */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:tunnel-termination-point/"
  + "tet:local-link-connectivities/"
  + "tet:label-restriction/tet:label-end/"
  + "tet:te-label/tet:technology" {
  when "../..../nw:network-types/tet:te-topology/"
  + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses otn-types:otn-link-label;
  }
}

```

```

/* Augment label hop of underlay primary path
of local-link-connectivities */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:tunnel-termination-point/"
  + "tet:local-link-connectivities/"
  + "tet:underlay/tet:primary-path/tet:path-element/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../.../..."
  + "nw:network-types/tet:te-topology/"
  + "otntopo:otn-topology" {
  description "Augment OTN TE label";
}
description "OTN label.";
case otn {
  uses otn-types:otn-path-label;
}
}

/* Augment label hop of underlay backup path
of local-link-connectivities */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:tunnel-termination-point/"
  + "tet:local-link-connectivities/"
  + "tet:underlay/tet:backup-path/tet:path-element/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../.../..."
  + "nw:network-types/tet:te-topology/"
  + "otntopo:otn-topology" {
  description "Augment OTN TE label";
}
description "OTN label.";
case otn {
  uses otn-types:otn-path-label;
}
}

/* Augment label hop of route-exclude of local-link-connectivities */
augment "/nw:networks/nw:network/nw:node/tet:te/"
  + "tet:tunnel-termination-point/"
  + "tet:local-link-connectivities/"
  + "tet:optimizations/tet:algorithm/tet:metric/"
  + "tet:optimization-metric/"
  + "tet:explicit-route-exclude-objects/"
  + "tet:route-object-exclude-object/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../.../..."
  + "nw:network-types/tet:te-topology/"
  + "otntopo:otn-topology" {

```

```

    description "Augment OTN TE label";
}
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

/* Augment label hop of route-include of local-link-connectivities */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:tunnel-termination-point/"
    + "tet:local-link-connectivities/"
    + "tet:optimizations/tet:algorithm/tet:metric/"
    + "tet:optimization-metric/"
    + "tet:explicit-route-include-objects/"
    + "tet:route-object-include-object/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
}
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

/* Augment label hop of path-route of local-link-connectivities */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:tunnel-termination-point/"
    + "tet:local-link-connectivities/"
    + "tet:path-properties/tet:path-route-objects/"
    + "tet:path-route-object/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
}
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

/* Augment label restrictions of local-link-connectivity (LLC) */
augment "/nw:networks/nw:network/nw:node/tet:te/"

```

```

+ "tet:tunnel-termination-point/"
+ "tet:local-link-connectivities/"
+ "tet:local-link-connectivity/"
+ "tet:label-restriction" {
when "../.../../.../../nw:network-types/tet:te-topology/"
+ "otntopo:otn-topology" {
description "Augment OTN TE label";
}
description "OTN label.";
uses otn-types:otn-label-restriction;
}

/* Augment label restrictions start of local-link-connectivity (LLC) */
augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:tunnel-termination-point/"
+ "tet:local-link-connectivities/"
+ "tet:local-link-connectivity/"
+ "tet:label-restriction/"
+ "tet:label-start/tet:te-label/tet:technology" {
when "../.../../.../../.../../nw:network-types/tet:te-topology/"
+ "otntopo:otn-topology" {
description "Augment OTN TE label";
}
description "OTN label.";
case otn {
uses otn-types:otn-link-label;
}
}

/* Augment label restrictions end of local-link-connectivity (LLC) */
augment "/nw:networks/nw:network/nw:node/tet:te/"
+ "tet:tunnel-termination-point/"
+ "tet:local-link-connectivities/"
+ "tet:local-link-connectivity/"
+ "tet:label-restriction/"
+ "tet:label-end/tet:te-label/tet:technology" {
when "../.../../.../../.../../nw:network-types/tet:te-topology/"
+ "otntopo:otn-topology" {
description "Augment OTN TE label";
}
description "OTN label.";
case otn {
uses otn-types:otn-link-label;
}
}

```

```

/* Augment label hop of underlay primary path
of local-link-connectivity (LLC) */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:tunnel-termination-point/"
    + "tet:local-link-connectivities/"
    + "tet:local-link-connectivity/"
    + "tet:underlay/tet:primary-path/tet:path-element/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when ".../.../.../.../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
}
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

/* Augment label hop of underlay backup path
of local-link-connectivity (LLC) */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:tunnel-termination-point/"
    + "tet:local-link-connectivities/"
    + "tet:local-link-connectivity/"
    + "tet:underlay/tet:backup-path/tet:path-element/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when ".../.../.../.../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
}
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

/* Augment label hop of route-exclude
of local-link-connectivity (LLC) */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:tunnel-termination-point/"
    + "tet:local-link-connectivities/"
    + "tet:local-link-connectivity/"
    + "tet:optimizations/tet:algorithm/tet:metric/"
    + "tet:optimization-metric/"
    + "tet:explicit-route-exclude-objects/"
    + "tet:route-object-exclude-object/tet:type/"

```

```

    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

/* Augment label hop of route-include
of local-link-connectivity (LLC) */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:tunnel-termination-point/"
    + "tet:local-link-connectivities/"
    + "tet:local-link-connectivity/"
    + "tet:optimizations/tet:algorithm/tet:metric/"
    + "tet:optimization-metric/"
    + "tet:explicit-route-include-objects/"
    + "tet:route-object-include-object/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
    }
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

/* Augment label hop of path-route of local-link-connectivity (LLC) */
augment "/nw:networks/nw:network/nw:node/tet:te/"
    + "tet:tunnel-termination-point/"
    + "tet:local-link-connectivities/"
    + "tet:local-link-connectivity/"
    + "tet:path-properties/tet:path-route-objects/"
    + "tet:path-route-object/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
when "../.../.../.../.../.../.../.../.../.../.../.../.../.../..."
    + "nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
    }
description "OTN label.";

```

```

    case otn {
        uses otn-types:otn-path-label;
    }
}

/* Augment label hop of underlay primary path of TE link */
augment "/nw:networks/nw:network/nt:link/tet:te/"
    + "tet:te-link-attributes/"
    + "tet:underlay/tet:primary-path/tet:path-element/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
    when "../..../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
        uses otn-types:otn-path-label;
    }
}

/* Augment label hop of underlay backup path of TE link */
augment "/nw:networks/nw:network/nt:link/tet:te/"
    + "tet:te-link-attributes/"
    + "tet:underlay/tet:backup-path/tet:path-element/tet:type/"
    + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
    when "../..../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    case otn {
        uses otn-types:otn-path-label;
    }
}

/* Augment label restrictions of TE link */
augment "/nw:networks/nw:network/nt:link/tet:te/"
    + "tet:te-link-attributes/"
    + "tet:label-restriction" {
    when "../..../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
    description "OTN label.";
    uses otn-types:otn-label-restriction;
}

```



```

/* Augment label restrictions start of TE link */
augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:te-link-attributes/"
  + "tet:label-restriction/"
  + "tet:label-start/tet:te-label/tet:technology" {
  when "../..../..../..../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses otn-types:otn-link-label;
  }
}

/* Augment label restrictions end of TE link */
augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:te-link-attributes/"
  + "tet:label-restriction/"
  + "tet:label-end/tet:te-label/tet:technology" {
  when "../..../..../..../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses otn-types:otn-link-label;
  }
}

/* Augment label restrictions of TE link information-source */
augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:information-source-entry/"
  + "tet:label-restriction" {
  when "../..../..../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  uses otn-types:otn-label-restriction;
}

/* Augment label restrictions start of TE link information-source */
augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:information-source-entry/"
  + "tet:label-restriction/"
  + "tet:label-start/tet:te-label/tet:technology" {
  when "../..../..../..../..../nw:network-types/tet:te-topology/"

```

```

    + "otntopo:otn-topology" {
      description "Augment OTN TE label";
    }
  description "OTN label.";
  case otn {
    uses otn-types:otn-link-label;
  }
}

/* Augment label restrictions end of TE link information-source */
augment "/nw:networks/nw:network/nt:link/tet:te/"
  + "tet:information-source-entry/"
  + "tet:label-restriction/"
  + "tet:label-end/tet:te-label/tet:technology" {
  when "../../../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
  description "OTN label.";
  case otn {
    uses otn-types:otn-link-label;
  }
}

/* Augment label hop of underlay primary path of TE link template */
augment "/nw:networks/tet:te/tet:templates/"
  + "tet:link-template/tet:te-link-attributes/"
  + "tet:underlay/tet:primary-path/tet:path-element/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
/*
  when "../../../nw:network-types/tet:te-topology/"
    + "otntopo:otn-topology" {
    description "Augment OTN TE label";
  }
*/
  description "OTN label.";
  case otn {
    uses otn-types:otn-path-label;
  }
}

/* Augment label hop of underlay backup path of TE link template */
augment "/nw:networks/tet:te/tet:templates/"
  + "tet:link-template/tet:te-link-attributes/"
  + "tet:underlay/tet:backup-path/tet:path-element/tet:type/"
  + "tet:label/tet:label-hop/tet:te-label/tet:technology" {
/*

```

```

        when "../../../nw:network-types/tet:te-topology/"
            + "otntopo:otn-topology" {
            description "Augment OTN TE label";
        }
    */
    description "OTN label.";
    case otn {
        uses otn-types:otn-path-label;
    }
}

/* Augment label restrictions of TE link template */
augment "/nw:networks/tet:te/tet:templates/"
    + "tet:link-template/tet:te-link-attributes/"
    + "tet:label-restriction" {
/*
    when "../../../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
*/
    description "OTN label.";
    uses otn-types:otn-label-restriction;
}

/* Augment label restrictions start of TE link template */
augment "/nw:networks/tet:te/tet:templates/"
    + "tet:link-template/tet:te-link-attributes/"
    + "tet:label-restriction/"
    + "tet:label-start/tet:te-label/tet:technology" {
/*
    when "../../../nw:network-types/tet:te-topology/"
        + "otntopo:otn-topology" {
        description "Augment OTN TE label";
    }
*/
    description "OTN label.";
    case otn {
        uses otn-types:otn-link-label;
    }
}

/* Augment label restrictions end of TE link template */
augment "/nw:networks/tet:te/tet:templates/"
    + "tet:link-template/tet:te-link-attributes/"
    + "tet:label-restriction/"
    + "tet:label-end/tet:te-label/tet:technology" {
/*

```

```
    when "../../../nw:network-types/tet:te-topology/"
      + "otntopo:otn-topology" {
      description "Augment OTN TE label";
    }
  */
  description "OTN label.";
  case otn {
    uses otn-types:otn-link-label;
  }
}
```

<CODE ENDS>

5. IANA Considerations

TBD.

6. Manageability Considerations

TBD.

7. Security Considerations

The data following the model defined in this document is exchanged via, for example, the interface between an orchestrator and a transport network controller. The security concerns mentioned in [I-D.ietf-teas-yang-te-topo] for using ietf-te-topology.yang model also applies to this document.

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

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

Editors note: to list specific subtrees and data nodes and their sensitivity/vulnerability.

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OTN Tunnel YANG Model
draft-ietf-ccamp-otn-tunnel-model-03

Abstract

This document describes the YANG data model for OTN Tunnels.

Status of This Memo

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1. Introduction

OTN transport networks can carry various types of client services. In many cases, the client signal is carried over an OTN tunnel across connected domains in a multi-domain network. These OTN services can either be transported or switched in the OTN network. If an OTN tunnel is switched, then additional parameters need to be provided to create a Mux OTN service.

This document provides YANG model for creating OTN tunnel. The model augments the TE Tunnel 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 draft is defined in

[I-D.ietf-netmod-yang-tree-diagrams]. They are provided below for reference.

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

3. OTN Tunnel Model Description

3.1. Overview of OTN Tunnel Model

The OTN tunnel model is using TE tunnel [I-D.ietf-teas-yang-te] as a basic model and augment to the TE tunnel with OTN-specific parameters, including the bandwidth information and label information. It is also worth noting that the OTN tunnel provisioning is usually based on the OTN topology. Therefore the OTN tunnel model is usually used together with OTN topology model specified in [I-D.ietf-ccamp-otn-topo-yang].

More scenarios and model applications can be found in [I-D.ietf-ccamp-transport-nbi-app-statement] and [I-D.ietf-teas-actn-yang]. The current model is following the YANG language specification as [RFC7950], and the corresponding protocol is recommended to be Netconf protocol in [RFC6241] or RESTconf protocol in [RFC8040].

3.2. OTN-specific Parameters in Tunnel Model

OTN specific parameters have been augmenting to the TE tunnel models. The attributes on both of the source and destination need to be configured when setting up the tunnel. Typical parameters, including client signal, TPN, TSG and corresponding tributary slot information, are required in the OTN tunnel model. These parameters are consistent with the framework in [RFC7062], and the specification in [RFC7138] and [RFC7139].

The OTN bandwidth information has been augmenting to various sections of TE tunnel models, including tunnel bandwidth, primary path

bandwidth and so on. The OTN label information has been augmenting to label hop of a group of routing objects and also LSPs.

3.3. OTN Path Compute RPC

Similarly with TE tunnel, a 'compute-only' mode of OTN tunnel model is also supported for stateful path computation. Given the OTN tunnel computed, the client may query and/or subscribe on the tunnel to be notified whenever it changes. In addition, also a stateless Remote Procedural Call (RPC) is specified. On receiving this RPC, the provider is expected to compute the available path subject to the constraints specified in RPC and feedback to the client without any changing of the OTN network or the OTN tunnels.

4. OTN Tunnel YANG Tree

```

module: ietf-otn-tunnel
  augment /te:te/te:tunnels/te:tunnel:
    +--rw src-client-signal?    identityref
    +--rw dst-client-signal?    identityref
  augment /te:te/te:globals/te:named-path-constraints
    /te:named-path-constraint/te:te-bandwidth/te:technology:
    +--:(otn)
      +--rw odu-type?    identityref
  augment /te:te/te:tunnels/te:tunnel/te:te-bandwidth/te:technology:
    +--:(otn)
      +--rw odu-type?    identityref
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
    /te:p2p-primary-path/te:te-bandwidth/te:technology:
    +--:(otn)
      +--rw odu-type?    identityref
  augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
    /te:p2p-primary-path/te:p2p-reverse-primary-path
    /te:te-bandwidth/te:technology:
    +--:(otn)
      +--rw odu-type?    identityref
  augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths
    /te:p2p-secondary-path/te:te-bandwidth/te:technology:
    +--:(otn)
      +--rw odu-type?    identityref
  augment /te:te/te:globals/te:named-path-constraints
    /te:named-path-constraint/te:explicit-route-objects
    /te:route-object-exclude-always/te:type/te:label
    /te:label-hop/te:te-label/te:technology:
    +--:(otn)
      +--rw tpn?          uint16

```

```

    +---rw tsg?          identityref
    +---rw ts-list?      string
augment /te:te/te:globals/te:named-path-constraints
    /te:named-path-constraint/te:explicit-route-objects
    /te:route-object-include-exclude/te:type/te:label
    /te:label-hop/te:te-label/te:technology:
+---:(otn)
    +---rw tpn?          uint16
    +---rw tsg?          identityref
    +---rw ts-list?      string
augment /te:te/te:globals/te:named-path-constraints
    /te:named-path-constraint/te:path-in-segment
    /te:forward/te:label-restrictions/te:label-restriction:
    +---rw range-type?   identityref
    +---rw tsg?          identityref
    +---rw priority?     uint8
augment /te:te/te:globals/te:named-path-constraints
    /te:named-path-constraint/te:path-in-segment/te:forward
    /te:label-restrictions/te:label-restriction/te:label-start
    /te:te-label/te:technology:
+---:(otn)
    +---rw (otn-label-type)?
    +---:(tributary-port)
    |   +---rw tpn?      uint16
    +---:(tributary-slot)
    |   +---rw ts?       uint16
augment /te:te/te:globals/te:named-path-constraints
    /te:named-path-constraint/te:path-in-segment/te:forward
    /te:label-restrictions/te:label-restriction/te:label-end
    /te:te-label/te:technology:
+---:(otn)
    +---rw (otn-label-type)?
    +---:(tributary-port)
    |   +---rw tpn?      uint16
    +---:(tributary-slot)
    |   +---rw ts?       uint16
augment /te:te/te:globals/te:named-path-constraints
    /te:named-path-constraint/te:path-in-segment/te:reverse
    /te:label-restrictions/te:label-restriction:
    +---rw range-type?   identityref
    +---rw tsg?          identityref
    +---rw priority?     uint8
augment /te:te/te:globals/te:named-path-constraints
    /te:named-path-constraint/te:path-in-segment/te:reverse
    /te:label-restrictions/te:label-restriction/te:label-start
    /te:te-label/te:technology:
+---:(otn)
    +---rw (otn-label-type)?

```

```

    +---:(tributary-port)
    |   +---rw tpn?    uint16
    +---:(tributary-slot)
        +---rw ts?    uint16
augment /te:te/te:globals/te:named-path-constraints
    /te:named-path-constraint/te:path-in-segment/te:reverse
    /te:label-restrictions/te:label-restriction/te:label-end
    /te:te-label/te:technology:
+---:(otn)
    +---rw (otn-label-type)?
    +---:(tributary-port)
    |   +---rw tpn?    uint16
    +---:(tributary-slot)
        +---rw ts?    uint16
augment /te:te/te:globals/te:named-path-constraints
    /te:named-path-constraint/te:path-out-segment/te:forward
    /te:label-restrictions/te:label-restriction:
    +---rw range-type?    identityref
    +---rw tsg?            identityref
    +---rw priority?      uint8
augment /te:te/te:globals/te:named-path-constraints
    /te:named-path-constraint/te:path-out-segment/te:forward
    /te:label-restrictions/te:label-restriction/te:label-start
    /te:te-label/te:technology:
+---:(otn)
    +---rw (otn-label-type)?
    +---:(tributary-port)
    |   +---rw tpn?    uint16
    +---:(tributary-slot)
        +---rw ts?    uint16
augment /te:te/te:globals/te:named-path-constraints
    /te:named-path-constraint/te:path-out-segment/te:forward
    /te:label-restrictions/te:label-restriction/te:label-end
    /te:te-label/te:technology:
+---:(otn)
    +---rw (otn-label-type)?
    +---:(tributary-port)
    |   +---rw tpn?    uint16
    +---:(tributary-slot)
        +---rw ts?    uint16
augment /te:te/te:globals/te:named-path-constraints
    /te:named-path-constraint/te:path-out-segment/te:reverse
    /te:label-restrictions/te:label-restriction:
    +---rw range-type?    identityref
    +---rw tsg?            identityref
    +---rw priority?      uint8
augment /te:te/te:globals/te:named-path-constraints
    /te:named-path-constraint/te:path-out-segment/te:reverse

```

```

        /te:label-restrictions/te:label-restriction/te:label-start
        /te:te-label/te:technology:
+---:(otn)
  +---rw (otn-label-type)?
  +---:(tributary-port)
  |   +---rw tpn?      uint16
  +---:(tributary-slot)
  |   +---rw ts?       uint16
augment /te:te/te:globals/te:named-path-constraints
        /te:named-path-constraint/te:path-out-segment/te:reverse
        /te:label-restrictions/te:label-restriction/te:label-end
        /te:te-label/te:technology:
+---:(otn)
  +---rw (otn-label-type)?
  +---:(tributary-port)
  |   +---rw tpn?      uint16
  +---:(tributary-slot)
  |   +---rw ts?       uint16
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:
+---:(otn)
  +---rw tpn?          uint16
  +---rw tsg?          identityref
  +---rw ts-list?      string
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:
+---:(otn)
  +---rw tpn?          uint16
  +---rw tsg?          identityref
  +---rw ts-list?      string
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
        /te:p2p-primary-path/te:explicit-route-objects
        /te:route-object-exclude-always/te:type/te:label
        /te:label-hop/te:te-label/te:technology:
+---:(otn)
  +---rw tpn?          uint16
  +---rw tsg?          identityref
  +---rw ts-list?      string
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
        /te:p2p-primary-path/te:explicit-route-objects
        /te:route-object-include-exclude/te:type/te:label
        /te:label-hop/te:te-label/te:technology:

```

```

+---:(otn)
  +---rw tpn?          uint16
  +---rw tsg?          identityref
  +---rw ts-list?      string
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
  /te:p2p-primary-path/te:path-in-segment/te:forward
  /te:label-restrictions/te:label-restriction:
  +---rw range-type?   identityref
  +---rw tsg?          identityref
  +---rw priority?     uint8
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
  /te:p2p-primary-path/te:path-in-segment/te:forward
  /te:label-restrictions/te:label-restriction
  /te:label-start/te:te-label/te:technology:
+---:(otn)
  +---rw (otn-label-type)?
  +---:(tributary-port)
  |   +---rw tpn?      uint16
  +---:(tributary-slot)
  |   +---rw ts?       uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
  /te:p2p-primary-path/te:path-in-segment/te:forward
  /te:label-restrictions/te:label-restriction
  /te:label-end/te:te-label/te:technology:
+---:(otn)
  +---rw (otn-label-type)?
  +---:(tributary-port)
  |   +---rw tpn?      uint16
  +---:(tributary-slot)
  |   +---rw ts?       uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
  /te:p2p-primary-path/te:path-in-segment/te:reverse
  /te:label-restrictions/te:label-restriction:
  +---rw range-type?   identityref
  +---rw tsg?          identityref
  +---rw priority?     uint8
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
  /te:p2p-primary-path/te:path-in-segment/te:reverse
  /te:label-restrictions/te:label-restriction
  /te:label-start/te:te-label/te:technology:
+---:(otn)
  +---rw (otn-label-type)?
  +---:(tributary-port)
  |   +---rw tpn?      uint16
  +---:(tributary-slot)
  |   +---rw ts?       uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
  /te:p2p-primary-path/te:path-in-segment/te:reverse

```



```

        /te:label-restrictions/te:label-restriction/te:label-end
        /te:te-label/te:technology:
+---:(otn)
  +---rw (otn-label-type)?
  +---:(tributary-port)
  |   +---rw tpn?    uint16
  +---:(tributary-slot)
  |   +---rw ts?     uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
        /te:p2p-primary-path/te:path-out-segment/te:forward
        /te:label-restrictions/te:label-restriction:
+---rw range-type?    identityref
+---rw tsg?           identityref
+---rw priority?      uint8
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
        /te:p2p-primary-path/te:path-out-segment/te:forward
        /te:label-restrictions/te:label-restriction/te:label-start
        /te:te-label/te:technology:
+---:(otn)
  +---rw (otn-label-type)?
  +---:(tributary-port)
  |   +---rw tpn?    uint16
  +---:(tributary-slot)
  |   +---rw ts?     uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
        /te:p2p-primary-path/te:path-out-segment/te:forward
        /te:label-restrictions/te:label-restriction/te:label-end
        /te:te-label/te:technology:
+---:(otn)
  +---rw (otn-label-type)?
  +---:(tributary-port)
  |   +---rw tpn?    uint16
  +---:(tributary-slot)
  |   +---rw ts?     uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
        /te:p2p-primary-path/te:path-out-segment/te:reverse
        /te:label-restrictions/te:label-restriction:
+---rw range-type?    identityref
+---rw tsg?           identityref
+---rw priority?      uint8
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
        /te:p2p-primary-path/te:path-out-segment/te:reverse
        /te:label-restrictions/te:label-restriction/te:label-start
        /te:te-label/te:technology:
+---:(otn)
  +---rw (otn-label-type)?
  +---:(tributary-port)
  |   +---rw tpn?    uint16

```

```

    +---:(tributary-slot)
        +---rw ts?      uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
    /te:p2p-primary-path/te:path-out-segment/te:reverse
    /te:label-restrictions/te:label-restriction/te:label-end
    /te:te-label/te:technology:
+---:(otn)
    +---rw (otn-label-type)?
    +---:(tributary-port)
        | +---rw tpn?      uint16
    +---:(tributary-slot)
        +---rw ts?      uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
    /te:p2p-primary-path/te:state/te:path-properties
    /te:path-route-objects/te:path-computed-route-object
    /te:state/te:type/te:label/te:label-hop/te:te-label
    /te:technology:
+---:(otn)
    +---ro tpn?          uint16
    +---ro tsg?          identityref
    +---ro ts-list?      string
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
    /te:p2p-primary-path/te:state/te:lsps/te:lsp
    /te:lsp-record-route-subobjects/te:record-route-subobject
    /te:type/te:label/te:label-hop/te:te-label/te:technology:
+---:(otn)
    +---ro tpn?          uint16
    +---ro tsg?          identityref
    +---ro ts-list?      string
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
    /te:p2p-primary-path/te:state/te:lsps/te:lsp
    /te:path-properties/te:path-route-objects
    /te:path-computed-route-object/te:state/te:type/te:label
    /te:label-hop/te:te-label/te:technology:
+---:(otn)
    +---ro tpn?          uint16
    +---ro tsg?          identityref
    +---ro ts-list?      string
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
    /te:p2p-primary-path/te:p2p-reverse-primary-path
    /te:optimizations/te:algorithm/te:metric
    /te:optimization-metric/te:explicit-route-exclude-objects
    /te:route-object-exclude-object/te:type/te:label
    /te:label-hop/te:te-label/te:technology:
+---:(otn)
    +---rw tpn?          uint16
    +---rw tsg?          identityref
    +---rw ts-list?      string

```

```

augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
  /te:p2p-primary-path/te:p2p-reverse-primary-path
  /te:optimizations/te:algorithm/te:metric
  /te:optimization-metric/te:explicit-route-include-objects
  /te:route-object-include-object/te:type/te:label
  /te:label-hop/te:te-label/te:technology:
  +--:(otn)
    +--rw tpn?          uint16
    +--rw tsg?          identityref
    +--rw ts-list?      string
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
  /te:p2p-primary-path/te:p2p-reverse-primary-path
  /te:explicit-route-objects/te:route-object-exclude-always
  /te:type/te:label/te:label-hop/te:te-label/te:technology:
  +--:(otn)
    +--rw tpn?          uint16
    +--rw tsg?          identityref
    +--rw ts-list?      string
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
  /te:p2p-primary-path/te:p2p-reverse-primary-path
  /te:explicit-route-objects/te:route-object-include-exclude
  /te:type/te:label/te:label-hop/te:te-label/te:technology:
  +--:(otn)
    +--rw tpn?          uint16
    +--rw tsg?          identityref
    +--rw ts-list?      string
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
  /te:p2p-primary-path/te:p2p-reverse-primary-path
  /te:path-in-segment/te:forward/te:label-restrictions
  /te:label-restriction:
  +--rw range-type?    identityref
  +--rw tsg?           identityref
  +--rw priority?      uint8
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
  /te:p2p-primary-path/te:p2p-reverse-primary-path
  /te:path-in-segment/te:forward/te:label-restrictions
  /te:label-restriction/te:label-start/te:te-label
  /te:technology:
  +--:(otn)
    +--rw (otn-label-type)?
      +--:(tributary-port)
        | +--rw tpn?    uint16
      +--:(tributary-slot)
        +--rw ts?      uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
  /te:p2p-primary-path/te:p2p-reverse-primary-path
  /te:path-in-segment/te:forward/te:label-restrictions
  /te:label-restriction/te:label-end/te:te-label

```

```

        /te:technology:
    +--:(otn)
      +--rw (otn-label-type)?
        +--:(tributary-port)
          | +--rw tpn?    uint16
        +--:(tributary-slot)
          +--rw ts?    uint16
    augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
      /te:p2p-primary-path/te:p2p-reverse-primary-path
      /te:path-in-segment/te:reverse/te:label-restrictions
      /te:label-restriction:
    +--rw range-type?    identityref
    +--rw tsg?            identityref
    +--rw priority?      uint8
    augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
      /te:p2p-primary-path/te:p2p-reverse-primary-path
      /te:path-in-segment/te:reverse/te:label-restrictions
      /te:label-restriction/te:label-start/te:te-label
      /te:technology:
    +--:(otn)
      +--rw (otn-label-type)?
        +--:(tributary-port)
          | +--rw tpn?    uint16
        +--:(tributary-slot)
          +--rw ts?    uint16
    augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
      /te:p2p-primary-path/te:p2p-reverse-primary-path
      /te:path-in-segment/te:reverse/te:label-restrictions
      /te:label-restriction/te:label-end/te:te-label
      /te:technology:
    +--:(otn)
      +--rw (otn-label-type)?
        +--:(tributary-port)
          | +--rw tpn?    uint16
        +--:(tributary-slot)
          +--rw ts?    uint16
    augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
      /te:p2p-primary-path/te:p2p-reverse-primary-path
      /te:path-out-segment/te:forward/te:label-restrictions
      /te:label-restriction:
    +--rw range-type?    identityref
    +--rw tsg?            identityref
    +--rw priority?      uint8
    augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
      /te:p2p-primary-path/te:p2p-reverse-primary-path
      /te:path-out-segment/te:forward/te:label-restrictions
      /te:label-restriction/te:label-start/te:te-label
      /te:technology:

```

```

+---:(otn)
  +---rw (otn-label-type)?
    +---:(tributary-port)
      | +---rw tpn?   uint16
    +---:(tributary-slot)
      +---rw ts?     uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
/te:p2p-primary-path/te:p2p-reverse-primary-path
/te:path-out-segment/te:forward/te:label-restrictions
/te:label-restriction/te:label-end/te:te-label
/te:technology:
+---:(otn)
  +---rw (otn-label-type)?
    +---:(tributary-port)
      | +---rw tpn?   uint16
    +---:(tributary-slot)
      +---rw ts?     uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
/te:p2p-primary-path/te:p2p-reverse-primary-path
/te:path-out-segment/te:reverse/te:label-restrictions
/te:label-restriction:
+---rw range-type?   identityref
+---rw tsg?          identityref
+---rw priority?     uint8
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
/te:p2p-primary-path/te:p2p-reverse-primary-path
/te:path-out-segment/te:reverse/te:label-restrictions
/te:label-restriction/te:label-start/te:te-label
/te:technology:
+---:(otn)
  +---rw (otn-label-type)?
    +---:(tributary-port)
      | +---rw tpn?   uint16
    +---:(tributary-slot)
      +---rw ts?     uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
/te:p2p-primary-path/te:p2p-reverse-primary-path
/te:path-out-segment/te:reverse/te:label-restrictions
/te:label-restriction/te:label-end/te:te-label
/te:technology:
+---:(otn)
  +---rw (otn-label-type)?
    +---:(tributary-port)
      | +---rw tpn?   uint16
    +---:(tributary-slot)
      +---rw ts?     uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
/te:p2p-primary-path/te:p2p-reverse-primary-path

```

```

        /te:state/te:path-properties/te:path-route-objects
        /te:path-computed-route-object/te:state/te:type
        /te:label/te:label-hop/te:te-label/te:technology:
+--:(otn)
  +--ro tpn?          uint16
  +--ro tsg?          identityref
  +--ro ts-list?      string
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
  /te:p2p-primary-path/te:p2p-reverse-primary-path
  /te:state/te:lsps/te:lsp/te:lsp-record-route-subobjects
  /te:record-route-subobject/te:type/te:label/te:label-hop
  /te:te-label/te:technology:
+--:(otn)
  +--ro tpn?          uint16
  +--ro tsg?          identityref
  +--ro ts-list?      string
augment /te:te/te:tunnels/te:tunnel/te:p2p-primary-paths
  /te:p2p-primary-path/te:p2p-reverse-primary-path
  /te:state/te:lsps/te:lsp/te:path-properties
  /te:path-route-objects/te:path-computed-route-object
  /te:state/te:type/te:label/te:label-hop/te:te-label
  /te:technology:
+--:(otn)
  +--ro tpn?          uint16
  +--ro tsg?          identityref
  +--ro ts-list?      string
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:
+--:(otn)
  +--rw tpn?          uint16
  +--rw tsg?          identityref
  +--rw ts-list?      string
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:
+--:(otn)
  +--rw tpn?          uint16
  +--rw tsg?          identityref
  +--rw ts-list?      string
augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths
  /te:p2p-secondary-path/te:explicit-route-objects

```

```

        /te:route-object-exclude-always/te:type/te:label
        /te:label-hop/te:te-label/te:technology:
+---:(otn)
  +---rw tpn?          uint16
  +---rw tsg?          identityref
  +---rw ts-list?      string
augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths
        /te:p2p-secondary-path/te:explicit-route-objects
        /te:route-object-include-exclude/te:type/te:label
        /te:label-hop/te:te-label/te:technology:
+---:(otn)
  +---rw tpn?          uint16
  +---rw tsg?          identityref
  +---rw ts-list?      string
augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths
        /te:p2p-secondary-path/te:path-in-segment/te:forward
        /te:label-restrictions/te:label-restriction:
  +---rw range-type?   identityref
  +---rw tsg?          identityref
  +---rw priority?     uint8
augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths
        /te:p2p-secondary-path/te:path-in-segment/te:forward
        /te:label-restrictions/te:label-restriction/te:label-start
        /te:te-label/te:technology:
+---:(otn)
  +---rw (otn-label-type)?
  +---:(tributary-port)
  |   +---rw tpn?      uint16
  +---:(tributary-slot)
  |   +---rw ts?       uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths
        /te:p2p-secondary-path/te:path-in-segment/te:forward
        /te:label-restrictions/te:label-restriction/te:label-end
        /te:te-label/te:technology:
+---:(otn)
  +---rw (otn-label-type)?
  +---:(tributary-port)
  |   +---rw tpn?      uint16
  +---:(tributary-slot)
  |   +---rw ts?       uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths
        /te:p2p-secondary-path/te:path-in-segment/te:reverse
        /te:label-restrictions/te:label-restriction:
  +---rw range-type?   identityref
  +---rw tsg?          identityref
  +---rw priority?     uint8
augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths
        /te:p2p-secondary-path/te:path-in-segment/te:reverse

```

```

        /te:label-restrictions/te:label-restriction/te:label-start
        /te:te-label/te:technology:
+---:(otn)
  +---rw (otn-label-type)?
  +---:(tributary-port)
  |   +---rw tpn?    uint16
  +---:(tributary-slot)
  |   +---rw ts?     uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths
        /te:p2p-secondary-path/te:path-in-segment/te:reverse
        /te:label-restrictions/te:label-restriction/te:label-end
        /te:te-label/te:technology:
+---:(otn)
  +---rw (otn-label-type)?
  +---:(tributary-port)
  |   +---rw tpn?    uint16
  +---:(tributary-slot)
  |   +---rw ts?     uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths
        /te:p2p-secondary-path/te:path-out-segment/te:forward
        /te:label-restrictions/te:label-restriction:
+---rw range-type?    identityref
+---rw tsg?            identityref
+---rw priority?      uint8
augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths
        /te:p2p-secondary-path/te:path-out-segment/te:forward
        /te:label-restrictions/te:label-restriction/te:label-start
        /te:te-label/te:technology:
+---:(otn)
  +---rw (otn-label-type)?
  +---:(tributary-port)
  |   +---rw tpn?    uint16
  +---:(tributary-slot)
  |   +---rw ts?     uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths
        /te:p2p-secondary-path/te:path-out-segment/te:forward
        /te:label-restrictions/te:label-restriction/te:label-end
        /te:te-label/te:technology:
+---:(otn)
  +---rw (otn-label-type)?
  +---:(tributary-port)
  |   +---rw tpn?    uint16
  +---:(tributary-slot)
  |   +---rw ts?     uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths
        /te:p2p-secondary-path/te:path-out-segment/te:reverse
        /te:label-restrictions/te:label-restriction:
+---rw range-type?    identityref

```



```

    +--rw tsg?          identityref
    +--rw priority?     uint8
augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths
    /te:p2p-secondary-path/te:path-out-segment/te:reverse
    /te:label-restrictions/te:label-restriction/te:label-start
    /te:te-label/te:technology:
    +--:(otn)
        +--rw (otn-label-type)?
            +--:(tributary-port)
                | +--rw tpn?    uint16
            +--:(tributary-slot)
                +--rw ts?      uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths
    /te:p2p-secondary-path/te:path-out-segment/te:reverse
    /te:label-restrictions/te:label-restriction/te:label-end
    /te:te-label/te:technology:
    +--:(otn)
        +--rw (otn-label-type)?
            +--:(tributary-port)
                | +--rw tpn?    uint16
            +--:(tributary-slot)
                +--rw ts?      uint16
augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths
    /te:p2p-secondary-path/te:state/te:path-properties
    /te:path-route-objects/te:path-computed-route-object
    /te:state/te:type/te:label/te:label-hop/te:te-label
    /te:technology:
    +--:(otn)
        +--ro tpn?          uint16
        +--ro tsg?          identityref
        +--ro ts-list?      string
augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths
    /te:p2p-secondary-path/te:state/te:lsps/te:lsp
    /te:lsp-record-route-subobjects/te:record-route-subobject
    /te:type/te:label/te:label-hop/te:te-label/te:technology:
    +--:(otn)
        +--ro tpn?          uint16
        +--ro tsg?          identityref
        +--ro ts-list?      string
augment /te:te/te:tunnels/te:tunnel/te:p2p-secondary-paths
    /te:p2p-secondary-path/te:state/te:lsps/te:lsp
    /te:path-properties/te:path-route-objects
    /te:path-computed-route-object/te:state/te:type/te:label
    /te:label-hop/te:te-label/te:technology:
    +--:(otn)
        +--ro tpn?          uint16
        +--ro tsg?          identityref
        +--ro ts-list?      string

```

```

augment /te:te/te:lsps-state/te:lsp
  /te:lsp-record-route-subobjects/te:record-route-subobject
  /te:type/te:label/te:label-hop/te:te-label/te:technology:
+--:(otn)
  +--ro tpn?          uint16
  +--ro tsg?          identityref
  +--ro ts-list?      string

rpcs:
+---x otn-te-tunnel-path-compute
+---w input
+---w request* [id]
+---w id              uint8
+---w type?           identityref
+---w source?         inet:ip-address
+---w destination?    inet:ip-address
+---w src-tp-id?      binary
+---w dst-tp-id?      binary
+---w switching-layer? identityref
+---w encoding?       identityref
+---w protection-type? identityref
+---w restoration-type? identityref
+---w provider-id?    te-types:te-global-id
+---w client-id?      te-types:te-global-id
+---w te-topology-id? te-types:te-topology-id
+---w setup-priority? uint8
+---w hold-priority?  uint8
+---w te-path-metric-type? identityref
+---w odu-type?       identityref
+---w p2p-primary-paths
+---w p2p-primary-path* [name]
+---w name              string
+---w te-default-metric? uint32
+---w te-delay-metric?  uint32
+---w te-hop-metric?    uint32
+---w explicit-route-objects
+---w explicit-route-object* [index]
+---w explicit-route-usage? identityref
+---w index              uint32
+---w (type)?
+---:(num-unnum-hop)
+---w num-unnum-hop
+---w node-id?          te-types:te-node-id
+---w link-tp-id?       te-types:te-tp-id
+---w hop-type?         te-hop-type
+---w direction?       te-link-direction
+---:(as-number)
+---w as-number-hop

```

```

|
|
|
|      +---w as-number?    binary
|      +---w hop-type?     te-hop-type
+---:(label)
|      +---w label-hop
|      +---w te-label
|      +---w (technology)?
|      |      +---:(generic)
|      |      |      +---w generic?    rt-types:generalized
- label
|
|
|      +---:(otn)
|      |      +---w tpn?            uint16
|      |      +---w tsg?            identityref
|      |      +---w ts-list?        string
|      |      +---w direction?      te-label-direction
+---w p2p-secondary-paths
|      +---w p2p-secondary-path* [name]
|      |      +---w name                string
|      |      +---w te-default-metric?  uint32
|      |      +---w te-delay-metric?    uint32
|      |      +---w te-hop-metric?      uint32
|      |      +---w explicit-route-objects
|      |      |      +---w explicit-route-object* [index]
|      |      |      |      +---w explicit-route-usage?  identityref
|      |      |      |      +---w index                uint32
|      |      |      |      +---w (type)?
|      |      |      |      |      +---:(num-unnum-hop)
|      |      |      |      |      |      +---w num-unnum-hop
|      |      |      |      |      |      |      +---w node-id?      te-types:te-node-id
|      |      |      |      |      |      |      +---w link-tp-id?    te-types:te-tp-id
|      |      |      |      |      |      |      +---w hop-type?      te-hop-type
|      |      |      |      |      |      |      +---w direction?    te-link-direction
|      |      |      |      |      +---:(as-number)
|      |      |      |      |      |      +---w as-number-hop
|      |      |      |      |      |      |      +---w as-number?    binary
|      |      |      |      |      |      |      +---w hop-type?      te-hop-type
|      |      |      |      |      +---:(label)
|      |      |      |      |      |      +---w label-hop
|      |      |      |      |      |      +---w te-label
|      |      |      |      |      |      |      +---w (technology)?
|      |      |      |      |      |      |      |      +---:(generic)
|      |      |      |      |      |      |      |      |      +---w generic?    rt-types:generalized
- label
|
|
|      +---:(otn)
|      |      +---w tpn?            uint16
|      |      +---w tsg?            identityref
|      |      +---w ts-list?        string
|      |      +---w direction?      te-label-direction
+---w src-client-signal?  identityref
+---w src-tributary-slots
|      +---w values*      uint8

```

```

|         +---w dst-client-signal?      identityref
|         +---w dst-tributary-slots
|             +---w values*      uint8
+--ro output
+--ro return-code?      enumeration
+--ro result* [id]
+--ro id                  uint8
+--ro p2p-primary-paths
|   +--ro p2p-primary-path* [name]
|       +--ro name                  string
|       +--ro te-default-metric?    uint32
|       +--ro te-delay-metric?      uint32
|       +--ro te-hop-metric?        uint32
|       +--ro explicit-route-objects
|           +--ro explicit-route-object* [index]
|               +--ro explicit-route-usage? identityref
|               +--ro index          uint32
|               +--ro (type)?
|                   +--:(num-unnum-hop)
|                       +--ro num-unnum-hop
|                           +--ro node-id?      te-types:te-node-id
|                           +--ro link-tp-id?    te-types:te-tp-id
|                           +--ro hop-type?      te-hop-type
|                           +--ro direction?    te-link-direction
|                   +--:(as-number)
|                       +--ro as-number-hop
|                           +--ro as-number?    binary
|                           +--ro hop-type?      te-hop-type
|                   +--:(label)
|                       +--ro label-hop
|                           +--ro te-label
|                               +--ro (technology)?
|                                   +--:(generic)
|                                       +--ro generic?    rt-types:generalized
-label
|
|       +--:(otn)
|           +--ro tpn?          uint16
|           +--ro tsg?          identityref
|           +--ro ts-list?      string
|           +--ro direction?    te-label-direction
+--ro p2p-secondary-paths
+--ro p2p-secondary-path* [name]
+--ro name                  string
+--ro te-default-metric?    uint32
+--ro te-delay-metric?      uint32
+--ro te-hop-metric?        uint32
+--ro explicit-route-objects
+--ro explicit-route-object* [index]
+--ro explicit-route-usage? identityref

```

```

      +--ro index                               uint32
      +--ro (type)?
        +--:(num-unnum-hop)
          | +--ro num-unnum-hop
          |   +--ro node-id?      te-types:te-node-id
          |   +--ro link-tp-id?   te-types:te-tp-id
          |   +--ro hop-type?     te-hop-type
          |   +--ro direction?    te-link-direction
          +--:(as-number)
            | +--ro as-number-hop
            |   +--ro as-number?  binary
            |   +--ro hop-type?   te-hop-type
          +--:(label)
            +--ro label-hop
              +--ro te-label
                +--ro (technology)?
                  | +--:(generic)
                  | | +--ro generic?  rt-types:generalized
                |
                | +--:(otn)
                | | +--ro tpn?        uint16
                | | +--ro tsg?        identityref
                | | +--ro ts-list?    string
                +--ro direction?      te-label-direction
-label

```

5. OTN Tunnel YANG Code

```

<CODE BEGINS>file "ietf-otn-tunnel@2018-06-30.yang"
module ietf-otn-tunnel {
  yang-version 1.1;

  namespace "urn:ietf:params:xml:ns:yang:ietf-otn-tunnel";
  prefix "otn-tunnel";

  import ietf-te {
    prefix "te";
  }

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

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

```

```
import ietf-inet-types {
  prefix "inet";
}

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

  Editor: Haomian Zheng
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  Editor: Yunbo Li
        <mailto:liyunbo@chinamobile.com>

  Editor: Yunbin Xu
        <mailto:xuyunbin@ritt.cn>";

description
  "This module defines a model for OTN Tunnel Services.";

revision "2018-07-02" {
  description
    "Revision 0.6";
  reference
    "draft-ietf-ccamp-otn-tunnel-model-03";
}

/*
```

```
* Groupings
*/

grouping otn-tunnel-attributes {
  description "Parameters for OTN tunnel";

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

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

/*
* Data nodes
*/

augment "/te:te/te:tunnels/te:tunnel" {
  description
    "Augment with additional parameters required for OTN service";
  uses otn-tunnel-attributes;
}

/*
* Augment TE bandwidth
*/

/* Augment bandwidth of named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
+ "te:named-path-constraint/"
+ "te:te-bandwidth/te:technology" {
  description "OTN bandwidth.";
  case otn {
    uses otn-types:otn-path-bandwidth;
  }
}
```

```
/* Augment bandwidth of tunnel */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:te-bandwidth/te:technology" {
    description "OTN bandwidth.";
    case otn {
      uses otn-types:otn-path-bandwidth;
    }
  }

/* Augment bandwidth of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:te-bandwidth/te:technology" {
    description "OTN bandwidth.";
    case otn {
      uses otn-types:otn-path-bandwidth;
    }
  }

/* Augment bandwidth of reverse primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:p2p-reverse-primary-path/"
  + "te:te-bandwidth/te:technology" {
    description "OTN bandwidth.";
    case otn {
      uses otn-types:otn-path-bandwidth;
    }
  }

/* Augment bandwidth of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-secondary-paths/te:p2p-secondary-path/"
  + "te:te-bandwidth/te:technology" {
    description "OTN bandwidth.";
    case otn {
      uses otn-types:otn-path-bandwidth;
    }
  }

/*
 * Augment TE label.
 */

/* Augment label hop of route-object-exclude-always of named-path-constraints
 */
augment "/te:te/te:globals/te:named-path-constraints/"
  + "te:named-path-constraint/te:explicit-route-objects/"
  + "te:route-object-exclude-always/te:type/te:label/"
```



```
        + "te:label-hop/te:te-label/te:technology" {
    description "OTN label.";
    case otn {
        uses otn-types:otn-path-label;
    }
}

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

/* Augment label restrictions for the forwarding direction of path-in-segment
of named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/te:path-in-segment/"
    + "te:forward/te:label-restrictions/"
    + "te:label-restriction" {
    description "OTN label.";
    uses otn-types:otn-label-restriction;
}

/* Augment label restrictions start for the forwarding direction of path-in-segment
of named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/te:path-in-segment/"
    + "te:forward/te:label-restrictions/"
    + "te:label-restriction/te:label-start/"
    + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
        uses otn-types:otn-link-label;
    }
}

/* Augment label restrictions end for the forwarding direction of path-in-segment
of named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/te:path-in-segment/"
    + "te:forward/te:label-restrictions/"
    + "te:label-restriction/te:label-end/"
    + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
        uses otn-types:otn-link-label;
    }
}
```

```

    }
  }

  /* Augment label restrictions for the reverse direction of path-in-segment of
  named-path-constraints */
  augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/te:path-in-segment/"
    + "te:reverse/te:label-restrictions/"
    + "te:label-restriction" {
    description "OTN label.";
    uses otn-types:otn-label-restriction;
  }

  /* Augment label restrictions start for the reverse direction of path-in-segment
  of named-path-constraints */
  augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/te:path-in-segment/"
    + "te:reverse/te:label-restrictions/"
    + "te:label-restriction/te:label-start/"
    + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
      uses otn-types:otn-link-label;
    }
  }

  /* Augment label restrictions end for the reverse direction of path-in-segment
  of named-path-constraints */
  augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/te:path-in-segment/"
    + "te:reverse/te:label-restrictions/"
    + "te:label-restriction/te:label-end/"
    + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
      uses otn-types:otn-link-label;
    }
  }

  /* Augment label restrictions for the forwarding direction of path-out-segment
  of named-path-constraints */
  augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/te:path-out-segment/"
    + "te:forward/te:label-restrictions/"
    + "te:label-restriction" {
    description "OTN label.";
    uses otn-types:otn-label-restriction;
  }

  /* Augment label restrictions start for the forwarding direction of path-out-segment
  of named-path-constraints */
  augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/te:path-out-segment/"
    + "te:forward/te:label-restrictions/"

```

```
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
        uses otn-types:otn-link-label;
    }
}

/* Augment label restrictions end for the forwarding direction of path-out-seg
ment of named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/te:path-out-segment/"
    + "te:forward/te:label-restrictions/"
    + "te:label-restriction/te:label-end/"
    + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
        uses otn-types:otn-link-label;
    }
}

/* Augment label restrictions for the reverse direction of path-out-segment of
named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/te:path-out-segment/"
    + "te:reverse/te:label-restrictions/"
    + "te:label-restriction" {
    description "OTN label.";
    uses otn-types:otn-label-restriction;
}

/* Augment label restrictions start for the reverse direction of path-out-segm
ent of named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/te:path-out-segment/"
    + "te:reverse/te:label-restrictions/"
    + "te:label-restriction/te:label-start/"
    + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
        uses otn-types:otn-link-label;
    }
}

/* Augment label restrictions end for the reverse direction of path-out-segmen
t of named-path-constraints */
augment "/te:te/te:globals/te:named-path-constraints/"
    + "te:named-path-constraint/te:path-out-segment/"
    + "te:reverse/te:label-restrictions/"
    + "te:label-restriction/te:label-end/"
    + "te:te-label/te:technology" {
    description "OTN label.";
```

```
    case otn {
      uses otn-types:otn-link-label;
    }
  }

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

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

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

/* Augment label hop of route-object-include-exclude of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:explicit-route-objects/"
  + "te:route-object-include-exclude/te:type/te:label/"
```

```

        + "te:label-hop/te:te-label/te:technology" {
    description "OTN label.";
    case otn {
        uses otn-types:otn-path-label;
    }
}

/* Augment label restrictions for the forwarding direction of path-in-segment
of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:path-in-segment/te:forward/te:label-restrictions/"
    + "te:label-restriction" {
    description "OTN label.";
    uses otn-types:otn-label-restriction;
}

/* Augment label restrictions start for the forwarding direction of path-in-segment
of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:path-in-segment/te:forward/te:label-restrictions/"
    + "te:label-restriction/te:label-start/"
    + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
        uses otn-types:otn-link-label;
    }
}

/* Augment label restrictions end for the forwarding direction of path-in-segment
of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:path-in-segment/te:forward/te:label-restrictions/"
    + "te:label-restriction/te:label-end/"
    + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
        uses otn-types:otn-link-label;
    }
}

/* Augment label restrictions for the reverse direction of path-in-segment of
primary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:path-in-segment/te:reverse/te:label-restrictions/"
    + "te:label-restriction" {
    description "OTN label.";
    uses otn-types:otn-label-restriction;
}

```

```
/* Augment label restrictions start for the reverse direction of path-in-segment of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:path-in-segment/te:reverse/te:label-restrictions/"
  + "te:label-restriction/te:label-start/"
  + "te:te-label/te:technology" {
  description "OTN label.";
  case otn {
    uses otn-types:otn-link-label;
  }
}

/* Augment label restrictions end for the reverse direction of path-in-segment of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:path-in-segment/te:reverse/te:label-restrictions/"
  + "te:label-restriction/te:label-end/"
  + "te:te-label/te:technology" {
  description "OTN label.";
  case otn {
    uses otn-types:otn-link-label;
  }
}

/* Augment label restrictions for the forwarding direction of path-out-segment of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:path-out-segment/te:forward/te:label-restrictions/"
  + "te:label-restriction" {
  description "OTN label.";
  uses otn-types:otn-label-restriction;
}

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

/* Augment label restrictions end for the forwarding direction of path-out-segment of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
```

```

    + "te:path-out-segment/te:forward/te:label-restrictions/"
    + "te:label-restriction/te:label-end/"
    + "te:te-label/te:technology" {
description "OTN label.";
case otn {
    uses otn-types:otn-link-label;
}
}

/* Augment label restrictions for the reverse direction of path-out-segment of
primary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:path-out-segment/te:reverse/te:label-restrictions/"
    + "te:label-restriction" {
description "OTN label.";
uses otn-types:otn-label-restriction;
}

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

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

/* Augment label hop of path-route of primary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:state/te:path-properties/"
    + "te:path-route-objects/te:path-computed-route-object/"
    + "te:state/te:type/te:label/"

```

```
    + "te:label-hop/te:te-label/te:technology" {
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

/* Augment label hop of record-route of primary LSP */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:state/te:lsps/te:lsp/te:lsp-record-route-subobjects/"
    + "te:record-route-subobject/te:type/te:label/"
    + "te:label-hop/te:te-label/te:technology" {
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

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

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

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



```
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:p2p-reverse-primary-path/"
    + "te:optimizations/te:algorithm/te:metric/"
    + "te:optimization-metric/te:explicit-route-include-objects/"
    + "te:route-object-include-object/te:type/te:label/"
    + "te:label-hop/te:te-label/te:technology" {
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

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

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

/* Augment label restrictions for the forwarding direction of path-in-segment
of reverse primary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:p2p-reverse-primary-path/"
    + "te:path-in-segment/te:forward/te:label-restrictions/"
    + "te:label-restriction" {
description "OTN label.";
uses otn-types:otn-label-restriction;
}
```

```

    }

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

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

    /* Augment label restrictions for the reverse direction of path-in-segment of reverse primary path */
    augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-primary-paths/te:p2p-primary-path/"
        + "te:p2p-reverse-primary-path/"
        + "te:path-in-segment/te:reverse/te:label-restrictions/"
        + "te:label-restriction" {
        description "OTN label.";
        uses otn-types:otn-label-restriction;
    }

    /* Augment label restrictions start for the reverse direction of path-in-segment of reverse primary path */
    augment "/te:te/te:tunnels/te:tunnel/"
        + "te:p2p-primary-paths/te:p2p-primary-path/"
        + "te:p2p-reverse-primary-path/"
        + "te:path-in-segment/te:reverse/te:label-restrictions/"
        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
        description "OTN label.";
        case otn {
            uses otn-types:otn-link-label;
        }
    }

```

```

    }
  }

  /* Augment label restrictions end for the reverse direction of path-in-segment
  of reverse primary path */
  augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:p2p-reverse-primary-path/"
    + "te:path-in-segment/te:reverse/te:label-restrictions/"
    + "te:label-restriction/te:label-end/"
    + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
      uses otn-types:otn-link-label;
    }
  }

  /* Augment label restrictions for the forwarding direction of path-out-segment
  of reverse primary path */
  augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:p2p-reverse-primary-path/"
    + "te:path-out-segment/te:forward/te:label-restrictions/"
    + "te:label-restriction" {
    description "OTN label.";
    uses otn-types:otn-label-restriction;
  }

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

  /* Augment label restrictions end for the forwarding direction of path-out-segment
  of reverse primary path */
  augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:p2p-reverse-primary-path/"
    + "te:path-out-segment/te:forward/te:label-restrictions/"
    + "te:label-restriction/te:label-end/"
    + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {

```

```

    uses otn-types:otn-link-label;
  }
}

/* Augment label restrictions for the reverse direction of path-out-segment of
reverse primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:p2p-reverse-primary-path/"
  + "te:path-out-segment/te:reverse/te:label-restrictions/"
  + "te:label-restriction" {
  description "OTN label.";
  uses otn-types:otn-label-restriction;
}

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

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

/* Augment label hop of path-route of reverse primary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-primary-paths/te:p2p-primary-path/"
  + "te:p2p-reverse-primary-path/"
  + "te:state/te:path-properties/"
  + "te:path-route-objects/te:path-computed-route-object/"
  + "te:state/te:type/te:label/"
  + "te:label-hop/te:te-label/te:technology" {

```

```
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

/* Augment label hop of record-route of reverse primary LSP */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-primary-paths/te:p2p-primary-path/"
    + "te:p2p-reverse-primary-path/"
    + "te:state/te:lsps/te:lsp/te:lsp-record-route-subobjects/"
    + "te:record-route-subobject/te:type/te:label/"
    + "te:label-hop/te:te-label/te:technology" {
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

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

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

/* Augment label hop of route-include of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
```

```

    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:optimizations/te:algorithm/te:metric/"
    + "te:optimization-metric/te:explicit-route-include-objects/"
    + "te:route-object-include-object/te:type/te:label/"
    + "te:label-hop/te:te-label/te:technology" {
description "OTN label.";
case otn {
    uses otn-types:otn-path-label;
}
}

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

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

/* Augment label restrictions for the forwarding direction of path-in-segment
of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:path-in-segment/te:forward/te:label-restrictions/"
    + "te:label-restriction" {
description "OTN label.";
uses otn-types:otn-label-restriction;
}

/* Augment label restrictions start for the forwarding direction of path-in-segment
of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:path-in-segment/te:forward/te:label-restrictions/"

```

```

        + "te:label-restriction/te:label-start/"
        + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
        uses otn-types:otn-link-label;
    }
}

/* Augment label restrictions end for the forwarding direction of path-in-segm
ent of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:path-in-segment/te:forward/te:label-restrictions/"
    + "te:label-restriction/te:label-end/"
    + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
        uses otn-types:otn-link-label;
    }
}

/* Augment label restrictions for the reverse direction of path-in-segment of
secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:path-in-segment/te:reverse/te:label-restrictions/"
    + "te:label-restriction" {
    description "OTN label.";
    uses otn-types:otn-label-restriction;
}

/* Augment label restrictions start for the reverse direction of path-in-segme
nt of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:path-in-segment/te:reverse/te:label-restrictions/"
    + "te:label-restriction/te:label-start/"
    + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
        uses otn-types:otn-link-label;
    }
}

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

```

```
    case otn {
      uses otn-types:otn-link-label;
    }
  }

  /* Augment label restrictions for the forwarding direction of path-out-segment
  of secondary path */
  augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:path-out-segment/te:forward/te:label-restrictions/"
    + "te:label-restriction" {
    description "OTN label.";
    uses otn-types:otn-label-restriction;
  }

  /* Augment label restrictions start for the forwarding direction of path-out-s
  egment of secondary path */
  augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:path-out-segment/te:forward/te:label-restrictions/"
    + "te:label-restriction/te:label-start/"
    + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
      uses otn-types:otn-link-label;
    }
  }

  /* Augment label restrictions end for the forwarding direction of path-out-seg
  ment of secondary path */
  augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:path-out-segment/te:forward/te:label-restrictions/"
    + "te:label-restriction/te:label-end/"
    + "te:te-label/te:technology" {
    description "OTN label.";
    case otn {
      uses otn-types:otn-link-label;
    }
  }

  /* Augment label restrictions for the reverse direction of path-out-segment of
  secondary path */
  augment "/te:te/te:tunnels/te:tunnel/"
    + "te:p2p-secondary-paths/te:p2p-secondary-path/"
    + "te:path-out-segment/te:reverse/te:label-restrictions/"
    + "te:label-restriction" {
    description "OTN label.";
    uses otn-types:otn-label-restriction;
  }

  /* Augment label restrictions start for the reverse direction of path-out-segm
  ent of secondary path */
```



```
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-secondary-paths/te:p2p-secondary-path/"
  + "te:path-out-segment/te:reverse/te:label-restrictions/"
  + "te:label-restriction/te:label-start/"
  + "te:te-label/te:technology" {
  description "OTN label.";
  case otn {
    uses otn-types:otn-link-label;
  }
}

/* Augment label restrictions end for the reverse direction of path-out-segment
of secondary path */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-secondary-paths/te:p2p-secondary-path/"
  + "te:path-out-segment/te:reverse/te:label-restrictions/"
  + "te:label-restriction/te:label-end/"
  + "te:te-label/te:technology" {
  description "OTN label.";
  case otn {
    uses otn-types:otn-link-label;
  }
}

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

/* Augment label hop of record-route of secondary LSP */
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-secondary-paths/te:p2p-secondary-path/"
  + "te:state/te:lsps/te:lsp/te:lsp-record-route-subobjects/"
  + "te:record-route-subobject/te:type/te:label/"
  + "te:label-hop/te:te-label/te:technology" {
  description "OTN label.";
  case otn {
    uses otn-types:otn-path-label;
  }
}

/* Augment label hop of path-route of secondary LSP */
```

```
augment "/te:te/te:tunnels/te:tunnel/"
  + "te:p2p-secondary-paths/te:p2p-secondary-path/"
  + "te:state/te:lsps/te:lsp/te:path-properties/"
  + "te:path-route-objects/"
  + "te:path-computed-route-object/te:state/te:type/te:label/"
  + "te:label-hop/te:te-label/te:technology" {
  description "OTN label.";
  case otn {
    uses otn-types:otn-path-label;
  }
}

/* Augment label hop of record-route of LSP */
augment "/te:te/te:lsps-state/"
  + "te:lsp/te:lsp-record-route-subobjects/"
  + "te:record-route-subobject/te:type/te:label/"
  + "te:label-hop/te:te-label/te:technology" {
  description "OTN label.";
  case otn {
    uses otn-types:otn-path-label;
  }
}

grouping p2p-path-ero {
  description
    "TE tunnel ERO configuration grouping";

  leaf te-default-metric {
    type uint32;
    description
      "Traffic engineering metric.";
  }
  leaf te-delay-metric {
    type uint32;
    description
      "Traffic engineering delay metric.";
  }
  leaf te-hop-metric {
    type uint32;
    description
      "Traffic engineering hop metric.";
  }
  container explicit-route-objects {
    description "Explicit route objects container";
    list explicit-route-object {
      key "index";
      description
        "List of explicit route objects";
    }
  }
}
```

```
    leaf explicit-route-usage {
      type identityref {
        base te-types:route-usage-type;
      }
      description "An explicit-route hop action.";
    }
    uses te-types:explicit-route-hop {
      augment "type/label/label-hop/te-label/technology" {
        description "OTN label.";
        case otn {
          uses otn-types:otn-path-label;
        }
      }
    }
  }
}

rpc otn-te-tunnel-path-compute {
  description "OTN TE tunnel path computation";
  input {
    list request {
      key "id";
      description "A list of path computation requests.";

      leaf id {
        type uint8;
        description
          "Request ID.";
      }
      leaf type {
        type identityref {
          base te-types:tunnel-type;
        }
        description "TE tunnel type.";
      }
      leaf source {
        type inet:ip-address;
        description
          "TE tunnel source address.";
      }
      leaf destination {
        type inet:ip-address;
        description
          "TE tunnel destination address";
      }
      leaf src-tp-id {
        type binary;
      }
    }
  }
}
```

```
    description
      "TE tunnel source termination point identifier.";
  }
  leaf dst-tp-id {
    type binary;
    description
      "TE tunnel destination termination point identifier.";
  }
  leaf switching-layer {
    type identityref {
      base te-types:switching-capabilities;
    }
    description
      "Switching layer where the requests are computed.";
  }
  leaf encoding {
    type identityref {
      base te-types:lsp-encoding-types;
    }
    description "LSP encoding type";
  }
  leaf protection-type {
    type identityref {
      base te-types:lsp-protection-type;
    }
    description "LSP protection type";
  }
  leaf restoration-type {
    type identityref {
      base te-types:lsp-restoration-type;
    }
    description "LSP restoration type";
  }
  leaf provider-id {
    type te-types:te-global-id;
    description
      "An identifier to uniquely identify a provider.";
  }
  leaf client-id {
    type te-types:te-global-id;
    description
      "An identifier to uniquely identify a client.";
  }
  leaf te-topology-id {
    type te-types:te-topology-id;
    description
      "It is presumed that a datastore will contain many
      topologies. To distinguish between topologies it is
```

```
        vital to have UNIQUE topology identifiers.";
    }
    leaf setup-priority {
        type uint8 {
            range "0..7";
        }
        description
            "TE LSP setup priority";
    }
    leaf hold-priority {
        type uint8 {
            range "0..7";
        }
        description
            "TE LSP hold priority";
    }
    leaf te-path-metric-type {
        type identityref {
            base te-types:path-metric-type;
        }
        default te-types:path-metric-te;
        description
            "The tunnel path metric type.";
    }
}

leaf odu-type {
    type identityref{
        base otn-types:tributary-protocol-type;
    }
    description "Type of ODU";
}

container p2p-primary-paths {
    description "Set of P2P primary paths container";
    list p2p-primary-path {
        key "name";
        description
            "List of primary paths for this tunnel.";
        leaf name {
            type string;
            description "TE path name";
        }
        uses p2p-path-ero;
    }
}

container p2p-secondary-paths {
    description "Set of P2P secondary paths container";
    list p2p-secondary-path {
        key "name";
    }
}
```

```
        description
            "List of secondary paths for this tunnel.";
        leaf name {
            type string;
            description "TE path name";
        }
        uses p2p-path-ero;
    }
    uses otn-tunnel-attributes;
}
}
output {
    leaf return-code {
        type enumeration {
            enum success {
                description "success";
            }
            enum aborted {
                description "aborted";
            }
            enum destination-not-found {
                description "destination-not-found";
            }
            enum invalid-argument {
                description "invalid-argument";
            }
            enum no-memory {
                description "no-memory";
            }
            enum no-path-found {
                description "no-path-found";
            }
            enum other-error {
                description "other-error";
            }
            enum some-path-not-found {
                description "some-path-not-found";
            }
            enum source-not-found {
                description "source-not-found";
            }
            enum topology-error {
                description "topology-error";
            }
        }
    }
    description
        "Return code";
}
```

```
    }
    list result {
      key "id";
      description
        "A list of results for all requests.";

      leaf id {
        type uint8;
        description
          "Request ID";
      }
      container p2p-primary-paths {
        description "Set of P2P primary paths container";
        list p2p-primary-path {
          key "name";
          description
            "List of resultant primary paths for this tunnel.";
          leaf name {
            type string;
            description "TE path name";
          }
          uses p2p-path-ero;
        }
      }
      container p2p-secondary-paths {
        description "Set of P2P secondary paths container";
        list p2p-secondary-path {
          key "name";
          description
            "List of resultant secondary paths for this tunnel.";
          leaf name {
            type string;
            description "TE path name";
          }
          uses p2p-path-ero;
        }
      }
    }
  }
}
```

<CODE ENDS>

6. OTN Types YANG Code

```
<CODE BEGINS> file "ietf-otn-types@2018-06-30.yang"

module ietf-otn-types {
  namespace "urn:ietf:params:xml:ns:yang:ietf-otn-types";
  prefix "otn-types";

  organization
    "IETF CCAMP Working Group";
  contact
    "WG Web: <http://tools.ietf.org/wg/ccamp/>
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  description
    "This module defines OTN types.";

  revision "2018-06-30" {
    description
      "Revision 0.6";
```



```
    reference
      "draft-ietf-ccamp-otn-tunnel-model-03";
  }

  identity tributary-slot-granularity {
    description
      "Tributary slot granularity";
    reference
      "G.709/Y.1331, February 2016: Interfaces for the Optical
      Transport Network (OTN)";
  }

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

  identity tsg-2.5G {
    base tributary-slot-granularity;
    description
      "2.5G tributary slot granularity";
  }
/*
  identity tsg-1.25Gand2.5G {
    base tributary-slot-granularity;
    description
      "Both 1.25G and 2.5G tributary slot granularity";
  }
*/
/*
Note: suggest to replace the term 'tributary-protocol-type' with
'odu-type', to avoid misleading.
*/
  identity tributary-protocol-type {
    description
      "Base identity for protocol framing used by tributary signals";
  }

/*
Note: suggest to remove all the prot-OTUx
*/

  identity prot-OTU1 {
    base tributary-protocol-type;
    description
      "OTU1 protocol (2.66G)";
  }
```

```
/*
  identity prot-OTU1e {
    base tributary-protocol-type;
    description
      "OTU1e type (11.04G)";
  }

  identity prot-OTU1f {
    base tributary-protocol-type;
    description
      "OTU1f type (11.27G)";
  }
*/
identity prot-OTU2 {
  base tributary-protocol-type;
  description
    "OTU2 type (10.70G)";
}

identity prot-OTU2e {
  base tributary-protocol-type;
  description
    "OTU2e type (11.09G)";
}
/*
  identity prot-OTU2f {
    base tributary-protocol-type;
    description
      "OTU2f type (11.31G)";
  }
*/
identity prot-OTU3 {
  base tributary-protocol-type;
  description
    "OTU3 type (43.01G)";
}
/*
  identity prot-OTU3e1 {
    base tributary-protocol-type;
    description
      "OTU3e1 type (44.57G)";
  }

  identity prot-OTU3e2 {
    base tributary-protocol-type;
    description
      "OTU3e2 type (44.58G)";
  }
}
```

```
*/
identity prot-OTU4 {
  base tributary-protocol-type;
  description
    "OTU4 type (111.80G)";
}

identity prot-OTUCn {
  base tributary-protocol-type;
  description
    "OTUCn type (beyond 100G)";
}

/*
Note: suggest to rename the term, remove the prefix 'prot-'.
*/

identity prot-ODU0 {
  base tributary-protocol-type;
  description
    "ODU0 protocol (1.24G)";
}

identity prot-ODU1 {
  base tributary-protocol-type;
  description
    "ODU1 protocol (2.49G)";
}

/*
identity prot-ODU1e {
  base tributary-protocol-type;
  description
    "ODU1e protocol (10.35G).";
}

identity prot-ODU1f {
  base tributary-protocol-type;
  description
    "ODU1f protocol (10.56G).";
}

*/
identity prot-ODU2 {
  base tributary-protocol-type;
  description
    "ODU2 protocol (10.03G)";
}

identity prot-ODU2e {
```

```
    base tributary-protocol-type;
    description
        "ODU2e protocol (10.39G)";
}
/*
identity prot-ODU2f {
    base tributary-protocol-type;
    description
        "ODU2f protocol (10.60G).";
}
*/
identity prot-ODU3 {
    base tributary-protocol-type;
    description
        "ODU3 protocol (40.31G)";
}
/*
identity prot-ODU3e1 {
    base tributary-protocol-type;
    description
        "ODU3e1 protocol (41.77G).";
}

identity prot-ODU3e2 {
    base tributary-protocol-type;
    description
        "ODU3e2 protocol (41.78G).";
}
*/
identity prot-ODU4 {
    base tributary-protocol-type;
    description
        "ODU4 protocol (104.79G)";
}

identity prot-ODUFlex-cbr {
    base tributary-protocol-type;
    description
        "ODU Flex CBR protocol for transporting constant bit rate
        signal";
}

identity prot-ODUFlex-gfp {
    base tributary-protocol-type;
    description
        "ODU Flex GFP protocol for transporting stream of packets
        using Generic Framing Procedure";
}
```

```
identity prot-ODUCn {
  base tributary-protocol-type;
  description
    "ODUCn protocol (beyond 100G)";
}

/*
Note: suggest to remove the types with 'prot-xGbE'.
*/

identity prot-1GbE {
  base tributary-protocol-type;
  description
    "1G Ethernet protocol";
}
identity prot-10GbE-LAN {
  base tributary-protocol-type;
  description
    "10G Ethernet LAN protocol";
}

identity prot-40GbE {
  base tributary-protocol-type;
  description
    "40G Ethernet protocol";
}

identity prot-100GbE {
  base tributary-protocol-type;
  description
    "100G Ethernet protocol";
}

identity client-signal {
  description
    "Base identity from which specific client signals for the
    tunnel are derived";
}

/*
Note: need to reconsider the prefix 'client-signal'.
Comment 1: need to understand whether for same client-signal, there
should be separate identity for transparent and non-transparent or not?
Comment 2: need to better align the term with other models, like L1CSM.
*/

identity client-signal-1GbE {
  base client-signal;
```

```
    description
      "Client signal type of 1GbE";
  }

  identity client-signal-10GbE-LAN {
    base client-signal;
    description
      "Client signal type of 10GbE LAN";
  }

  identity client-signal-10GbE-WAN {
    base client-signal;
    description
      "Client signal type of 10GbE WAN";
  }

  identity client-signal-40GbE {
    base client-signal;
    description
      "Client signal type of 40GbE";
  }

  identity client-signal-100GbE {
    base client-signal;
    description
      "Client signal type of 100GbE";
  }

  identity client-signal-OC3_STM1 {
    base client-signal;
    description
      "Client signal type of OC3 & STM1";
  }

  identity client-signal-OC12_STM4 {
    base client-signal;
    description
      "Client signal type of OC12 & STM4";
  }

  identity client-signal-OC48_STM16 {
    base client-signal;
    description
      "Client signal type of OC48 & STM16";
  }

  identity client-signal-OC192_STM64 {
    base client-signal;
```

```
    description
      "Client signal type of OC192 & STM64";
  }

  identity client-signal-OC768_STM256 {
    base client-signal;
    description
      "Client signal type of OC768 & STM256";
  }

  identity client-signal-ODU0 {
    base client-signal;
    description
      "Client signal type of ODU0 (1.24G)";
  }

  identity client-signal-ODU1 {
    base client-signal;
    description
      "ODU1 protocol (2.49G)";
  }

  identity client-signal-ODU2 {
    base client-signal;
    description
      "Client signal type of ODU2 (10.03G)";
  }

  identity client-signal-ODU2e {
    base client-signal;
    description
      "Client signal type of ODU2e (10.39G)";
  }

  identity client-signal-ODU3 {
    base client-signal;
    description
      "Client signal type of ODU3 (40.31G)";
  }
/*
  identity client-signal-ODU3e2 {
    base client-signal;
    description
      "Client signal type of ODU3e2 (41.78G)";
  }
*/
  identity client-signal-ODU4 {
    base client-signal;
```

```
    description
      "Client signal type of ODU4 (104.79G)";
  }

  identity client-signal-ODUflex-cbr {
    base client-signal;
    description
      "Client signal type of ODU Flex CBR";
  }

  identity client-signal-ODUflex-gfp {
    base client-signal;
    description
      "Client signal type of ODU Flex GFP";
  }

  identity client-signal-ODUCn {
    base client-signal;
    description
      "Client signal type of ODUCn (beyond 100G)";
  }

  identity client-signal-FC400 {
    base client-signal;
    description
      "Client signal type of Fibre Channel FC400";
  }

  identity client-signal-FC800 {
    base client-signal;
    description
      "Client signal type of Fibre Channel FC800";
  }

  identity client-signal-FICON-4G {
    base client-signal;
    description
      "Client signal type of Fibre Connection 4G";
  }

  identity client-signal-FICON-8G {
    base client-signal;
    description
      "Client signal type of Fibre Connection 8G";
  }

  identity client-signal-OTU1 {
    base client-signal;
```



```
    description
      "Client signal type of OTU1";
  }

  identity client-signal-OTU2 {
    base client-signal;
    description
      "Client signal type of OTU2";
  }

  identity client-signal-OTU2e {
    base client-signal;
    description
      "Client signal type of OTU2e";
  }

  identity client-signal-OTU3 {
    base client-signal;
    description
      "Client signal type of OTU3";
  }

  identity client-signal-OTU4 {
    base client-signal;
    description
      "Client signal type of OTU4";
  }

  identity otn-label-range-type {
    description
      "Base identity from which specific OTN label
        range types derived";
  }

  identity label-range-trib-slot {
    base otn-label-range-type;
    description
      "Defines a range of OTN tributary slots";
  }

  identity label-range-trib-port {
    base otn-label-range-type;
    description
      "Defines a range of OTN tributary ports";
  }

  grouping otn-link-bandwidth {
    list odulist {
```

```
    key "odu-type";
    description
      "OTN bandwidth definition";
    leaf odu-type {
      type identityref {
        base otn-types:tributary-protocol-type;
      }
      description "ODU type";
    }
    leaf number {
      type uint16;
      description "Number of ODUs";
    }
  }
}

grouping otn-path-bandwidth {
  leaf odu-type {
    type identityref {
      base otn-types:tributary-protocol-type;
    }
    description "ODU type";
  }
}

grouping otn-label-restriction {
  leaf range-type {
    type identityref {
      base otn-types:otn-label-range-type;
    }
  }
  leaf tsg {
    type identityref {
      base otn-types:tributary-slot-granularity;
    }
    description "Tributary slot granularity.";
    reference
      "G.709/Y.1331, February 2016: Interfaces for the
      Optical Transport Network (OTN)";
  }
  leaf priority {
    type uint8;
    description "priority.";
  }
}

grouping otn-link-label {
```

```
choice otn-label-type {
  description
    "OTN label type";
  case tributary-port {
    leaf tpn {
      type uint16 {
        range "1..4095";
      }
      description
        "Tributary Port Number. Applicable in case of mux services.";
      reference
        "RFC7139: GMPLS Signaling Extensions for Control of Evolving
        G.709 Optical Transport Networks.";
    }
  }
  case tributary-slot {
    leaf ts {
      type uint16 {
        range "1..4095";
      }
      description
        "Tributary Slot Number. Applicable in case of mux services.";
      reference
        "RFC7139: GMPLS Signaling Extensions for Control of Evolving
        G.709 Optical Transport Networks.";
    }
  }
}

grouping otn-path-label {
  leaf tpn {
    type uint16 {
      range "1..4095";
    }
    description
      "Tributary Port Number. Applicable in case of mux services.";
    reference
      "RFC7139: GMPLS Signaling Extensions for Control of Evolving
      G.709 Optical Transport Networks.";
  }
  leaf tsg {
    type identityref {
      base otn-types:tributary-slot-granularity;
    }
    description "Tributary slot granularity.";
    reference
      "G.709/Y.1331, February 2016: Interfaces for the
```

```
        Optical Transport Network (OTN)";
    }
    leaf ts-list {
        type string {
            pattern "([1-9][0-9]{0,3}(-[1-9][0-9]{0,3})?"
                + "(, [1-9][0-9]{0,3}(-[1-9][0-9]{0,3})?)*)";
        }
        description
            "A list of available tributary slots ranging
            between 1 and 9999.
            For example 1-20,25,50-1000";
        reference "RFC 7139: GMPLS Signaling Extensions for Control
            of Evolving G.709 Optical Transport Networks";
    }
}
}
```

<CODE ENDS>

7. Security Considerations

TBD.

8. IANA Considerations

TBD.

9. Acknowledgements

TBD.

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Abstract

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

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

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

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1. Introduction

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

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

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

1.1. Scope of this document

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

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

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

Detailed analysis of the CMI (interface between the Customer Network Controller (CNC) and the MDSC) as well as of the interface between service and network orchestrators are outside the scope of this

document. However, some considerations and assumptions about the information could be described when needed.

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

The analysis of how to use the attributes in the I2RS Topology YANG model, defined in [I2RS-TOPO], is for further study.

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

1.2. Assumptions

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

1. The MDSC can request, at the MPI, a PNC to setup a Transit Tunnel Segment using the TE Tunnel YANG model: in this case, since the endpoints of the E2E Tunnel are outside the domain controlled by that PNC, the MDSC would not specify any source or destination TTP (i.e., it would leave the source, destination, src-tp-id and dst-tp-id attributes empty) for the tunnel and it would use the explicit-route-object/route-object-include-exclude list to specify the ingress and egress links for each path of the Transit Tunnel Segment.
2. Each PNC provides to the MDSC, at the MPI, the list of available timeslots on the inter-domain links using the TE Topology YANG model and OTN Topology augmentation. The TE Topology YANG model in [TE-TOPO] is being updated to report the label set information.

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

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

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

2. Terminology

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

E-LINE: Ethernet Line

EPL: Ethernet Private Line

EVPL: Ethernet Virtual Private Line

OTN: Optical Transport Network

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

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

UNI: User Network Interface

MDSC: Multi-Domain Service Coordinator

CNC: Customer Network Controller

PNC: Provisioning Network Controller

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

3. Conventions used in this document

3.1. Topology and traffic flow processing

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

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

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

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

For example, the following traffic flow:

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

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

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

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

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

3.2. JSON code

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

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

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

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

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

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

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

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

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

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

4. Scenarios Description

4.1. Reference Network

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

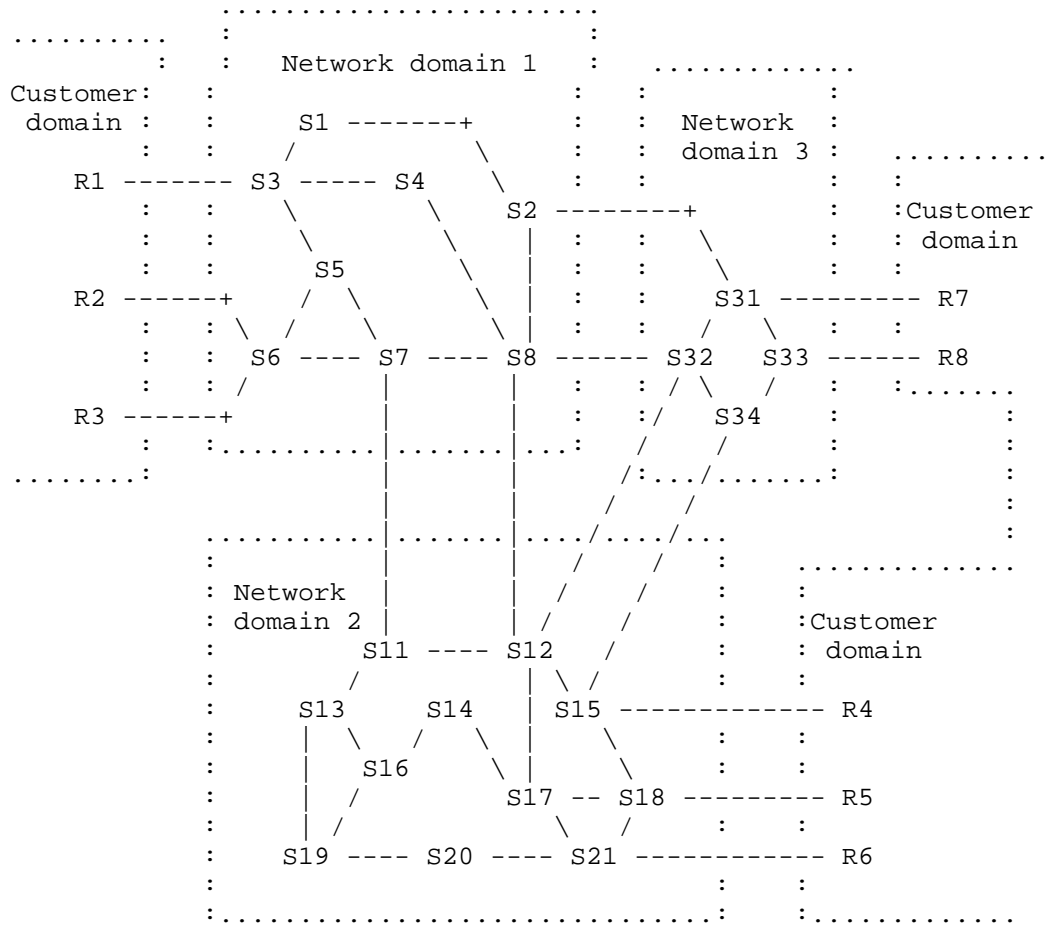


Figure 1 Reference network

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

It is also assumed that, within the transport network, the physical/optical interconnections supporting the S_i - S_j OTN links (up to the OTU4 trail), are pre-configured using mechanisms which are

outside the scope of this document and are not exposed at the MPIs to the MDSC.

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

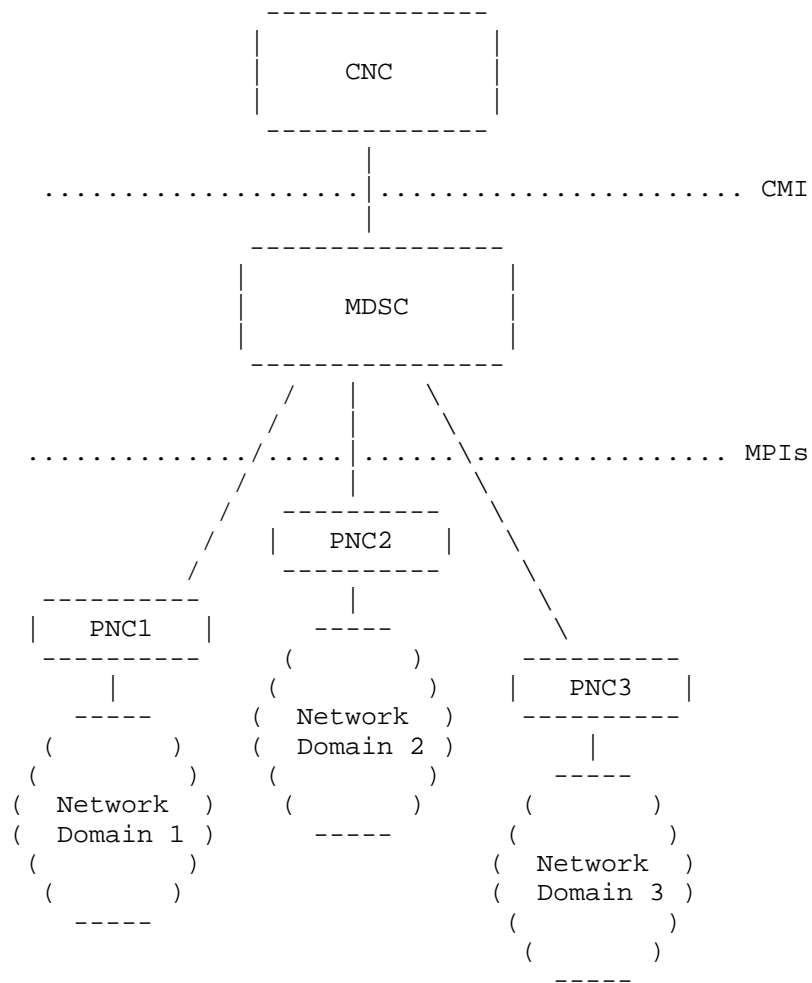


Figure 2 Controlling Hierarchy

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

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

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

4.1.1. Single-Domain Scenario

In case the CNC requests transport connectivity between IP routers attached to the same transport domain (e.g., between R1 and R3 in Figure 1), the MDSC can just pass the service request to the PNC controlling that domain (e.g., PNC1 in Figure 2) and let the PNC take decisions about how to implement the service (e.g., setting up the intra-domain end-to-end OTN connection).

4.1.2. Multi-Domain Scenario

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

4.2. Topology Abstractions

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

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

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

- o White topology: This is a case where the PNC provides the actual network topology to the MDSC without any hiding or filtering. In this case, the MDSC has the full knowledge of the underlying network topology;
- o Black topology: The entire domain network is abstracted as a single virtual node with the access/egress links without disclosing any node internal connectivity information;
- o Grey topology: This abstraction level is between black topology and white topology from a granularity point of view. This is abstraction of TE tunnels for all pairs of border nodes. We may further differentiate from a perspective of how to abstract internal TE resources between the pairs of border nodes:
 - Grey topology type A: border nodes with a TE links between them in a full mesh fashion;
 - Grey topology type B: border nodes with some internal abstracted nodes and abstracted links.

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

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

The MPI operates on the abstract topology regardless on the type of abstraction provided by the PNC.

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

- o PNC1 provides a topology abstraction which exposes at MPI1 an abstract node and an abstract link for each physical node and link within network domain 1
- o PNC2 provides a topology abstraction which exposes at MPI2 a single abstract node (representing the whole network domain) with abstract links representing only the inter-domain physical links
- o PNC3 provides a topology abstraction which exposes at MPI3 two abstract nodes (called AN31 and AN32). They abstract respectively nodes S31+S33 and nodes S32+S34. At MPI3, only the abstract nodes should be reported: the mapping between the abstract nodes (AN31 and AN32) and the physical nodes (S31, S32, S33 and S34) should be done internally by PNC3.

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

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

4.3. Service Configuration

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

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

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

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

4.3.1. ODU Transit

The physical links interconnecting the IP routers and the transport network can be OTN links. In this case, it is assumed that the physical/optical interconnections below the ODU layer (up to the OTU2 trail) are pre-configured using mechanisms which are outside the scope of this document and not exposed at the MPis to the MDSC.

To setup a 10Gb IP link between R_1 and R_5 , an ODU2 end-to-end data plane connection needs be created between R_1 and R_5 , crossing transport nodes S_3 , S_1 , S_2 , S_{31} , S_{33} , S_{34} , S_{15} and S_{18} which belong to different PNC domains.

The traffic flow between R_1 and R_5 can be summarized as:

```
R1 ([PKT]  $\rightarrow$  ODU2), S3 ([ODU2]), S1 ([ODU2]), S2 ([ODU2]),  
S31 ([ODU2]), S33 ([ODU2]), S34 ([ODU2]),  
S15 ([ODU2]), S18 ([ODU2]), R5 (ODU2  $\rightarrow$  [PKT])
```

It is assumed that the CNC requests, via the CMI, the setup of an ODU2 transit service, providing all the information that the MDSC needs to understand that it shall setup a multi-domain ODU2 segment connection between nodes S_3 and S_{18} .

In case the CNC needs the setup of a 10Gb IP link between R_1 and R_3 (single-domain service request), the traffic flow between R_1 and R_3 can be summarized as:

```
R1 ([PKT]  $\rightarrow$  ODU2), S3 ([ODU2]), S5 ([ODU2]), S6 ([ODU2]),  
R3 (ODU2  $\rightarrow$  [PKT])
```

Since the CNC is unaware of the transport network domains, it requests the setup of an ODU2 transit service in the same way as

before, regardless the fact the fact that this is a single-domain service.

It is assumed that the information provided at the CMI is sufficient for the MDSC to understand that this is a single-domain service request.

The MDSC can then just request PNC1 to setup a single-domain ODU2 data plane segment connection between nodes S3 and S6.

4.3.2. EPL over ODU

The physical links interconnecting the IP routers and the transport network can be Ethernet links. In this case, it is assumed that the Ethernet physical interconnections below the MAC layer (up to the OTU2 trail) are pre-configured using mechanisms which are outside the scope of this document and not exposed at the MPIs to the MDSC.

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

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

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

It is assumed that the CNC requests, via the CMI, the setup of an EPL service, providing all the information that the MDSC needs to understand that it shall coordinate the three PNCs to setup a multi-domain ODU2 end-to-end connection between nodes S3 and S18 as well as the configuration of the adaptation functions inside nodes S3 and S18: S3 (ETH -> [ODU2]), S18 ([ODU2] -> ETH), S18 (ETH -> [ODU2]) and S3 ([ODU2] -> ETH).

In case the CNC needs the setup of a 10Gb IP link between R1 and R3 (single-domain service request), the traffic flow between R1 and R3 can be summarized as:

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

As described in section 4.3.1, the CNC requests the setup of an EPL service in the same way as before and the information provided at the CMI is sufficient for the MDSC to understand that this is a single-domain service request.

The MDSC can then just request PNC1 to setup a single-domain EPL service between nodes S3 and S6. PNC1 can take care of setting up the single-domain ODU2 end-to-end connection between nodes S3 and S6 as well as of configuring the adaptation functions on these edge nodes.

4.3.3. Other OTN Clients Services

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

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

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

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

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

As described in section 4.3.2, it is assumed that the CNC is capable, via the CMI, to request the setup of an STM-64 Private Line service, providing all the information that the MDSC needs to coordinate the setup of a multi-domain ODU2 connection as well as the adaptation functions on the edge nodes.

In the single-domain case (10Gb IP link between R1 and R3), the traffic flow between R1 and R3 can be summarized as:


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

As described in section 4.3.1, the CNC requests the setup of an STM-64 Private Line service in the same way as before and the information provided at the CMI is sufficient for the MDSC to understand that this is a single-domain service request.

As described in section 4.3.2, the MDSC could just request PNC1 to setup a single-domain STM-64 Private Line service between nodes S3 and S6.

4.3.4. EVPL over ODU

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

To setup two 1Gb IP links between R1 to R3 and between R1 and R5, two EVPL services need to be created, supported by two ODU0 end-to-end connections respectively between S3 and S6, crossing transport node S5, and between S3 and S18, crossing transport nodes S1, S2, S31, S33, S34 and S15 which belong to different PNC domains.

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

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

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

The traffic flow between R1 and R3 can be summarized as:

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

As described in section 4.3.2, it is assumed that the CNC is capable, via the CMI, to request the setup of these EVPL services, providing all the information that the MDSC needs to understand that it need to request PNC1 to setup an EVPL service between nodes S3

and S6 (single-domain service request) and it also needs to coordinate the setup of a multi-domain ODU0 connection between nodes S3 and S16 as well as the adaptation functions on these edge nodes.

4.3.5. EVPLAN and EVPTree Services

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

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

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

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

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

- o MAC Bridging in node S3 is needed to select, based on the MAC Destination Address, whether received Ethernet frames should be forwarded to R1 or to the ODUFlex terminating on node S6 or to the other ODUFlex terminating on node S18;
- o MAC bridging function in node S6 is needed to select, based on the MAC Destination Address, whether received Ethernet frames should be sent to R2 or to R3 or to the ODUFlex terminating on node S3.

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

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

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

```
R3 ([PKT] -> VLAN), S6 (VLAN -> [MAC] -> [ODUflex]),
S5 ([ODUflex]), S3 ([ODUflex] -> [MAC] -> [ODUflex]),
S1 ([ODUflex]), S2 ([ODUflex]), S31 ([ODUflex]),
S33 ([ODUflex]), S34 ([ODUflex]),
S15 ([ODUflex]), S18 ([ODUflex] -> VLAN), R5 (VLAN -> [PKT])
```

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

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

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

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

4.3.6. Dynamic Service Configuration

Given the service established in the previous sections, there is a demand for an update of some service characteristics. A straightforward approach would be terminate the current service and replace with a new one. Another more advanced approach would be

dynamic configuration, in which case there will be no interruption for the connection.

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

4.4. Multi-function Access Links

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

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

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

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

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

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

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

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

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

4.5. Protection and Restoration Configuration

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

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

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

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

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

4.5.1. Linear Protection (end-to-end)

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

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

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

Two cases can be considered:

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

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

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

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

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

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

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

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

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

4.5.2. Segmented Protection

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

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

Working transport entity: S3, S1, S2

Protection transport entity: S3, S4, S8, S2

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

Working transport entity: S15, S18

Protection transport entity: S15, S12, S17, S18

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

Working transport entity: S31, S33, S34

Protection transport entity: S31, S32, S34

4.5.3. End-to-End Dynamic restoration

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

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

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

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

4.5.4. Segmented Dynamic Restoration

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

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

When a link failure between S1 and S2 occurred in network domain 1, PNC1 will restore the tunnel and send the alarm or tunnel update notification to the MDSC, MDSC will update the restored tunnel.

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

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

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

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

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

4.6. Service Modification and Deletion

To be discussed in future versions of this document.

4.7. Notification

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

1. Object create
2. Object delete
3. Object state change
4. Alarm

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

4.8. Path Computation with Constraint

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

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

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

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

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

When there is a technology specific network (e.g, OTN), the corresponding technology (OTN) model should also be used to specify

the tunnel information on MPI, with the constraint included in TE Tunnel model.

5. YANG Model Analysis

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

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

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

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

5.1. YANG Models for Topology Abstraction

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

5.1.1. Domain 1 Topology Abstraction

PNC1 provides the required topology abstraction to expose at its MPI toward the MDSC (called "MPI1") one TE Topology instance for the ODU layer (called "MPI1 ODU Topology"), containing one TE Node (called "ODU Node") for each physical node, as shown in Figure 3 below.

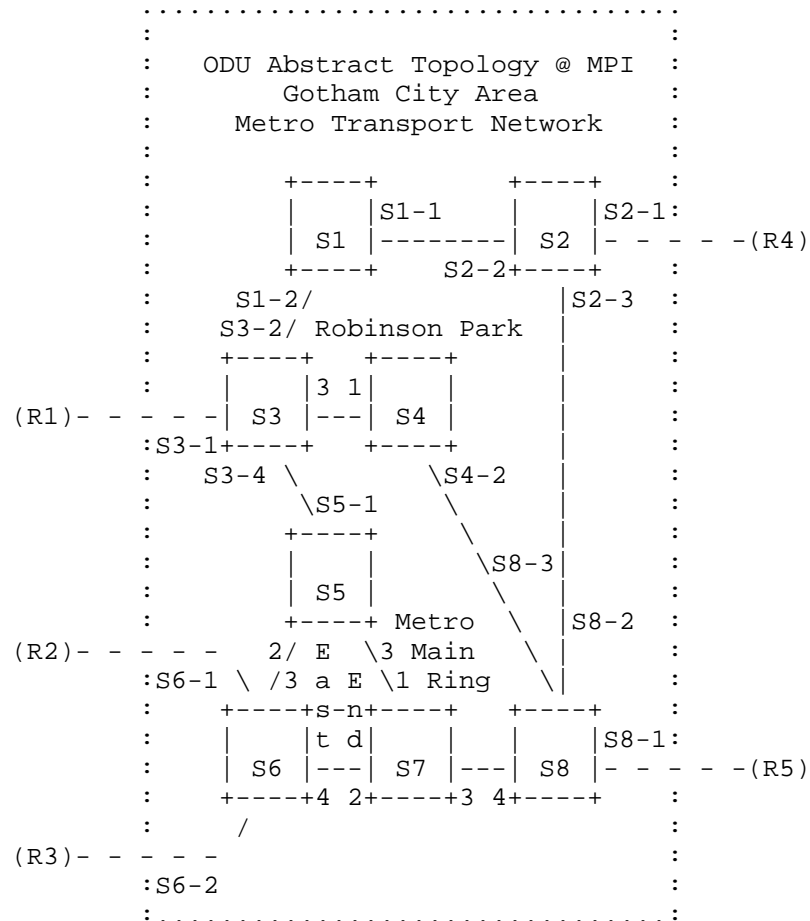


Figure 3 Abstract Topology exposed at MPI1 (MPI1 ODU Topology)

The ODU Nodes in Figure 3 are using the same names as the physical nodes to simplify the description of the mapping between the ODU Nodes exposed by the Transport PNCs at the MPI and the physical

nodes in the data plane. This does not correspond to the reality of the usage of the topology model, as described in section 4.3 of [TE-TOPO], in which renaming by the client it is necessary.

As described in section 4.1, it is assumed that the physical links between the physical nodes are pre-configured and therefore PNC1 exports at MPI1 one TE Link (called "ODU Link") for each of these OTU4 trails.

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

5.1.2. Domain 2 Grey (Type A) Topology Abstraction

PNC2 provides the required topology abstraction to expose at its MPI towards the MDSC (called "MPI2") only one abstract node (i.e., AN2), with only inter-domain and access links, is reported at the MPI2.

5.1.3. Domain 3 Grey (Type B) Topology Abstraction

PNC3 provides the required topology abstraction to expose at its MPI towards the MDSC (called "MPI3") only two abstract nodes (i.e., AN31 and AN32), with internal links, inter-domain links and access links.

5.1.4. Multi-domain Topology Stitching

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

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

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

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

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

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

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

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

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

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

5.1.5. Access Links

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

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

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

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

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

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

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

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

5.2. YANG Models for Service Configuration

The service configuration procedure is assumed to be initiated (step 1 in Figure 4) at the CMI from CNC to MDSC. Analysis of the CMI models is (e.g., L1SM, L2SM, Transport-Service, VN, et al.) is outside the scope of this document.

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

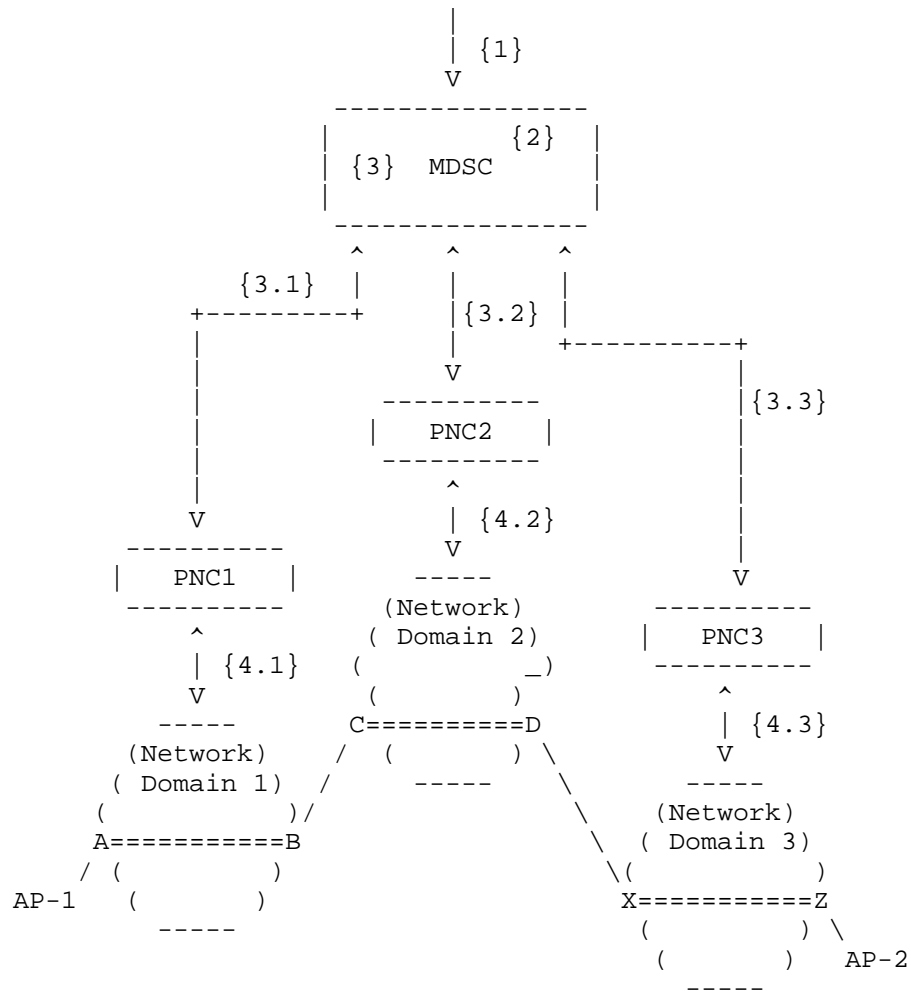


Figure 4 Multi-domain Service Setup

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

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

After receiving such request, MDSC determines the domain sequence, i.e., domain 1 <-> domain 2 <-> domain 3, with corresponding PNCs and inter-domain links (step 2 in Figure 4).

As described in [PATH-COMPUTE], the domain sequence can be determined by running the MDSC own path computation on the MDSC internal topology, defined in section 5.1.4, if and only if the MDSC has enough topology information. Otherwise the MDSC can send path computation requests to the different PNCs (steps 2.1, 2.2 and 2.3 in Figure 4) and use this information to determine the optimal path on its internal topology and therefore the domain sequence.

The MDSC will then decompose the tunnel request into a few tunnel segments via tunnel model (including both TE tunnel model and OTN tunnel model), and request different PNCs to setup each intra-domain tunnel segment (steps 3, 3.1, 3.2 and 3.3 in Figure 4).

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

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

5.2.1. ODU Transit Service

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

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

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

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

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

- o Source and Destination TTPs are not specified (since it is a Transit Tunnel)
- o Ingress and egress points are indicated in the route-object-include-exclude list of the explicit-route-objects of the primary path:
 - o The first element references the access link terminating on S3-1 LTP
 - o The last two element references respectively the inter-domain link terminating on S2-1 LTP and the data plane resources (i.e., the timeslots and the TPN, called "OTN Label") used by the ODU2 connection over that link.

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

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

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

controlling the OTN physical nodes (e.g., PNC1 and PNC3 controlling respectively the physical nodes S2 and S31).

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

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

5.2.1.1. Single Domain Example

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

The Transport PNC reports the status of the created ODU2 (Transit Segment) Tunnel and its path within the ODU Topology as shown in Figure 5 below:

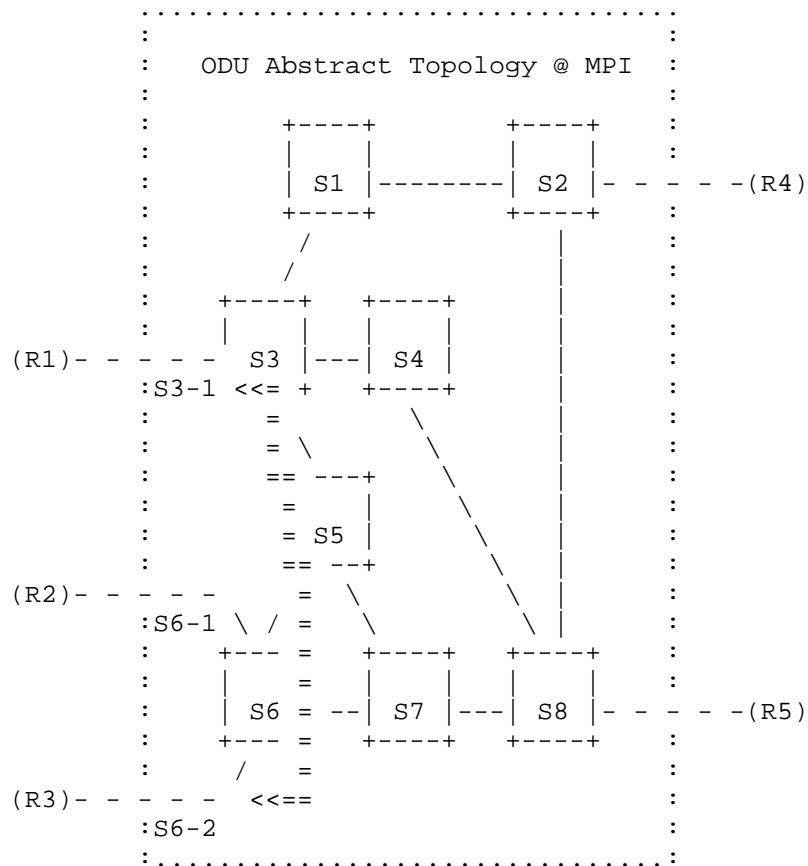


Figure 5 ODU2 Transit Tunnel

5.2.2. EPL over ODU Service

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

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

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

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

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

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

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

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

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

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

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

5.2.3. Other OTN Client Services

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

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

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

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

The same issues, as described in section 5.2.2, apply here:

- o the MDSC needs to understand that R1 and R3 are connected, through STM-64 access links, with S3 and S6
- o the MDSC needs to understand which TTPs in S3 and S6 can be accessed by these access links
- o the MDSC needs to configure the private line service from these access links through the ODU2 tunnel

5.2.4. EVPL over ODU Service

In this scenario, the access links are configured as Ethernet links, as described in section 5.2.2 above.

As described in section 4.3.4, the CNC needs to setup EVPL services, supporting IP links, between R1 and R3, as well as between R1 and R4 and requests these services at the CMI to the MDSC.

MDSC needs to setup two EVPL services, between R1 and R3, as well as between R1 and R4, supported by ODU0 end-to-end connections between S3 and S6 and between S3 and S2 respectively.

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

The same issues, as described in section 5.1.5 above, apply here:

- o the MDSC needs to understand that R1, R3 and R4 are connected, through the Ethernet access links, with S3, S6 and S2
- o the MDSC needs to understand which TTPs in S3, S6 and S2 can be accessed by these access links
- o the MDSC needs to configure the EVPL services from these access links through the ODU0 tunnels

In addition, the MDSC needs to get the information that the access links on S3, S6 and S2 are capable to support EVPL (rather than just EPL) as well as to coordinate the VLAN configuration, for each EVPL service, on these access links (this is a similar issue as the timeslot configuration on access links discussed in section 4.3.1 above).

5.3. YANG Models for Protection Configuration

5.3.1. Linear Protection (end-to-end)

To be discussed in future versions of this document.

5.3.2. Segmented Protection

To be discussed in future versions of this document.

6. Security Considerations

This section is for further study

7. IANA Considerations

This document requires no IANA actions.

8. References

8.1. Normative References

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8.2. Informative References

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- [ONF TR-527] ONF Technical Recommendation TR-527, "Functional Requirements for Transport API", June 2016.
- [ONF GitHub] ONF Open Transport (SNOWMASS)
<https://github.com/OpenNetworkingFoundation/Snowmass-ONFOpenTransport>

9. Acknowledgments

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Appendix A Validating a JSON fragment against a YANG Model

The objective is to have a tool that allows validating whether a piece of JSON code embedded in an Internet-Draft is compliant with a YANG model without using a client/server.

A.1. Manipulation of JSON fragments

This section describes the various ways JSON fragments are used in the I-D processing and how to manage them.

Let's call "folded-JSON" the JSON embedded in the I-D: it fits the 72 chars width and it is acceptable for it to be invalid JSON.

We then define "unfolded-JSON" a valid JSON fragment having the same contents of the "folded-JSON" without folding, i.e. limits on the text width. The folding/unfolding operation may be done according to draft-kwatsen-netmod-artwork-folding. The "unfolded-JSON" can be edited by the authors using JSON editors with the advantages of syntax validation and pretty-printing.

Both the "folded" and the "unfolded" JSON fragments can include comments having descriptive fields and directives we'll describe later to facilitate the reader and enable some automatic processing.

The presence of comments in the "unfolded-JSON" fragment makes it an invalid JSON encoding of YANG data. Therefore we call "naked JSON" the JSON where the comments have been stripped out: not only it is valid JSON but it is a valid JSON encoding of YANG data.

The following schema resumes these definitions:

	unfold_it -->	stripper -->	
	Folded-JSON	Unfolded-JSON	Naked JSON
	<-- fold_it	<-- author edits	
<=72-chars?	MUST	MAY	MAY
valid JSON?	MAY	MUST	MUST
JSON-encoding	MAY	MAY	MUST
of YANG data			

Our validation toolchain has been designed to take a JSON in any of the three formats and validate it automatically against a set of relevant YANG modules using available open-source tools. It can be found at: <https://github.com/GianmarcoBruno/json-yang/>

A.2. Comments in JSON fragments

We found useful to introduce two kinds of comments, both defined as key-value pairs where the key starts with "//":

- free-form descriptive comments, e.g. "// COMMENT" : "refine this" to describe properties of JSON fragments.

- machine-usable directives e.g. "// __REFERENCES__DRAFTS__" : { "ietf-routing-types@2017-12-04": "rfc8294", } which can be used to automatically download from the network the relevant I-Ds or RFCs and extract from them the YANG models of interest. This is particularly useful to keep consistency when the drafting work is rapidly evolving.

A.3. Validation of JSON fragments: DSDL-based approach

The idea is to generate a JSON driver file (JTOX) from YANG, then use it to translate JSON to XML and validate it against the DSDL schemas, as shown in Figure 6.

Useful link: <https://github.com/mbj4668/pyang/wiki/XmlJson>

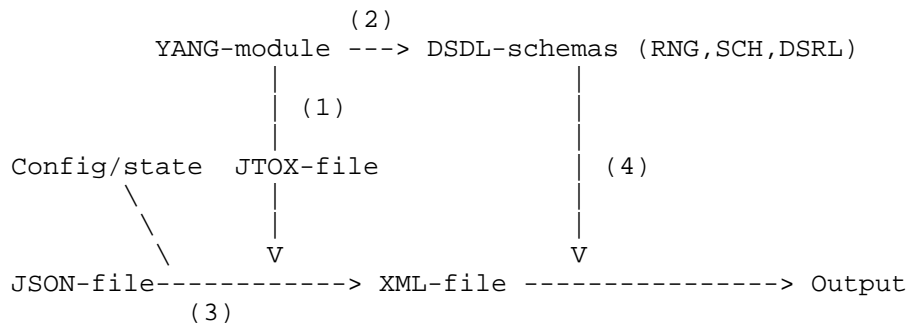


Figure 6 - DSDL-based approach for JSON code validation

In order to allow the use of comments following the convention defined in section 3 without impacting the validation process, these comments will be automatically removed from the JSON-file that will be validate.

A.4. Validation of JSON fragments: why not using a XSD-based approach

This approach has been analyzed and discarded because no longer supported by pyang.

The idea is to convert YANG to XSD, JSON to XML and validate it against the XSD, as shown in Figure 7:

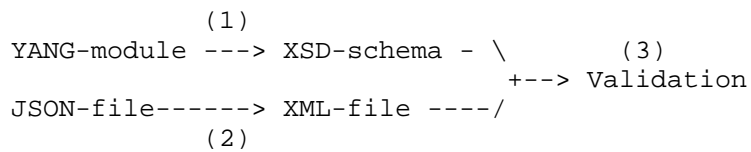


Figure 7 - XSD-based approach for JSON code validation

The pyang support for the XSD output format was deprecated in 1.5 and removed in 1.7.1. However pyang 1.7.1 is necessary to work with YANG 1.1 so the process shown in Figure 7 will stop just at step (1).

Appendix B Detailed JSON Examples

B.1. JSON Examples for Topology Abstractions

B.1.1. JSON Code: mpil-otn-topology.json

```

{
  "// __TITLE__": "ODU Abstract Topology @ MPI1",
  "// __LAST_UPDATE__": "July 2, 2018",
  "// __RESTCONF_OPERATION__": {
    "operation": "GET",
    "url":
      "http://{{PNC1-ADDR}}/restconf/data/ietf-network:networks"
  },
  "// __REFERENCE_DRAFTS__": {
    "ietf-network@2017-12-18":
      "draft-ietf-i2rs-yang-network-topo-20",
    "ietf-network-topology@2017-12-18":
      "draft-ietf-i2rs-yang-network-topo-20",
    "ietf-te-topology@2018-02-21":
      "draft-ietf-teas-yang-te-topo-15",
    "ietf-te-types@2018-02-19": "draft-ietf-teas-yang-te-12",
    "ietf-routing-types@2017-12-04": "rfc8294",
    "ietf-otn-topology@2017-10-30":
      "draft-ietf-ccamp-otn-topo-yang-02",
    "ietf-otn-types@2017-10-30":
      "draft-ietf-ccamp-otn-tunnel-model-01"
  },
  "// __MISSING_ATTRIBUTES__": true,
  "ietf-network:networks": {
    "network": [
      {
        "network-id": "tnbi",
        "network-types": {
          "ietf-te-topology:te-topology": {
            "ietf-otn-topology:otn-topology": {}
          }
        },
        "// __DISCUSS__ ietf-te-topology:provider-id": null,
        "ietf-te-topology:provider-id": 0,
        "// __DISCUSS__ ietf-te-topology:client-id": 0,
        "ietf-te-topology:client-id": 0,
        "// __DISCUSS__ ietf-te-topology:te-topology-id": null,
        "ietf-te-topology:te-topology-id": "tnbi",
        "// comment": [

```

```

    "te container presence requires:           ",
    " provider-id, client-id and te-topology-id"
  ],
  "ietf-te-topology:te": {
    "name": "gotham-city:metro-transport-network"
  },
  "ietf-network:node": [
    {
      "// __NODE__:__DESCRIPTION__": [
        "S3",
        "10.0.0.3",
        "ADM"
      ],
      "node-id": "10.0.0.3",
      "ietf-te-topology:te-node-id": "10.0.0.3",
      "ietf-te-topology:te": {
        "oper-status": "up",
        "te-node-attributes": {
          "// comment-on-name": [
            "Often transport domains contain subdomain      ",
            "topological partitioning that may be reported  ",
            "in node te name                                   "
          ],
          "name": "S3-metro_main_ring-gateway",
          "admin-status": "up",
          "// __DISCUSS__ domain-id": 65001
        },
        "// __DISCUSS__ tunnel-termination-point": []
      },
      "ietf-network-topology:termination-point": [
        {
          "// __DESCRIPTION__:__LTP__": [
            "S3-1 LTP",
            "connected to (C-R1)",
            "unnumberd/ifIndex: 1",
            "OTU-2",
            "tributary port"
          ],
          "tp-id": "1",
          "ietf-te-topology:te-tp-id": 1,
          "ietf-te-topology:te": {
            "// _OBSOLETE_ ietf-otn-topology:client-facing": [
              null
            ],
            "admin-status": "up",

```

```

        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
            "__DISCUSS__",
        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
            "ietf-transport-types:prot-OTU2",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
            "ODU"
    }
},
{
    "// __DESCRIPTION__:__LTP__": [
        "S3-2 LTP",
        "connected to S1-2",
        "unnumberd/ifIndex: 2",
        "OTU-4",
        "line port"
    ],
    "tp-id": "2",
    "ietf-te-topology:te-tp-id": 2,
    "ietf-te-topology:te": {
        "admin-status": "up",
        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
            "__DISCUSS__",
        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
            "ietf-transport-types:prot-OTU4",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
            "ODU"
    }
},
{
    "// __DESCRIPTION__:__LTP__": [
        "S3-3 LTP",
        "connected to S4-1",
        "unnumberd/ifIndex: 3",
        "OTU-4",
        "line port"
    ],
    "tp-id": "3",
    "ietf-te-topology:te-tp-id": 3,
    "ietf-te-topology:te": {
        "admin-status": "up",
        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
            "__DISCUSS__",

```



```

        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
        "ietf-transport-types:prot-OTU4",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
        "ODU"
    }
},
{
    "// __DESCRIPTION__: __LTP__": [
        "S3-4 LTP",
        "connected to S5-1",
        "unnumberd/ifIndex: 4",
        "OTU-4",
        "line port"
    ],
    "tp-id": "4",
    "ietf-te-topology:te-tp-id": 4,
    "ietf-te-topology:te": {
        "admin-status": "up",
        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
        "__DISCUSS__",
        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
        "ietf-transport-types:prot-OTU4",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
        "ODU"
    }
}
]
},
{
    "// __NODE__: __DESCRIPTION__": [
        "S4",
        "10.0.0.4",
        "pizza-box"
    ],
    "node-id": "10.0.0.4",
    "ietf-te-topology:te-node-id": "10.0.0.4",
    "ietf-te-topology:te": {
        "// comment": "TO BE COMPLETED",
        "oper-status": "up",
        "te-node-attributes": {
            "name": "S4-line-metro_main_ring",
            "admin-status": "up",
            "// __DISCUSS__ domain-id": 65001
        }
    },

```

```

    "// __DISCUSS__ tunnel-termination-point": []
  },
  "ietf-network-topology:termination-point": [
    {
      "// __DESCRIPTION__:__LTP__": [
        "S4-1 LTP",
        "connected to S3-3",
        "unnumberd/ifIndex: 1",
        "OTU-4",
        "line port"
      ],
      "// comment": "S4-1 LTP",
      "tp-id": "1",
      "ietf-te-topology:te-tp-id": 1,
      "ietf-te-topology:te": {
        "admin-status": "up",
        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
          "__DISCUSS__",
        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
          "ietf-transport-types:prot-OTU4",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
          "ODU"
      }
    }
  ],
  {
    "// __DESCRIPTION__:__LTP__": [
      "S4-2 LTP",
      "connected to S8-3",
      "unnumberd/ifIndex: 2",
      "OTU-4",
      "line port"
    ],
    "// comment": "S4-2 LTP",
    "tp-id": "2",
    "ietf-te-topology:te-tp-id": 2,
    "ietf-te-topology:te": {
      "admin-status": "up",
      "oper-status": "up",
      "// ietf-otn-topology:supported-payload-types":
        "__DISCUSS__",
      "// _OBSOLETE_ ietf-otn-topology:protocol-type":
        "ietf-transport-types:prot-OTU4",
      "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
        "ODU"
    }
  }
]

```

```

    }
  }
]
},
{
  "// __NODE__:__DESCRIPTION__": [
    "S1",
    "10.0.0.1",
    "pizza-box"
  ],
  "node-id": "10.0.0.1",
  "ietf-te-topology:te-node-id": "10.0.0.1",
  "ietf-te-topology:te": {
    "// comment": "TO BE COMPLETED",
    "oper-status": "up",
    "te-node-attributes": {
      "name": "S1-robinson_park_ring-line",
      "admin-status": "up",
      "// __DISCUSS__ domain-id": 65001
    },
    "// __DISCUSS__ tunnel-termination-point": []
  },
  "ietf-network-topology:termination-point": [
    {
      "// __DESCRIPTION__:__LTP__": [
        "S1-1 LTP",
        "connected to S2-2",
        "unnumberd/ifIndex: 1",
        "OTU-4",
        "line port"
      ],
      "// comment": "S1-1 LTP",
      "tp-id": "1",
      "ietf-te-topology:te-tp-id": 1,
      "ietf-te-topology:te": {
        "admin-status": "up",
        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
          "__DISCUSS__",
        "// __OBSOLETE__ ietf-otn-topology:protocol-type":
          "ietf-transport-types:prot-OTU4",
        "// __OBSOLETE__ ietf-otn-topology:adaptation-type":
          "ODU"
      }
    }
  ],
},

```

```

{
  "// __DESCRIPTION__: __LTP__": [
    "S1-2 LTP",
    "connected to S3-2",
    "unnumberd/ifIndex: 2",
    "OTU-4",
    "line port"
  ],
  "// comment": "S1-2 LTP",
  "tp-id": "2",
  "ietf-te-topology:te-tp-id": 2,
  "ietf-te-topology:te": {
    "admin-status": "up",
    "oper-status": "up",
    "// ietf-otn-topology:supported-payload-types":
      "__DISCUSS__",
    "// _OBSOLETE_ ietf-otn-topology:protocol-type":
      "ietf-transport-types:prot-OTU4",
    "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
      "ODU"
  }
}
]
},
{
  "// __NODE__: __DESCRIPTION__": [
    "S2",
    "10.0.0.2",
    "ADM"
  ],
  "node-id": "10.0.0.2",
  "ietf-te-topology:te-node-id": "10.0.0.2",
  "ietf-te-topology:te": {
    "// comment": "TO BE COMPLETED",
    "oper-status": "up",
    "te-node-attributes": {
      "name": "S2-robinson_park_ring-access",
      "admin-status": "up",
      "// __DISCUSS__ domain-id": 65001
    },
    "// __DISCUSS__ tunnel-termination-point": []
  },
  "ietf-network-topology:termination-point": [
    {
      "// __DESCRIPTION__: __LTP__": [

```

```

        "S2-1 LTP",
        "connected to (C-R4)",
        "unnumberd/ifIndex: 1",
        "OTU-2",
        "tributary port"
    ],
    "// comment": "S2-1 LTP",
    "tp-id": "1",
    "ietf-te-topology:te-tp-id": 1,
    "ietf-te-topology:te": {
        "// _OBSOLETE_ ietf-otn-topology:client-facing": [
            null
        ],
        "admin-status": "up",
        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
            "__DISCUSS__",
        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
            "ietf-transport-types:prot-OTU2",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
            "ODU"
    }
},
{
    "// __DESCRIPTION__:__LTP__": [
        "S2-2 LTP",
        "connected to S1-1",
        "unnumberd/ifIndex: 2",
        "OTU-4",
        "line port"
    ],
    "// comment": "S2-2 LTP",
    "tp-id": "2",
    "ietf-te-topology:te-tp-id": 2,
    "ietf-te-topology:te": {
        "admin-status": "up",
        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
            "__DISCUSS__",
        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
            "ietf-transport-types:prot-OTU4",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
            "ODU"
    }
}
},

```

```

{
  "// __DESCRIPTION__: __LTP__": [
    "S2-3 LTP",
    "connected to S8-2",
    "unnumberd/ifIndex: 3",
    "OTU-4",
    "line port"
  ],
  "// comment": "S2-3 LTP",
  "tp-id": "3",
  "ietf-te-topology:te-tp-id": 3,
  "ietf-te-topology:te": {
    "admin-status": "up",
    "oper-status": "up",
    "// ietf-otn-topology:supported-payload-types":
      "__DISCUSS__",
    "// _OBSOLETE_ ietf-otn-topology:protocol-type":
      "ietf-transport-types:prot-OTU4",
    "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
      "ODU"
  }
}
]
},
{
  "// __NODE__: __DESCRIPTION__": [
    "S7",
    "10.0.0.7",
    "ADM"
  ],
  "node-id": "10.0.0.7",
  "ietf-te-topology:te-node-id": "10.0.0.7",
  "ietf-te-topology:te": {
    "// comment": "TO BE COMPLETED",
    "oper-status": "up",
    "te-node-attributes": {
      "name": "S7-east_end_ring-gateway",
      "admin-status": "up",
      "// __DISCUSS__ domain-id": 65001
    },
    "// __DISCUSS__ tunnel-termination-point": []
  },
  "ietf-network-topology:termination-point": [
    {
      "// __DESCRIPTION__: __LTP__": [

```

```

        "S7-1 LTP",
        "connected to S5-3",
        "unnumberd/ifIndex: 1",
        "OTU-4",
        "line port"
    ],
    "// comment": "S7-1 LTP",
    "tp-id": "1",
    "ietf-te-topology:te-tp-id": 1,
    "ietf-te-topology:te": {
        "admin-status": "up",
        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
            "__DISCUSS__",
        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
            "ietf-transport-types:prot-OTU4",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
            "ODU"
    }
},
{
    "// __DESCRIPTION__:__LTP__": [
        "S7-2 LTP",
        "connected to S6-4",
        "unnumberd/ifIndex: 2",
        "OTU-4",
        "line port"
    ],
    "// comment": "S7-2 LTP",
    "tp-id": "2",
    "ietf-te-topology:te-tp-id": 2,
    "ietf-te-topology:te": {
        "admin-status": "up",
        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
            "__DISCUSS__",
        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
            "ietf-transport-types:prot-OTU4",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
            "ODU"
    }
},
{
    "// __DESCRIPTION__:__LTP__": [
        "S7-3 LTP",

```

```

        "connected to S8-4",
        "unnumberd/ifIndex: 3",
        "OTU-4",
        "line port"
    ],
    "// comment": "S7-3 LTP",
    "tp-id": "3",
    "ietf-te-topology:te-tp-id": 3,
    "ietf-te-topology:te": {
        "admin-status": "up",
        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
            "__DISCUSS__",
        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
            "ietf-transport-types:prot-OTU4",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
            "ODU"
    }
}
]
},
{
    "// __NODE__:__DESCRIPTION__": [
        "S8",
        "10.0.0.8",
        "ADM"
    ],
    "node-id": "10.0.0.8",
    "ietf-te-topology:te-node-id": "10.0.0.8",
    "ietf-te-topology:te": {
        "// comment": "TO BE COMPLETED",
        "oper-status": "up",
        "te-node-attributes": {
            "name": "S8-metro_main_ring-access",
            "admin-status": "up",
            "// __DISCUSS__ domain-id": 65001
        },
        "// __DISCUSS__ tunnel-termination-point": []
    },
    "ietf-network-topology:termination-point": [
        {
            "// __DESCRIPTION__:__LTP__": [
                "S8-1 LTP",
                "connected to (C-R5)",
                "unnumberd/ifIndex: 1",

```



```

        "OTU-2",
        "tributary port"
    ],
    "// comment": "S8-1 LTP",
    "tp-id": "1",
    "ietf-te-topology:te-tp-id": 1,
    "ietf-te-topology:te": {
        "// _OBSOLETE_ ietf-otn-topology:client-facing": [
            null
        ],
        "admin-status": "up",
        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
            "__DISCUSS__",
        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
            "ietf-transport-types:prot-OTU2",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
            "ODU"
    }
},
{
    "// __DESCRIPTION__:__LTP__": [
        "S8-2 LTP",
        "connected to S2-3",
        "unnumberd/ifIndex: 2",
        "OTU-4",
        "line port"
    ],
    "// comment": "S8-2 LTP",
    "tp-id": "2",
    "ietf-te-topology:te-tp-id": 2,
    "ietf-te-topology:te": {
        "admin-status": "up",
        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
            "__DISCUSS__",
        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
            "ietf-transport-types:prot-OTU4",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
            "ODU"
    }
},
{
    "// __DESCRIPTION__:__LTP__": [
        "S8-3 LTP",

```

```

        "connected to S4-2",
        "unnumberd/ifIndex: 3",
        "OTU-4",
        "line port"
    ],
    "// comment": "S8-3 LTP",
    "tp-id": "3",
    "ietf-te-topology:te-tp-id": 3,
    "ietf-te-topology:te": {
        "admin-status": "up",
        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
            "__DISCUSS__",
        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
            "ietf-transport-types:prot-OTU4",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
            "ODU"
    }
},
{
    "// __DESCRIPTION__:__LTP__": [
        "S8-4 LTP",
        "connected to S7-3",
        "unnumberd/ifIndex: 4",
        "OTU-4",
        "line port"
    ],
    "// comment": "S8-4 LTP",
    "tp-id": "4",
    "ietf-te-topology:te-tp-id": 4,
    "ietf-te-topology:te": {
        "admin-status": "up",
        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
            "__DISCUSS__",
        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
            "ietf-transport-types:prot-OTU4",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
            "ODU"
    }
}
]
},
{
    "// __NODE__:__DESCRIPTION__": [

```

```

    "S5",
    "10.0.0.5",
    "ADM"
  ],
  "node-id": "10.0.0.5",
  "ietf-te-topology:te-node-id": "10.0.0.5",
  "ietf-te-topology:te": {
    "// comment": "TO BE COMPLETED",
    "oper-status": "up",
    "te-node-attributes": {
      "name": "S5-east_end_ring-gateway",
      "admin-status": "up",
      "// __DISCUSS__ domain-id": 65001
    },
    "// __DISCUSS__ tunnel-termination-point": []
  },
  "ietf-network-topology:termination-point": [
    {
      "// __DESCRIPTION__: __LTP__": [
        "S5-1 LTP",
        "connected to S3-4",
        "unnumberd/ifIndex: 1",
        "OTU-4",
        "line port"
      ],
      "// comment": "S5-1 LTP",
      "tp-id": "1",
      "ietf-te-topology:te-tp-id": 1,
      "ietf-te-topology:te": {
        "admin-status": "up",
        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
          "__DISCUSS__",
        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
          "ietf-transport-types:prot-OTU4",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
          "ODU"
      }
    },
    {
      "// __DESCRIPTION__: __LTP__": [
        "S5-2 LTP",
        "connected to S6-3",
        "unnumberd/ifIndex: 2",
        "OTU-4",

```

```

        "line port"
    ],
    "// comment": "S5-2 LTP",
    "tp-id": "2",
    "ietf-te-topology:te-tp-id": 2,
    "ietf-te-topology:te": {
        "admin-status": "up",
        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
            "__DISCUSS__",
        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
            "ietf-transport-types:prot-OTU4",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
            "ODU"
    }
},
{
    "// __DESCRIPTION__:__LTP__": [
        "S5-3 LTP",
        "connected to S7-1",
        "unnumberd/ifIndex: 3",
        "OTU-4",
        "line port"
    ],
    "// comment": "S5-3 LTP",
    "tp-id": "3",
    "ietf-te-topology:te-tp-id": 3,
    "ietf-te-topology:te": {
        "admin-status": "up",
        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
            "__DISCUSS__",
        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
            "ietf-transport-types:prot-OTU4",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
            "ODU"
    }
}
]
},
{
    "// __NODE__:__DESCRIPTION__": [
        "S6",
        "10.0.0.6",
        "ADM"
    ]
}

```

```

],
"node-id": "10.0.0.6",
"ietf-te-topology:te-node-id": "10.0.0.6",
"ietf-te-topology:te": {
  "// comment": "TO BE COMPLETED",
  "oper-status": "up",
  "te-node-attributes": {
    "name": "S6-east_end_ring-access",
    "admin-status": "up",
    "// __DISCUSS__ domain-id": 65001
  },
  "// __DISCUSS__ tunnel-termination-point": []
},
"ietf-network-topology:termination-point": [
{
  "// __DESCRIPTION__:__LTP__": [
    "S6-1 LTP",
    "connected to (C-R2)",
    "unnumberd/ifIndex: 1",
    "OTU-2",
    "tributary port"
  ],
  "// comment": "S6-1 LTP",
  "tp-id": "1",
  "ietf-te-topology:te-tp-id": 1,
  "ietf-te-topology:te": {
    "admin-status": "up",
    "oper-status": "up",
    "// _OBSOLETE_ ietf-otn-topology:client-facing": [
      null
    ],
  },
  "// ietf-otn-topology:supported-payload-types":
    "__DISCUSS__",
  "// _OBSOLETE_ ietf-otn-topology:protocol-type":
    "ietf-transport-types:prot-OTU2",
  "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
    "ODU"
  },
},
{
  "// __DESCRIPTION__:__LTP__": [
    "S6-2 LTP",
    "connected to (C-R3)",
    "unnumberd/ifIndex: 2",
    "OTU-2",

```

```

        "tributary port"
    ],
    "// comment": "S6-2 LTP",
    "tp-id": "2",
    "ietf-te-topology:te-tp-id": 2,
    "ietf-te-topology:te": {
        "admin-status": "up",
        "oper-status": "up",
        "// _OBSOLETE_ ietf-otn-topology:client-facing": [
            null
        ],
        "// ietf-otn-topology:supported-payload-types":
            "__DISCUSS__",
        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
            "ietf-transport-types:prot-OTU2",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
            "ODU"
    }
},
{
    "// __DESCRIPTION__:__LTP__": [
        "S6-3 LTP",
        "connected to S5-2",
        "unnumberd/ifIndex: 3",
        "OTU-4",
        "line port"
    ],
    "// comment": "S6-3 LTP",
    "tp-id": "3",
    "ietf-te-topology:te-tp-id": 3,
    "ietf-te-topology:te": {
        "admin-status": "up",
        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
            "__DISCUSS__",
        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
            "ietf-transport-types:prot-OTU4",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
            "ODU"
    }
},
{
    "// __DESCRIPTION__:__LTP__": [
        "S6-4 LTP",
        "connected to S7-2",

```

```

        "unnumberd/ifIndex: 4",
        "OTU-4",
        "line port"
    ],
    "// comment": "S6-4 LTP",
    "tp-id": "4",
    "ietf-te-topology:te-tp-id": 4,
    "ietf-te-topology:te": {
        "admin-status": "up",
        "oper-status": "up",
        "// ietf-otn-topology:supported-payload-types":
            "__DISCUSS__",
        "// _OBSOLETE_ ietf-otn-topology:protocol-type":
            "ietf-transport-types:prot-OTU4",
        "// _OBSOLETE_ ietf-otn-topology:adaptation-type":
            "ODU"
    }
}
]
}
],
"// ietf-network-topology:link":
    "Access links to be added in a future update.",
"ietf-network-topology:link": [
    {
        "// __DESCRIPTION__:__LINK__": [
            "Link from S1-2 to S3-2",
            "internal link"
        ],
        "// link-id": "S1, S1-2, S3, S3-2",
        "link-id": "10.0.0.1,2,10.0.0.3,2",
        "ietf-te-topology:te": {
            "oper-status": "up",
            "te-link-attributes": {
                "access-type": "point-to-point",
                "// comment": [
                    "external-domain container",
                    "not present for internal links"
                ],
            },
            "name": "Link between S1 and S3",
            "admin-status": "up",
            "interface-switching-capability": [
                {
                    "switching-capability":
                        "ietf-te-types:switching-otn",

```

```

        "encoding": "ietf-te-types:lsp-encoding-oduk",
        "max-lsp-bandwidth": [
            {
                "priority": 0,
                "te-bandwidth": {
                    "// _OBSOLETE_ otn": [
"_WARNING_ : technology specific bandwidth definition",
                        {
                            "rate-type": "ietf-te-types:odu2",
                            "counter": 1
                        }
                    ]
                }
            },
            {
                "priority": 1,
                "te-bandwidth": {
                    "// _OBSOLETE_ otn": [
"_WARNING_ : technology specific bandwidth definition",
                        {
                            "rate-type": "ietf-te-types:odu2",
                            "counter": 1
                        }
                    ]
                }
            },
            {
                "priority": 2,
                "te-bandwidth": {
                    "// _OBSOLETE_ otn": [
"_WARNING_ : technology specific bandwidth definition",
                        {
                            "rate-type": "ietf-te-types:odu2",
                            "counter": 1
                        }
                    ]
                }
            },
            {
                "priority": 3,
                "te-bandwidth": {
                    "// _OBSOLETE_ otn": [
"_WARNING_ : technology specific bandwidth definition",
                        {
                            "rate-type": "ietf-te-types:odu2",

```



```

        "counter": 1
      }
    ]
  },
  {
    "priority": 4,
    "te-bandwidth": {
      "// _OBSOLETE_ otn": [
        "_WARNING_ : technology specific bandwidth definition",
        {
          "rate-type": "ietf-te-types:odu2",
          "counter": 1
        }
      ]
    }
  },
  {
    "priority": 5,
    "te-bandwidth": {
      "// _OBSOLETE_ otn": [
        "_WARNING_ : technology specific bandwidth definition",
        {
          "rate-type": "ietf-te-types:odu2",
          "counter": 1
        }
      ]
    }
  },
  {
    "priority": 6,
    "te-bandwidth": {
      "// _OBSOLETE_ otn": [
        "_WARNING_ : technology specific bandwidth definition",
        {
          "rate-type": "ietf-te-types:odu2",
          "counter": 1
        }
      ]
    }
  },
  {
    "priority": 7,
    "te-bandwidth": {
      "// _OBSOLETE_ otn": [

```

```

    "_WARNING_": technology specific bandwidth definition",
    {
        "rate-type": "ietf-te-types:odu2",
        "counter": 1
    }
  ]
}
}
}
}
}
}
}
}
{
  "// __DESCRIPTION__:__LINK__": [
    "Link from S5-2 to S6-3",
    "internal link"
  ],
  "// link-id": "S5, S5-2, S6, S6-3",
  "link-id": "10.0.0.5,2,10.0.0.6,3",
  "ietf-te-topology:te": {
    "oper-status": "up",
    "te-link-attributes": {
      "access-type": "point-to-point",
      "name": "Link between S5 and S6",
      "admin-status": "up"
    }
  }
},
{
  "// __DESCRIPTION__:__LINK__": [
    "Link from S3-3 to S4-1",
    "internal link"
  ],
  "// link-id": "S3, S3-3, S4, S4-1",
  "link-id": "10.0.0.3,3,10.0.0.4,1",
  "ietf-te-topology:te": {
    "oper-status": "up",
    "te-link-attributes": {
      "access-type": "point-to-point",
      "name": "Link between S3 and S4",
      "admin-status": "up"
    }
  }
}
}

```

```

    },
    {
      "/* __DESCRIPTION__:__LINK__": [
        "Link from S5-3 to S7-1",
        "internal link"
      ],
      "/* link-id": "S5, S5-3, S7, S7-1",
      "link-id": "10.0.0.5,3,10.0.0.7,1",
      "ietf-te-topology:te": {
        "oper-status": "up",
        "te-link-attributes": {
          "access-type": "point-to-point",
          "name": "Link between S5 and S7",
          "admin-status": "up"
        }
      }
    }
  },
  {
    "/* __DESCRIPTION__:__LINK__": [
      "Link from S3-4 to S5-1",
      "internal link"
    ],
    "/* link-id": "S3, S3-4, S5, S5-1",
    "link-id": "10.0.0.3,4,10.0.0.5,1",
    "ietf-te-topology:te": {
      "oper-status": "up",
      "te-link-attributes": {
        "access-type": "point-to-point",
        "name": "Link between S3 and S5",
        "admin-status": "up"
      }
    }
  }
},
{
  "/* __DESCRIPTION__:__LINK__": [
    "Link from S4-2 to S8-3",
    "internal link"
  ],
  "/* link-id": "S4, S4-2, S8, S8-3",
  "link-id": "10.0.0.4,2,10.0.0.8,3",
  "ietf-te-topology:te": {
    "oper-status": "up",
    "te-link-attributes": {
      "access-type": "point-to-point",
      "name": "Link between S4 and S8",

```

```

        "admin-status": "up"
    }
}
},
{
    "// __DESCRIPTION__:__LINK__": [
        "Link from S2-3 to S8-2",
        "internal link"
    ],
    "// link-id": "S2, S2-3, S8, S8-2",
    "link-id": "10.0.0.2,3,10.0.0.8,2",
    "ietf-te-topology:te": {
        "oper-status": "up",
        "te-link-attributes": {
            "access-type": "point-to-point",
            "name": "Link between S2 and S8",
            "admin-status": "up"
        }
    }
}
},
{
    "// __DESCRIPTION__:__LINK__": [
        "Link from S8-2 to S2-3",
        "internal link"
    ],
    "// link-id": "S8, S8-2, S2, S2-3",
    "link-id": "10.0.0.8,2,10.0.0.2,3",
    "ietf-te-topology:te": {
        "oper-status": "up",
        "te-link-attributes": {
            "access-type": "point-to-point",
            "name": "Link between S8 and S2",
            "admin-status": "up"
        }
    }
}
},
{
    "// __DESCRIPTION__:__LINK__": [
        "Link from S3-2 to S1-2",
        "internal link"
    ],
    "// link-id": "S3, S3-2, S1, S1-2",
    "link-id": "10.0.0.3,2,10.0.0.1,2",
    "ietf-te-topology:te": {
        "oper-status": "up",

```

```

        "te-link-attributes": {
            "access-type": "point-to-point",
            "name": "Link between S3 and S1",
            "admin-status": "up"
        }
    },
    {
        "// __DESCRIPTION__:__LINK__": [
            "Link from S7-1 to S5-3",
            "internal link"
        ],
        "// link-id": "S7, S7-1, S5, S5-3",
        "link-id": "10.0.0.7,1,10.0.0.5,3",
        "ietf-te-topology:te": {
            "oper-status": "up",
            "te-link-attributes": {
                "access-type": "point-to-point",
                "name": "Link between S7 and S5",
                "admin-status": "up"
            }
        }
    },
    {
        "// __DESCRIPTION__:__LINK__": [
            "Link from S8-3 to S4-2",
            "internal link"
        ],
        "// link-id": "S8, S8-3, S4, S4-2",
        "link-id": "10.0.0.8,3,10.0.0.4,2",
        "ietf-te-topology:te": {
            "oper-status": "up",
            "te-link-attributes": {
                "access-type": "point-to-point",
                "name": "Link between S8 and S4",
                "admin-status": "up"
            }
        }
    },
    {
        "// __DESCRIPTION__:__LINK__": [
            "Link from S5-1 to S3-4",
            "internal link"
        ],
        "// link-id": "S5, S5-1, S3, S3-4",

```

```

    "link-id": "10.0.0.5,1,10.0.0.3,4",
    "ietf-te-topology:te": {
      "oper-status": "up",
      "te-link-attributes": {
        "access-type": "point-to-point",
        "name": "Link between S5 and S3",
        "admin-status": "up"
      }
    }
  },
  {
    "// __DESCRIPTION__:__LINK__": [
      "Link from S2-2 to S1-1",
      "internal link"
    ],
    "// link-id": "S2, S2-2, S1, S1-1",
    "link-id": "10.0.0.2,2,10.0.0.1,1",
    "ietf-te-topology:te": {
      "oper-status": "up",
      "te-link-attributes": {
        "access-type": "point-to-point",
        "name": "Link between S2 and S1",
        "admin-status": "up"
      }
    }
  },
  {
    "// __DESCRIPTION__:__LINK__": [
      "Link from S7-2 to S6-4",
      "internal link"
    ],
    "// link-id": "S7, S7-2, S6, S6-4",
    "link-id": "10.0.0.7,2,10.0.0.6,4",
    "ietf-te-topology:te": {
      "oper-status": "up",
      "te-link-attributes": {
        "access-type": "point-to-point",
        "name": "Link between S7 and S6",
        "admin-status": "up"
      }
    }
  },
  {
    "// __DESCRIPTION__:__LINK__": [
      "Link from S8-4 to S7-3",

```

```

        "internal link"
    ],
    "// link-id": "S8, S8-4, S7, S7-3",
    "link-id": "10.0.0.8,4,10.0.0.7,3",
    "ietf-te-topology:te": {
        "oper-status": "up",
        "te-link-attributes": {
            "access-type": "point-to-point",
            "name": "Link between S8 and S7",
            "admin-status": "up"
        }
    }
},
{
    "// __DESCRIPTION__:__LINK__": [
        "Link from S6-3 to S5-2",
        "internal link"
    ],
    "// link-id": "S6, S6-3, S5, S5-2",
    "link-id": "10.0.0.6,3,10.0.0.5,2",
    "ietf-te-topology:te": {
        "oper-status": "up",
        "te-link-attributes": {
            "access-type": "point-to-point",
            "name": "Link between S6 and S5",
            "admin-status": "up"
        }
    }
},
{
    "// __DESCRIPTION__:__LINK__": [
        "Link from S4-1 to S3-3",
        "internal link"
    ],
    "// link-id": "S4, S4-1, S3, S3-3",
    "link-id": "10.0.0.4,1,10.0.0.3,3",
    "ietf-te-topology:te": {
        "oper-status": "up",
        "te-link-attributes": {
            "access-type": "point-to-point",
            "name": "Link between S4 and S3",
            "admin-status": "up"
        }
    }
},

```

```

{
  "// __DESCRIPTION__:__LINK__": [
    "Link from S6-4 to S7-2",
    "internal link"
  ],
  "// link-id": "S6, S6-4, S7, S7-2",
  "link-id": "10.0.0.6,4,10.0.0.7,2",
  "ietf-te-topology:te": {
    "oper-status": "up",
    "te-link-attributes": {
      "access-type": "point-to-point",
      "name": "Link between S6 and S7",
      "admin-status": "up"
    }
  }
},
{
  "// __DESCRIPTION__:__LINK__": [
    "Link from S1-1 to S2-2",
    "internal link"
  ],
  "// link-id": "S1, S1-1, S2, S2-2",
  "link-id": "10.0.0.1,1,10.0.0.2,2",
  "ietf-te-topology:te": {
    "oper-status": "up",
    "te-link-attributes": {
      "access-type": "point-to-point",
      "name": "Link between S1 and S2",
      "admin-status": "up"
    }
  }
},
{
  "// __DESCRIPTION__:__LINK__": [
    "Link from S7-3 to S8-4",
    "internal link"
  ],
  "// link-id": "S7, S7-3, S8, S8-4",
  "link-id": "10.0.0.7,3,10.0.0.8,4",
  "ietf-te-topology:te": {
    "oper-status": "up",
    "te-link-attributes": {
      "access-type": "point-to-point",
      "name": "Link between S7 and S8",
      "admin-status": "up"
    }
  }
}

```



```

    }
  }
]
}
]
}
}

```

B.2. JSON Examples for Service Configuration

B.2.1. JSON Code: mpil-odu2-service-config.json

```

{
  "// __TITLE__": "ODU2 Service Configuration @ MPI1",
  "// __LAST_UPDATE__": "July 2, 2018",
  "// __RESTCONF_OPERATION__": {
    "operation": "PUT",
    "url": "http://{PNC1-ADDR}}/restconf/data/ietf-te:te"
  },
  "// __REFERENCE_DRAFTS__": {
    "ietf-te-types@2018-06-12": "draft-ietf-teas-yang-te-15",
    "ietf-routing-types@2017-12-04": "rfc8294",
    "ietf-te@2018-06-12": "draft-ietf-teas-yang-te-15",
    "ietf-otn-types@2018-06-07":
      "draft-ietf-ccamp-otn-tunnel-model-02",
    "ietf-otn-tunnel@2018-06-07":
      "draft-ietf-ccamp-otn-tunnel-model-02"
  },
  "// __MISSING_ATTRIBUTES__": true,
  "ietf-te:te": {
    "tunnels": {
      "tunnel": [
        {
          "name": "mpil-odu2-service",
          "// identifier": "ODU2-SERVICE-TUNNEL-ID @ MPI1",
          "identifier": 1,
          "description":
            "ODU2 Service implemented by ODU2 OTN Tunnel Segment @ MPI1",
          "// encoding and switching-type": "ODU",
          "encoding": "ietf-te-types:lsp-encoding-oduk ",
          "switching-type": "ietf-te-types:switching-otn",
          "// source": "None: transit tunnel segment",
          "// destination": "None: transit tunnel segment",
          "// src-tp-id": "None: transit tunnel segment",

```

```
    "// dst-tp-id": "None: transit tunnel segment",
    "// __ ACTION __ ietf-otn-tunnel:payload-treatment": [
    "This attribute should be removed in the next otn-tunnel",
    " model update"
    ],
    "ietf-otn-tunnel:src-client-signal":
    "ietf-otn-types:client-signal-ODU2",
    "// __ ACTION __ src-tpn": [
    "This attribute should be removed in the next otn-tunnel",
    " model update"
    ],
    "// __ ACTION __ src-tsg": [
    "This attribute should be removed in the next otn-tunnel",
    " model update"
    ],
    "// __ ACTION __ src-tributary-slot-count": [
    "This attribute should be removed in the next otn-tunnel",
    " model update"
    ],
    "// __ ACTION __ src-tributary-slots": [
    "This attribute should be removed in the next otn-tunnel",
    " model update"
    ],
    "ietf-otn-tunnel:dst-client-signal":
    "ietf-otn-types:client-signal-ODU2",
    "// __ ACTION __ dst-tpn": [
    "This attribute should be removed in the next otn-tunnel",
    " model update"
    ],
    "// __ ACTION __ dst-tsg": [
    "This attribute should be removed in the next otn-tunnel",
    " model update"
    ],
    "// __ ACTION __ dst-tributary-slot-count": [
    "This attribute should be removed in the next otn-tunnel",
    " model update"
    ],
    "// __ ACTION __ dst-tributary-slots": [
    "This attribute should be removed in the next otn-tunnel",
    " model update"
    ],
    "bidirectional": true,
    "// __ DEFAULT __ protection": {
    " // __ DEFAULT __ enable": false
    },
  },
```

```

    "// __ DEFAULT __ restoration": {
        "// __ DEFAULT __ enable": false
    },
    "// __ DISCUSS __ te-topology-identifier": [
        "Need to add the te-topology-identifier",
        "information. Waiting for updates to topology identifiers"
    ],
    "te-bandwidth": {
        "ietf-otn-tunnel:odu-type": "ietf-otn-types:prot-ODU2"
    },
    "// hierarchical-link":
        "Not to be specified: transit tunnel segment",
    "p2p-primary-paths": {
        "p2p-primary-path": [
            {
                "name": "mpil-odu2-tunnel-primary-path",
                "// __ DISCUSS __ path-scope": [
                    "Need to align the model based on the on-going",
                    " disucssion of the related open issue"
                ],
                "path-scope": "ietf-te-types:path-scope-segment",
                "// te-bandwidth": [
                    "None: only the tunnel bandwidth needs to be specified",
                    " in transport applications"
                ],
                "explicit-route-objects": {
                    "route-object-include-exclude": [
                        {
                            "// comment":
                                "Tunnel hand-off OTU2 ingress interface (S3-1)",
                            "index": 1,
                            "explicit-route-usage":
                                "ietf-te-types:route-include-ero",
                            "num-unnum-hop": {
                                "// node-id": "S3-NODE-ID",
                                "node-id": "10.0.0.3",
                                "// link-tp-id": "S3-1-LTP-ID",
                                "link-tp-id": 1,
                                "hop-type": "STRICT",
                                "direction": "INCOMING"
                            }
                        }
                    ],
                    {
                        "// comment": [
                            "Tunnel hand-off ODU2 ingress label (ODU2 over",

```

```

    " OTU2) at S3-1"
  ],
  "index": 2,
  "explicit-route-usage":
    "ietf-te-types:route-include-ero",
  "label-hop": {
    "te-label": {
      "// __ DISCUSS __ odu-label": [
        "How are HO-ODU (ODUk voer OTUk) label",
        " represented?"
      ],
      "// __ ACTION __ direction":
        "Check with TE Tunnel authors",
      "direction": "FORWARD "
    }
  }
},
{
  "// comment":
    "Tunnel hand-off OTU4 egress interface (S2-1)",
  "index": 3,
  "explicit-route-usage":
    "ietf-te-types:route-include-ero",
  "num-unnum-hop": {
    "// node-id": "S2-NODE-ID",
    "node-id": "10.0.0.2",
    "// link-tp-id": "S2-1-LTP-ID",
    "link-tp-id": 1,
    "hop-type": "STRICT",
    "direction": "OUTGOING"
  }
},
{
  "// comment": [
    "Tunnel hand-off ODU2 egress label (ODU2 over",
    " OTU4) at S2-1"
  ],
  "index": 4,
  "explicit-route-usage":
    "ietf-te-types:route-include-ero",
  "label-hop": {
    "te-label": {
      "ietf-otn-tunnel:tpn": 1,
      "ietf-otn-tunnel:tsg":
        "ietf-otn-types:tsg-1.25G",
    }
  }
}

```



```

    "TNBI Example for an ODU2 Head Tunnel Segment @ MPI1",
    "// encoding and switching-type": "ODU",
    "encoding": "ietf-te-types:lsp-encoding-oduk ",
    "switching-type": "ietf-te-types:switching-otn",
    "source": "10.0.0.3",
    "// destination": "None: head tunnel segment",
    "src-tp-id": "AAAB",
    "// dst-tp-id": "None: head tunnel segment",
    "ietf-otn-tunnel:src-client-signal":
    "ietf-otn-types:client-signal-ODU2",
    "ietf-otn-tunnel:dst-client-signal":
    "ietf-otn-types:client-signal-ODU2",
    "bidirectional": true,
    "// __ DEFAULT __ protection": {
    "    // __ DEFAULT __ enable": false
    },
    "// __ DEFAULT __ restoration": {
    "    // __ DEFAULT __ enable": false
    },
    "// __ DISCUSS __ te-topology-identifier":
    "Need to add the te-topology-identifier information",
    "te-bandwidth": {
    "ietf-otn-tunnel:odu-type": "ietf-otn-types:prot-ODU2"
    },
    "// __ DISCUSS __ hierarchical-link":
    "Optional: tunnel supports service, not link in the client layer",
    "p2p-primary-paths": {
    "p2p-primary-path": [
    {
    "name": "mpil-odu2-tunnel-primary-path",
    "    // __ DISCUSS __ path-scope":
    "Need to align the model",
    "path-scope": "ietf-te-types:path-scope-segment",
    "    // te-bandwidth":
    "None: only the tunnel bandwidth needed in transport",
    "explicit-route-objects": {
    "route-object-include-exclude": [
    {
    "    // comment": "Tunnel TTP in node S3",
    "index": 1,
    "explicit-route-usage":
    "ietf-te-types:route-include-ero",
    "num-unnum-hop": {
    "    // node-id": "S3-NODE-ID",
    "node-id": "10.0.0.3",

```

```

        "hop-type": "STRICT",
        "// __ ACTION __ direction":
            "Check with TE Tunnel authors",
        "direction": "OUTGOING"
    }
},
{
    "// comment":
    "Tunnel hand-off OTU4 egress interface (S2-1)",
    "index": 2,
    "explicit-route-usage":
        "ietf-te-types:route-include-ero",
    "num-unnum-hop": {
        "// node-id": "S2-NODE-ID",
        "node-id": "10.0.0.2",
        "// link-tp-id": "S2-1-LTP-ID",
        "link-tp-id": 1,
        "hop-type": "STRICT",
        "direction": "OUTGOING"
    }
},
{
    "// comment":
    "Tunnel hand-off ODU2 egress label (ODU2 over OTU4) at S2-1",
    "index": 3,
    "explicit-route-usage":
        "ietf-te-types:route-include-ero",
    "label-hop": {
        "te-label": {
            "ietf-otn-tunnel:tpn": 2,
            "ietf-otn-tunnel:tsg":
                "ietf-otn-types:tsg-1.25G",
            "ietf-otn-tunnel:ts-list": "9-16",
            "// __ ACTION __ direction":
                "Check with TE Tunnel authors",
            "direction": "FORWARD "
        }
    }
}
]
}
]
```

```

    }
  }
}

```

B.2.3. JSON Code: mpil-epl-service-config.json

```

{
  "// __TITLE__": "EPL Configuration @ MPI1",
  "// __LAST_UPDATE__": "July 2, 2018",
  "// __RESTCONF_OPERATION__": {
    "operation": "PUT",
    "url":
"http://{{PNC1}}/restconf/data/ietf-trans-client-service:ethht-svc"
  },
  "// __REFERENCE_DRAFTS__": {
    "ietf-te-types@2018-03-05": "draft-ietf-teas-yang-te-14",
    "ietf-eth-tran-types@2018-03-01":
      "draft-zheng-ccamp-otn-client-signal-yang-02",
    "ietf-routing-types@2017-12-04": "rfc8294",
    "ietf-eth-tran-service@2018-03-01":
      "draft-zheng-ccamp-otn-client-signal-yang-02"
  },
  "// __MISSING_ATTRIBUTES__": true,
  "ietf-eth-tran-service:ethht-svc": {
    "ethht-svc-instances": [
      {
        "ethht-svc-name": "mpil-epl-service",
        "ethht-svc-descr":
          "TNBI Example for an EPL over ODU2 Service @ MPI1",
        "// __ DEFAULT __ ethht-svc-type": "p2p-svc",
        "// __ DISCUSS __ te-topology-identifier": [
          "Would it be possible to use this grouping instead of",
          " re-defining the three attributes below?"
        ],
        "// __ ACTION __ access-provider-id":
          "Need to add the te-topology-identifier information",
        "// __ ACTION __ access-client-id":
          "Need to add the te-topology-identifier information",
        "// __ ACTION __ topology-id":
          "Need to add the te-topology-identifier information",
        "ethht-svc-access-ports": [
          {
            "// comment": "10GE access interface (S3-1)",
            "access-port-id": 1,

```



```
    "// access-node-id": "S3-NODE-ID",
    "access-node-id": "10.0.0.3",
    "// access-ltp-id": "S3-1-LTP-ID",
    "access-ltp-id": 1,
    "service-classification-type":
      "ietf-eth-tran-types:port-classification",
    "// __ DISCUSS __ ingress-egress-bandwidth-profile-name":
      "10G-EPL-BWP",
    "// vlan-operations":
      "None: transparent VLAN operations"
  }
],
"eth-t-svc-tunnels": [
  {
    "tunnel-name": "mpil-odu2-tunnel"
  }
],
"admin-status": "ietf-te-types:tunnel-state-up"
}
]
}
```

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Information Encoding for WSON with Impairments Validation
draft-ietf-ccamp-wson-iv-encode-01

Abstract

Impairment-Aware (IA) Routing and Wavelength Assignment (RWA) function might be required in Wavelength Switched Optical Networks (WSON) that already support RWA. This document defines proper encoding to support this operation. It goes in addition to the available impairment-free WSON encoding and it is fully compatible with it.

As the information model, the encoding is independent from control plane architectures and protocol implementations. Its definitions can be used in related protocol extensions.

Status of This Memo

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1. Introduction

In case of WSON where optical impairments play a significant role, the framework document [RFC6566] defines related control plane architectural options for Impairment Aware Routing and Wavelength Assignment (IA-RWA). This document provides a suitable encoding for the related WSON impairment information model as defined [I-D.ietf-ccamp-wson-iv-info].

This document directly refers to ITU recommendations [ITU.G680] and [ITU.G697] as already detailed in the information model.

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].

2. Encoding

This section details encoding for all elements defined within [I-D.ietf-ccamp-wson-iv-info]. Elements to encode are:

Optical Parameter (OPTICAL_PARAM)

Optical Impairment Vector (OIV)

Impairment Matrix

Impairment Resource Block Information

2.1. Optical Parameter

The OPTICAL_PARAM is defined as a sub-TLV object.

0										1										2										3									
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1								
S V										Reserved										ParamSource										ParamID									
										Value																													
										Variance (Optional)																													

The following flag is defined:

S: Standard bit.

S=1 identifies a set of parameters standardized by ITU; while
S=0 identifies a non-standardized set of parameters.

V: Variance bit.

V=0 only parameter value, V=1 parameter value and variance.

With the flag S=1 the following parameters are defined:

ParamSource = 1.

Identify the ITU document that defines the following parameter list. Currently [ITU.G697] defines this value 1 for this parameter.

ParamID.

Parameter identifier according to the source. [ITU.G697] table V.3 defines the following identifiers:

1. Total Power (dBm)
Not reported within [I-D.ietf-ccamp-wson-iv-info] parameter list but relates to Channel Power through the number of channels.
2. Channel Power (dBm).
Referred as parameter L-3 in [I-D.ietf-ccamp-wson-iv-info]
3. Reserved ("Frequency Deviation from Nominal, GHz", defined in [ITU.G697] but not used)
4. Reserved ("Wavelength Deviation from Nominal, nm", defined in [ITU.G697] but not used)
5. OSNR (db).
Referred as parameter G-1 in [I-D.ietf-ccamp-wson-iv-info]
6. Reserved. (Q Factor, a pure number).
Not reported within [I-D.ietf-ccamp-wson-iv-info] parameter list but is a known index for assessing channel quality.
7. PMD (ps).
Referred as parameter G-3 in [I-D.ietf-ccamp-wson-iv-info]
8. Residual Chromatic Dispersion (ps/nm).
Referred as parameter G-2 in [I-D.ietf-ccamp-wson-iv-info]

Value.

Value for the parameter. As defined by [ITU.G697], it is a 32 bit IEEE floating point number.

Variance.

Variance for the parameter, a 32 bit IEEE floating point number.

According to [I-D.ietf-ccamp-wson-iv-info], there are some parameters required for the IV function not listed within [ITU.G697]. Current information source for such parameters is [LS78] hence, this document proposes to use a different value for the field parameter source.

ParamSource = 0 (proposal).

List of parameters within [I-D.ietf-ccamp-wson-iv-info].

ParamID.

A number that take the following list of values.

1. Ripple (dBm). L-4 in [I-D.ietf-ccamp-wson-iv-info].
2. Channel signal-spontaneous noise figure. L-5 in [I-D.ietf-ccamp-wson-iv-info].
3. DGD, Differential Group Delay. L-8 in [I-D.ietf-ccamp-wson-iv-info].
4. Reflectance. L-11 in [I-D.ietf-ccamp-wson-iv-info].
5. Isolation. L-12 in [I-D.ietf-ccamp-wson-iv-info].
6. Channel extinction. L-13 in [I-D.ietf-ccamp-wson-iv-info].
7. Attenuation Coefficient. L-14 in [I-D.ietf-ccamp-wson-iv-info].

2.2. Impairment Vector

This sub-TLV is a list of optical parameters and they MAY have a wavelength dependency information.

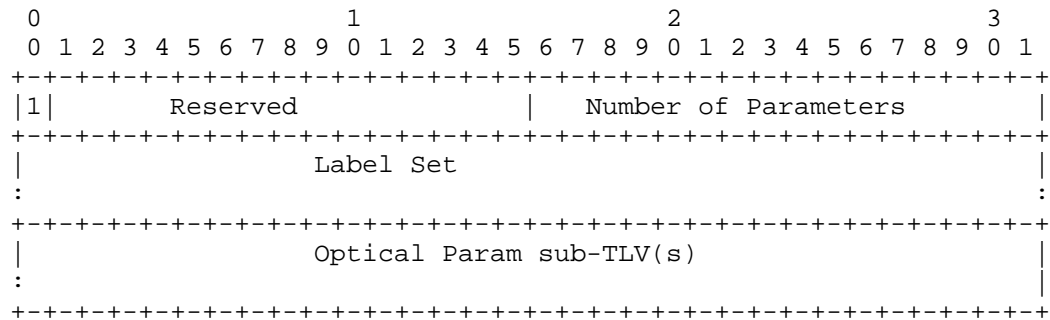
0										1										2										3											
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1
0										Reserved										Number of Parameters																					
										Optical Param sub-TLV(s)																															
:																																									

Where:

W = 0. Wavelength Dependency flag. There is no wavelength dependency.

Number of Parameters contained in this vector.

Optical Param sub-TLV(s) present a list of Object as defined in Section 2.1.



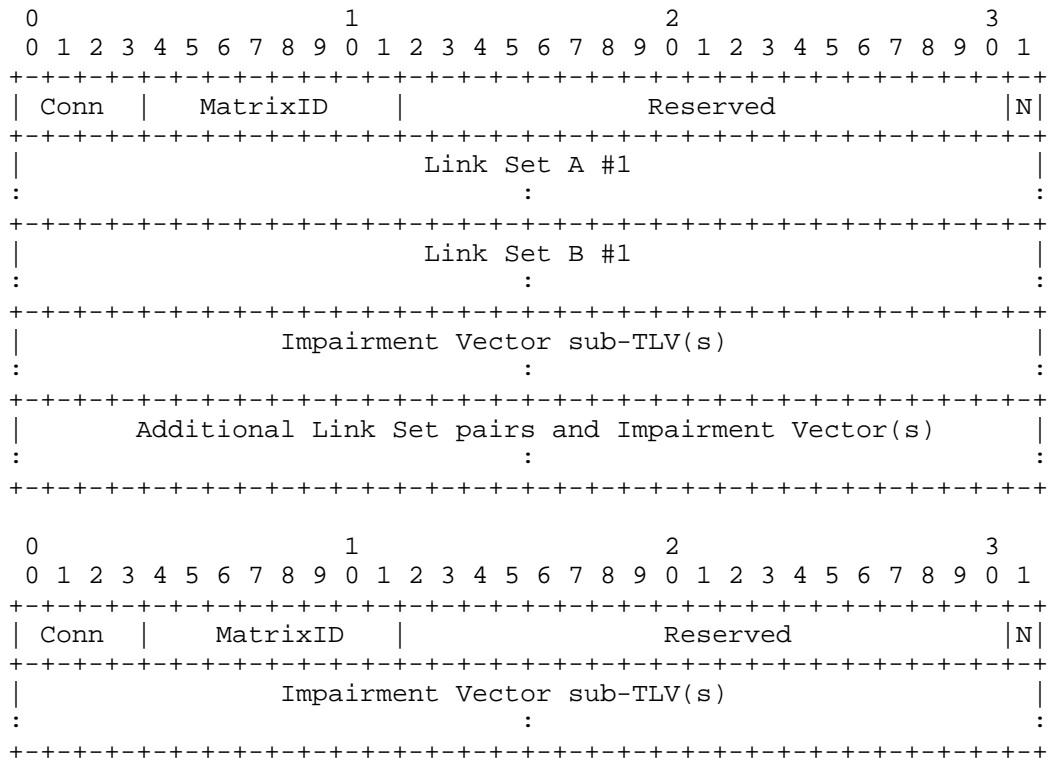
Where:

W = 1. Wavelength Dependency flag. There is wavelength dependency.

The Label Set object is defined in [RFC7579] Section 2.6. Likely an inclusive range will be the only option required by the Action defined in the Label Set.

2.3. Connectivity Matrix Field for Impairment

As defined by the [I-D.ietf-ccamp-wson-iv-info], the impairment matrix follows the same structure as the connectivity matrix. The encoding of the connectivity matrix for impairment is enhanced from the Connectivity Matrix Field as defined in Section 2.1 of [RFC7579].



Where:

Connectivity (Conn) (4 bits) has value 2 for the impairment matrix (Values 0 and 1 defined by [RFC7579]).

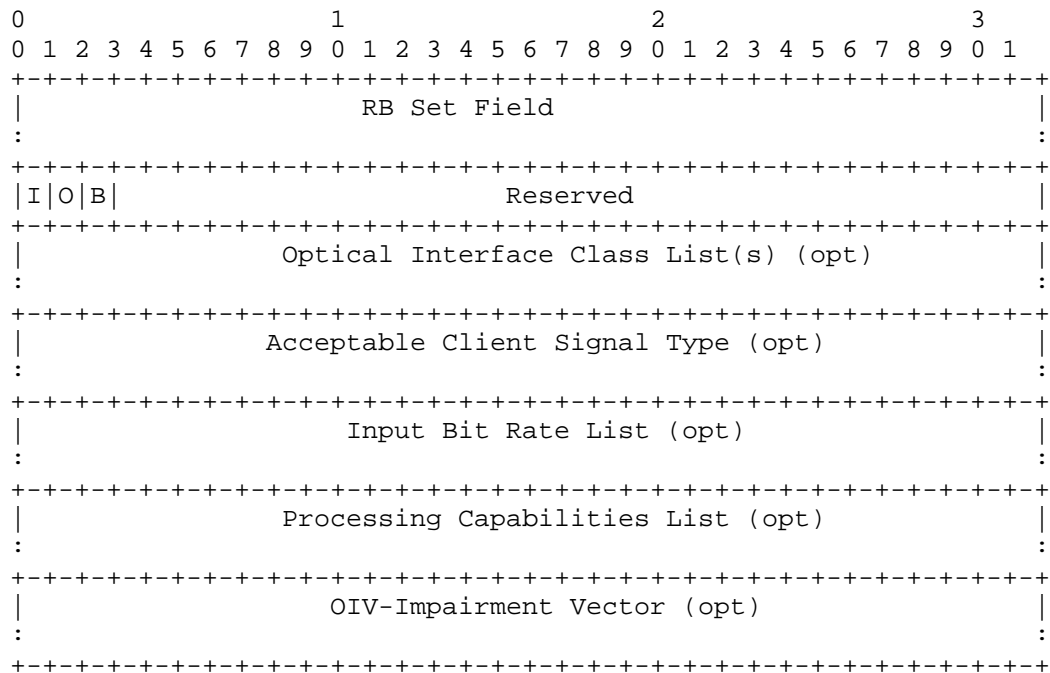
MatrixID: matrix identifier, following same rules as [RFC7579].

N: Node scope flag. With this flag set (N=0), there's no Link Set information but only a list of optical parameters TLVs that apply to the whole optical node.

The usage of multiple matrixes with connectivity type equal to 2 (Impairment Matrix) MIGHT be used to group optical parameters by connectivity. For example, if a subset of parameters apply to the whole node, a unique matrix with flag N=1 is used. At the same some another subset of parameters applies only to some LinkSet pairs, a specific Impairment Matrix will be added.

2.4. Resource Block Information

The Resource Block Information field is used to represent resource signal constraints and processing capabilities of a node. As defined by [I-D.ietf-ccamp-wson-iv-info], the concept of resource block is extended to support the description of the impairments related to that block. The encoding expands the same structure as the one defined in Section 4 of [RFC7581], with the addition of an optional Impairment Vector sub-object:



The Impairment Vector is defined within Section 2.2. All the other fields are defined within [RFC7581].

3. Acknowledgements

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5. IANA Considerations

This document does not contain any IANA request.

6. Security Considerations

This document defines an protocol-neutral encoding for an information model describing impairments in optical networks and it does not introduce any security issues. If such a encoding is put into use within a network it will by its nature contain details of the physical characteristics of an optical network. Such information would need to be protected from intentional or unintentional disclosure.

7. References

7.1. Normative References

- [ITU.G680] International Telecommunications Union, "Physical transfer functions of optical network elements", ITU-T Recommendation G.680, July 2007.
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[RFC7581] Bernstein, G., Ed., Lee, Y., Ed., Li, D., Imajuku, W., and J. Han, "Routing and Wavelength Assignment Information Encoding for Wavelength Switched Optical Networks", RFC 7581, DOI 10.17487/RFC7581, June 2015, <<https://www.rfc-editor.org/info/rfc7581>>.

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DLEP Credit-Based Flow Control Messages and Data Items
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Abstract

This document defines new DLEP protocol Data Items that are used to support credit-based flow control. The Data Items enable separate but related functions: traffic classification and credit window control. Traffic classification information is used to identify traffic flows based on frame/packet content such as destination address. Credit window control is used to regulate when data may be sent to an associated virtual or physical queue. The Data Items are defined in an extensible and reusable fashion. Their use will be mandated in other documents defining specific DLEP extensions. This document also introduces DLEP sub data items.

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1. Introduction

The Dynamic Link Exchange Protocol (DLEP) is defined in [RFC8175]. It provides the exchange of link related control information between DLEP peers. DLEP peers are comprised of a modem and a router. DLEP

defines a base set of mechanisms as well as support for possible extensions. DLEP defines Data Items which are sets of information that can be reused in DLEP messaging. The base DLEP specification does not include any flow identification beyond DLEP endpoints or flow control capability. There are various flow control techniques theoretically possible with DLEP. For example, a credit-window scheme for destination-specific flow control which provides aggregate flow control for both modem and routers has been proposed in [I-D.ietf-manet-credit-window], and a control plane pause based mechanism is defined in [I-D.ietf-manet-dlep-pause-extension].

This document defines DLEP Data Items and Messages which provide flow identification, and a flow control mechanism for traffic sent from a router to a modem. Flow control is provided using one or more logical "Credit Windows", each of which will typically be supported by an associated virtual or physical queue. Traffic sent by a router will use traffic flow classification information provided by the modem to identify which traffic is associated with each credit window. In this case, a flow is identified based on information found in a data plane header and one or more matches are associated with a single flow. (For general background on traffic classification see [RFC2475] Section 2.3.) Credit windows may be shared or dedicated on a per flow basis. The Data Items are structured to allow for reuse of the defined traffic classification information with non-credit window applications as well as reuse of the credit window based flow control with different traffic classification techniques.

This document defines traffic classification based on a DLEP destination and flows identified by either DiffServ [RFC2475] DSCPs (differentiated services codepoints) or IEEE 802.1Q [IEEE.802.1Q_2014] Ethernet Priority Code Points (PCP). The defined mechanism allows for credit windows to be shared across traffic sent to multiple DLEP destinations and flows, or used exclusively for traffic sent to a particular destination and/or flow. The extension also supports the "wildcard" matching of any flow (DSCP or PCP). Traffic classification information is provided such that it can be readily extended to support other traffic classification techniques, or be used by non-credit window related extensions, such as [I-D.ietf-manet-dlep-pause-extension] or even 5-tuple IP flows.

Note that this document defines common Messages, Data Items and mechanisms that are reusable. They are expected to be required by DLEP extensions defined in other documents such as found in [I-D.ietf-manet-dlep-da-credit-extension].

This document defines support for traffic classification using a single new Data Item in Section 2.1 for general support and two new

sub Data Items are defined to support identification of flows based on DSCPs and PCPs. The document supports credit window control by introducing two new DLEP messages in Section 3.2, and five new DLEP Data Items in Section 3.3.

1.1. Key Words

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

2. Traffic Classification

The Traffic Classification Data Item is used to represent a list of flows that may be used at the same time for traffic sent from a router to a modem. The data plane information used to identify each flow is represented in a separate sub Data Item. The Data Item and Sub Data Item structure is intended to be independent of any specific usage of the flow identification, e.g., flow control. The Sub Data Item structure is also intended to allow for future traffic classification types, e.g., 5-tuple flows. While the structure of the Data Items is extensible, actual flow information is expected to be used in an extension dependent manner. Support for DSCP and PCP-based flows are defined via individual sub Data Items below. Other types of flow identification, e.g., based on IP protocol and ports, may be defined in the future via new sub Data Items.

The list of flows contained in the Data Item can be used per sender or shared across multiple senders. Each list of flows is identified using a "Traffic Classification Identifier" or "TID" and is expected to represent a valid combination of data plane identifiers that may be used at the same time. Each flow is identified via a "Flow Identifier" or "FID". Each FID is defined in a sub Data Item which carries the data plane identifier or identifiers used to associate traffic with the flow. A DLEP destination address is also needed to complete traffic classification information used in extensions such as flow control. This information is expected to be provided in an extension specific manner. For example, this address can be provided by a modem when it identifies the traffic classification set in a Destination Up Message using the Credit Window Associate Data Item defined in Section 3.3.2. The scope of TID and FID values is a modem.

2.1. Traffic Classification Data Item

This section defines the Traffic Classification Data Item. This Data Item is used by a modem to provide a router with traffic classification information. When an extension requires use of this Data Item the Traffic Classification Data Item SHOULD be included by a modem in any Session Initialization Response Message that also indicates support for an extension that requires support for the credit window control mechanisms defined in this document, e.g., see [I-D.ietf-manet-dlep-da-credit-extension]. Updates to previously provided traffic classifications or new traffic classifications MAY be sent by a modem by including the Data Item in Session Update Messages. More than one Data Item MAY be included in a message to provide information on multiple traffic classifiers.

The set of traffic classification information provided in the data item is identified using a Traffic Classification Identifier, or TID. The actual data plane related information used in traffic classification is provided in a variable list of Traffic Classification Sub Data Items.

The format of the Traffic Classification Data Item is:

```

      0                               1                               2                               3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Data Item Type | Length |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Traffic Class. Identifier (TID) | Num SDIs | Reserved |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Traffic Classification Sub Data Item 1 |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
:                                     ...                                     :
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Traffic Classification Sub Data Item n |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+

```

Data Item Type: TBA1

Length: Variable

Per [RFC8175] Length is the number of octets in the Data Item, excluding the Type and Length fields.

Traffic Classification Identifier (TID):

A 16-bit unsigned integer identifying a traffic classification set. There is no restriction on values used by a modem, and there is no requirement for sequential or ordered values.

Num SDIs:

An 8-bit unsigned integer indicating the number of Traffic Classification Sub Data Items included in the Data Item. A value of zero (0) is allowed and indicates that no traffic should be matched against this TID.

Reserved:

MUST be set to zero by the sender (a modem) and ignored by the receiver (a router).

Traffic Classification Sub Data Item:

Zero or more Traffic Classification Sub Data Items of the format defined below MAY be included. The number MUST match the value carried in the Num SDIs field.

A router receiving the Traffic Classification Data Item MUST locate the traffic classification information that is associated with the TID indicated in each received Data Item. If no associated traffic classification information is found, the router MUST initialize a new information set using the values carried in the Data Item. When associated traffic classification information is found, the router MUST update the information using the values carried in the Data Item. In both cases, a router MUST also ensure that any data plane state, e.g., see Section 3.1, that is associated with the TID is updated as needed.

2.1.1.1. Traffic Classification Sub Data Item

All Traffic Classification Sub Data Items share a common format that is patterned after the standard DLEP Data Item format, see [RFC8175] Section 11.3. There is no requirement on, or meaning to sub Data Item ordering. Any errors or inconsistencies encountered in parsing sub Data Items are handled in the same fashion as any other Data Item parsing error encountered in DLEP.

The format of the Traffic Classification Sub Data Item is:

```

      0               1               2               3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Sub Data Item Type                               | Length |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                               Value...                               :
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

Sub Data Item Type:

A 16-bit unsigned integer that indicates the type and corresponding format of the Sub Data Item's Value field. Sub Data Item Types are scoped within the Data Item in which they are carried, i.e., the Sub Data Item Type field MUST be used together with the Data Item Type to identify the format of the Sub Data Item. Traffic Classification Sub Data Item Types are managed according to the IANA registry described in Section 6.3.

Length: Variable

Copying [RFC8175], Length is a 16-bit unsigned integer that is the number of octets in the sub Data Item, excluding the Type and Length fields.

2.2. DiffServ Traffic Classification Sub Data Item

The DiffServ Traffic Classification Sub Data Item is used to identify the set of DSCPs that should be treated as a single flow, i.e., receive the same traffic treatment. DSCPs are identified in a list of DiffServ fields. An implementation that does not support DSCPs and wants the same traffic treatment for all traffic to a destination or destinations would indicate 0 DSCPs.

The format of the DiffServ Traffic Classification Sub Data Item is:

```

      0               1               2               3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Must be one (1)                               | Length |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Flow Identifier (FID)                         | Num DSCPs | DS Field 1 |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| DS Field 2 | ... | DS Field n |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

Length: Variable

Length is defined above. For this Sub Data Item, it is equal to three (3) plus the value of the Num DSCPs field.

Flow Identifier (FID):

A 16-bit unsigned integer representing the data plane information carried in the sub Data Item that is to be used in identifying a flow. The value of 0xFFFF is reserved and MUST NOT be used in this field.

Num DSCPs:

An 8-bit unsigned integer indicating the number of DSCPs carried in the sub Data Item. A zero (0) indicates a (wildcard) match against any DSCP value.

DS Field:

Each DS Field is an 8-bit whose definition is the same as [RFC2474].

0	1	2	3	4	5	6	7
+-----+-----+-----+-----+-----+-----+-----+-----+							
DSCP				CU			
+-----+-----+-----+-----+-----+-----+-----+-----+							

DSCP: differentiated services codepoint
CU: currently unused, MUST be zero

2.2.1. Router Receive Processing

A router receiving the Traffic Classification Sub Data Item MUST validate the information on receipt, prior to using the carried information, including potentially updating the data behavior as determined by the extension requiring the use of the Sub Data Item. Validation failures MUST be treated as an error as described above.

Once validated, the receiver MUST ensure that each DS Field value is listed only once across the whole Traffic Classification Data Item. Note, this check is across the Data Item and not the individual sub Data Item. If the same DS Field value is listed more than once within the same Traffic Classification Data Item, the Data Item MUST be treated as an error as described above.

2.3. Ethernet Traffic Classification Sub Data Item

The Ethernet Traffic Classification Sub Data Item is used to identify the VLAN and PCPs that should be treated as a single flow, i.e., receive the same traffic treatment. Ethernet Priority Code Point support is defined as part of the IEEE 802.1Q [IEEE.802.1Q_2014] tag format and includes a 3 bit "PCP" field. The tag format also includes a 12 bit VLAN identifier (VID) field. PCPs are identified in a list of priority fields. An implementation that does not support PCPs and wants the same traffic treatment for all traffic to a destination or destinations would indicate 0 PCPs. Such an implementation could identify a VLAN to use per destination.

The format of the Ethernet Traffic Classification Sub Data Item is:

```

0                               1                               2                               3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
| Must be two (2) | Length |
+-----+-----+-----+-----+-----+-----+-----+-----+
| Flow Identifier (FID) | NumPCPs | VLAN Identifier (VID) |
+-----+-----+-----+-----+-----+-----+-----+-----+
| Pri. 1 | Pri. 2 | ..... | ..... | ..... | Pad |
+-----+-----+-----+-----+-----+-----+-----+-----+

```

Length: Variable

Length is defined above. For this Sub Data Item, it is equal to four (4) plus the number of octets needed to carry the carried Priority fields is indicated by the NumPCPs field. Note that as length is in octets and each Priority field is 4 bits, the additional length is the value carried in the NumPCPs field divided by two and rounded up to the next higher integer quantity.

Flow Identifier (FID):

A 16-bit unsigned integer representing the data plane information carried in the sub Data Item that is to be used in identifying a flow. The value of 0xFFFF is reserved and MUST NOT be used in this field.

Num PCPs:

A 4-bit unsigned integer indicating the number of Priority fields carried in the sub Data Item. A zero (0) indicates a (wildcard) match against any PCP value.

VLAN identifier (VID):

A 12-bit unsigned integer field indicating the VLAN to be used in traffic classification. A value of zero (0) indicates that the VID is to be ignored and any VID is to be accepted during traffic classification.

Priority:

Each Priority Field is 4-bits long and indicates a PCP field defined in [IEEE.802.1Q_2014]. Note that zero (0) is a valid value for either PCP or DEI.

```

    0   1   2   3
    +---+---+---+---+
    |       PCP       |DEI|
    +---+---+---+---+

```

PCP: Priority code point

DEI: currently unused, MUST be zero

Pad:

A 4-bit long field included when NumPCPs is an odd number. This field MUST be set to zero when added, and MUST be ignored on receipt.

2.3.1. Router Receive Processing

A router receiving the Traffic Classification Sub Data Item MUST validate the information on receipt, prior to the using the carried information, including potentially updating the data behavior as determined by the extension requiring the use of the Sub Data Item. Validation failures MUST be treated as an error as described above.

Once validated, the receiver MUST ensure that each Priority Field value is listed only once across the whole Traffic Classification Data Item. Note, this check is across the Data Item and not the individual sub Data Item. If the same Priority Field value is listed more than once within the same Traffic Classification Data Item, the Data Item MUST be treated as an error as described above.

3. Credit Window Control

This section defines additions to DLEP used in credit based flow control. In addition to the Traffic Classification Data Item, two new messages and five Data Items are defined to support credit window control. The use of credit window control impacts the data plane.

The credit window control mechanisms defined in this document support credit based flow control of traffic sent from a router to a modem. The mapping of specific flows of traffic to a particular credit window is based on the Traffic Classification Data Item defined in Section 2.1. Both types of DLEP endpoints, i.e., a router and a modem, negotiate the use of extension during session initialization, e.g., see [I-D.ietf-manet-dlep-da-credit-extension]. When using credit windows, data traffic is only allowed to be sent by the router to the modem when there are credits available.

Credits are managed on a per logical "Credit Windows" basis. Each credit window can be thought of as corresponding to a queue within a modem. Credit windows may be shared across, or dedicated to, destinations and data plane identifiers, e.g., DSCPs, at a granularity that is appropriate for a modem's implementation and its attached transmission technology. As defined below, there is a direct one-for-one mapping of credit windows to flows as identified by FIDs carried within the Traffic Classification Data Item. Modems pass to the router information on their credit windows and FIDs prior to a router being able to send data when an extension requiring the use of credit window control is used. In addition to the traffic classification information associated with an FID, routers provide an initial credit window size, as well as the maximum size of the logical queue associated with each credit window. The maximum size is included for informative and potential future uses.

Modems provide an initial credit window size at the time of "Credit Window Initialization". Such initialization can take place during session initiation or any point thereafter. It can also take place when rate information changes. Additional "Credit Grants", i.e., increments to Credit Window size, are provided using a Destination Up or the new "Credit Control" Message. A router provides its view of the Credit Window, which is known as "Status", in Destination Up Response and the new "Credit Control Response" Messages. Routers can also request credits using the new "Credit Control" Message.

When modems provide credits to a router, they will need to take into account any overhead of their attached transmission technology and map it into the credit semantics defined in this document. In particular, the credit window is defined below to include per frame (packet) MAC headers, and this may not match the actual overhead of the modem attached transmission technology. In that case a direct mapping, or an approximation will need to be made by the modem to provide appropriate credit values.

Actual flows of traffic are mapped to credit windows based on flow identification information provided by modems in the Traffic Classification Data item defined in Section 2. This data item

supports traffic classification on a per destination or more fine grain level. Routers use the combination of the DLEP identified destination and flow information associated with a credit window in order to match traffic they send to specific credit windows.

When a destination becomes reachable, a modem "Associates" (identifies) the appropriate traffic classification information via the TID to be used for traffic sent by the router to that destination. As defined, each credit window has a corresponding FID. This means that the use of FIDs, TIDs and the association of a TID to a DLEP destination enables a modem to share or dedicate resources as needed to match the specifics of its implementation and its attached transmission technology.

The defined credit window control has similar objectives as the control found in [I-D.ietf-manet-credit-window]. One notable difference from that credit control is that in this document, credits are never provided by the router to the modem.

3.1. Data Plane Considerations

When credit windowing is used, a router MUST NOT send data traffic to a modem for forwarding when there are no credits available in the associated Credit Window. This document defines credit windows in octets. A credit window value MUST be larger than the number of octets contained in a packet, including any MAC headers used between the router and the modem, in order for the router to send the packet to a modem for forwarding. The credit window is decremented by the number of sent octets.

A router MUST identify the credit window associated with traffic sent to a modem based on the traffic classification information provided in the Data Items defined in this document. Note that routers will typically view a DLEP destination as the next hop MAC address.

3.2. Credit Window Messages

Two new messages are defined in support for credit window control: the Credit Control and the Credit Control Response Message. Sending and receiving both message types is REQUIRED to support the credit window control defined in this document.

3.2.1. Credit Control Message

Credit Control Messages are sent by modems and routers. Each sender is only permitted to have one message outstanding at one time. That is, a sender (i.e., modem or router) MUST NOT send a second or any

subsequent Credit Control Message until a Credit Control Response Message is received from its peer (i.e., router or modem).

Credit Control Messages are sent by modems to provide credit window increases. Modems send credit increases when there is transmission or local queue availability that exceeds the credit window value previously provided to the router. Modems will need to balance the load generated by sending and processing frequent credit window increases against a router having data traffic available to send, but no credits available.

Credit Control Messages MAY be sent by routers to request credits and provide window status. Routers will need to balance the load generated by sending and processing frequent credit window requests against a having data traffic available to send, but no credits available.

The Message Type value in the DLEP Message Header is set to TBA2.

A message sent by a modem, MUST contain one or more Credit Window Grant Data Items as defined below in Section 3.3.3. A router receiving this message MUST respond with a Credit Control Response Message.

A message sent by a router, MUST contain one or more Credit Window Request Data Items defined below in Section 3.3.5 and SHOULD contain a Credit Window Status Data Item, defined in Section 3.3.4, corresponding to each credit window request. A modem receiving this message MUST respond with a Credit Control Response Message based on the received message and Data Item and the processing defined below, which will typically result in credit window increments being provided.

Specific processing associated with each Credit Data Item is provided below.

3.2.2. Credit Control Response Message

Credit Control Response Messages are sent by routers to report the current Credit Window for a destination. A message sent by a router, MUST contain one or more Credit Window Status Data Items as defined below in Section 3.3.4. Specific receive processing associated with the Credit Window Status Data Item is provided below.

Credit Control Response Messages sent by modems MUST contain one or more Credit Window Grant Data Items. A Data Item for every Credit Window Request Data Item contained in the corresponding Credit Control Response Message received by the modem MUST be included.

Each Credit Grant Data Item MAY provide zero or more additional credits based on the modem's transmission or local queue availability. Specific receive processing associated with each Grant Data Item is provided below.

The Message Type value in the DLEP Message Header is set to TBA3.

3.3. Credit Window Control Data Items

Five new Data Items are defined to support credit window control. The Credit Window Initialization Data Item is used by a modem to identify a credit window and set its size. The Credit Window Association Data Item is used by a modem to identify which traffic classification identifiers (flows) should be used when sending traffic to a particular DLEP identified destination. The Credit Window Grant is used by a modem to provide additional credits to a router. The Credit Request is used by a router to request additional credits. The Credit Window Status is used to advertise the sender's view of number of available credits for state synchronization purposes.

Any errors or inconsistencies encountered in parsing Data Items are handled in the same fashion as any other data item parsing error encountered in DLEP, see [RFC8175]. In particular, the node parsing the Data Item MUST terminate the session with a Status Data Item indicating Invalid Data.

3.3.1. Credit Window Initialization

The Credit Window Initialization Data Item is used by a modem to identify a credit window and set its size. This Data Item SHOULD be included in any Session Initialization Response Message that also indicates support for an extension that requires support for the credit window control mechanisms defined in this document, e.g., see [I-D.ietf-manet-dlep-da-credit-extension]. Updates to previously identified credit windows or new credit windows MAY be sent by a modem by including the Data Item in Session Update Messages. More than one data item MAY be included in a message to provide information on multiple credit windows.

The Credit Window Initialization Data Item identifies a credit window using a Flow Identifier, or FID. It also provides the size of the identified credit window. Finally, a queue size (in bytes) is provided for informational purposes. Note that to be used, a FID must be defined within a Traffic Classification Data Item and the associated TID must be provided via a Credit Window Association Data Item.

Value	Scale

0	B - Bytes (Octets)
1	KB - Kilobytes (B/1024)
2	MB - Megabytes (KB/1024)
3	GB - Gigabytes (MB/1024)

Credit Window Size:

A 24-bit unsigned integer representing the maximum size, in the octet scale indicated by the Scale field, of the associated credit window.

A router that receives a Credit Window Initialization Data Item MUST ensure that the FID field value has been provided by the modem in a Traffic Classification Data Item carried in either the current or previous message. If the FID cannot be found the router SHOULD report or log this information. Note that no traffic will be associated with the credit window in this case. After FID validation, the router MUST locate the credit window that is associated with the FID indicated in each received Data Item. If no associated credit window is found, the router MUST initialize a new credit window using the values carried in the Data Item. When an associated credit window is found, the router MUST update the credit window and associated data plane state using the values carried in the Data Item. It is worth noting, that such updates can result in a credit window size being reduced, for example, due to a transmission rate change on the modem.

3.3.2. Credit Window Associate

The Credit Window Associate Data Item is used by a modem to associate traffic classification information with a destination. The traffic classification information is identified using a TID value that has previously been sent by the modem or is listed in a Traffic Classification Data Item carried in the same message as the Data Item.

A single Credit Window Associate Data Item MUST be included in all Destination Up and Destination Update Messages sent by a modem when the credit window control defined in this document is used. Note that a TID will not be used unless it is listed in a Credit Window Associate Data Item.

The format of the Credit Window Associate Data Item is:

```

      0                   1                   2                   3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Data Item Type                               | Length (2)          |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|Traffic Class. Identifier (TID)|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

Data Item Type: TBA5

Length: 2

Per [RFC8175] Length is the number of octets in the Data Item. It MUST be equal to two (2).

Traffic Classification Identifier (TID):

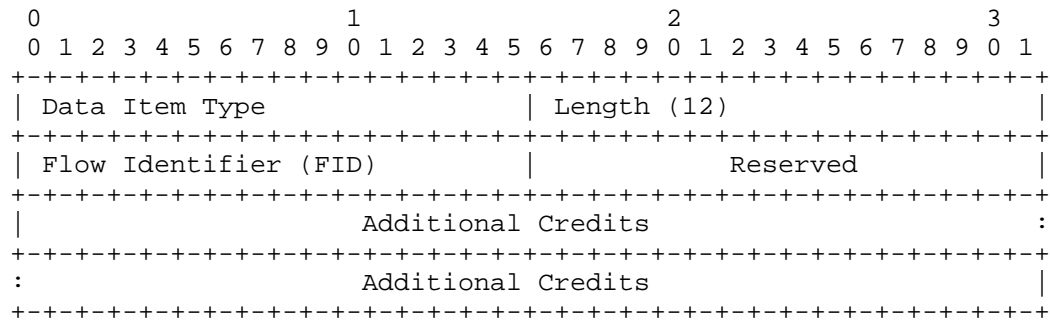
A 16-bit unsigned integer identifying a traffic classification set that has been identified in a Traffic Classification Data Item, see Section 2.1.

A router that receives the Credit Window Associate Data Item MUST locate the traffic classification information indicated by the received TID. If no corresponding information can be located, the Data Item MUST be treated as an error as described above. Once the traffic classification information is located, it MUST be associated with the destination and the router MUST ensure that any data plane state, see Section 3.1, that is associated with the TID and its corresponding FIDs is updated as needed.

3.3.3. Credit Window Grant

The Credit Window Grant Data Item is used by a modem to provide credits to a router. One or more Credit Window Grant Data Items MAY be carried in the DLEP Destination Up, Destination Announce Response, Destination Update, Credit Control Messages, and Credit Control Response Messages. Multiple Credit Window Grant Data Items in a single message are used to indicate different credit values for different credit windows. In all message types, this Data Item provides an additional number of octets to be added to the indicated credit window. Credit windows are identified using FID values that have been previously been sent by the modem or are listed in a Credit Window Initialization Data Item carried in the same messages as the Data Item.

The format of the Credit Window Grant Data Item is:



Data Item Type: TBA6

Length: 12

Per [RFC8175], Length is the number of octets in the Data Item. It MUST be equal to twelve (12).

Flow Identifier (FID):

A flow identifier as defined by the Traffic Classification Data Item. The FID also uniquely identifies a credit window.

Additional Credit:

A 64-bit unsigned integer representing the credits, in octets, to be added to the Credit Window. This value includes MAC headers as seen on the link between the modem and router. A value of zero indicates that no additional credits are being provided.

When receiving this Data Item, a router MUST identify the credit window indicated by the FID. If the FID is not known to the router, it SHOULD report or log this information and discard the Data Item. It is important to note that while this Data Item can be received in a destination specific message, credit windows are managed independently from the destination identified in the message carrying this Data Item, and the indicated FID MAY even be disjoint from the identified destination.

Once the credit window is identified, the credit window size MUST be increased by the value contained in the Additional Credits field. If the increase results in a window overflow, i.e., the size of the credit window after the increase is smaller than the original credit window size, the Credit Window must be set to its maximum (0xFFFFFFFFFFFFFFFF).

No response is sent by the router to a modem after processing a Credit Window Grant Data Item received in a Credit Control Response Message. In other cases, the receiving router MUST send a Credit Window Status Data Item or items reflecting the resulting Credit Window value of the updated credit window. When the Credit Grant Data Item is received in a Destination Up Message, the Credit Window Status Data Item(s) MUST be sent in the corresponding Destination Up Response Message. Otherwise, a Credit Control Message MUST be sent.

3.3.4. Credit Window Status

The Credit Window Status Data Item is used by a router to report the current credit window size to its peer modem. One or more Credit Window Status Data Items MAY be carried in a Destination Up Response Message or a Credit Control Response Message. As discussed above, the Destination Up Response Message is used when the Data Item is sent in response to a Destination Up Message, and the Credit Control Response Message is sent in response to a Credit Control Message. Multiple Credit Window Status Data Items in a single message are used to indicate different sizes of different credit windows. Similar to the Credit Window Grant, credit windows are identified using FID values that have been previously sent by the modem.

The format of the Credit Window Status Data Item is:

0												1												2												3											
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1																
Data Item Type												Length (12)																																			
Flow Identifier (FID)												Reserved																																			
Credit Window Size																								:																							
:												Credit Window Size																																			

Data Item Type: TBA7

Length: 12

Per [RFC8175] Length is the number of octets in the Data Item. It MUST be equal to twelve (12).

Flow Identifier (FID):

A flow identifier as defined by the Traffic Classification Data Item. The FID also uniquely identifies a credit window.

Credit Window Size:

A 64-bit unsigned integer, indicating the current number of credits, in octets, available for the router to send to the modem. This is referred to as the Modem Receive Window in [I-D.ietf-manet-credit-window].

When receiving this Data Item, a modem MUST identify the credit window indicated by the FID. If the FID is not known to the modem, it SHOULD report or log this information and discard the Data Item. As with the Credit Window Grant Data Item, the FID MAY be unrelated to the Destination indicated in the message carrying the Data Item.

Once the credit window is identified, the modem SHOULD check the received Credit Window Size field value against the outstanding credit window's available credits at the time the most Credit Window Initialization or Grant Data Item associated with the indicated FID was sent. If the values significantly differ, i.e., greater than can be accounted for based on observed data frames, then the modem SHOULD send a Credit Window Initialization Data Item to reset the associated credit window size to the modem's current view of the available credits. As defined above, Credit Window Initialization Data Items are sent in Session Update Messages. When multiple Data Items need to be sent, they SHOULD be combined into a single message when possible. Alternatively, and also in cases where there are small differences, the modem MAY adjust the values sent in Credit Window Grant Data Items to account for the reported Credit Window.

3.3.5. Credit Window Request

The Credit Window Request Data Item is used by a router to request additional credits for particular credit windows. Credit Window Request Data Items are carried in Credit Control Messages, and one or more Credit Window Request Data Items MAY be present in a message.

Credit windows identified using a FID as defined above in Section 3.3.1. Multiple FIDs MAY be present to allow for the case where the router identifies that credits are needed in multiple credit windows. A special FID value, as defined below, is used to indicate that a credit request is being made across all queues.

The format of the Credit Window Request Data Item is:

```

      0               1               2               3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
| Data Item Type                                     | Length |
+-----+-----+-----+-----+-----+-----+-----+-----+
| Flow Identifier (FID)                             | ...      | :
+-----+-----+-----+-----+-----+-----+-----+-----+
: ...                                               | Flow Identifier (FID) |
+-----+-----+-----+-----+-----+-----+-----+-----+

```

Data Item Type: TBA8

Length: Variable

Per [RFC8175] Length is the number of octets in the Data Item, excluding the Type and Length fields. It will equal the number of FID fields carried in the Data Item times 2 and MUST be at least 2.

Flow Identifier (FID):

A flow identifier as defined by the Traffic Classification Data Item. The FID also uniquely identifies a credit window. The special value of 0xFFFF indicates that the request applies to all FIDs.

A modem receiving this Data Item MUST provide a Credit Increment for the indicated credit windows via Credit Window Grant Data Items carried in a new Credit Control Message. Multiple values and queue indexes SHOULD be combined into a single Credit Control Message when possible. Unknown FID values SHOULD be reported or logged and then ignored by the modem.

3.4. Management Considerations

This section provides several network management guidelines to implementations supporting the credit window mechanisms defined in this document.

Modems MAY support the configuration of the number of credit windows (queues) to advertise to a router.

Routers may have limits on the number of queues that they can support and, perhaps, even limits in supported credit window combinations, e.g., if per destination queues can even be supported at all. When modem-provided credit window information exceeds the capabilities of a router, the router MAY use a subset of the provided credit windows. Alternatively, a router MAY reset the session and indicate that the

extension is not supported. In either case, the mismatch of capabilities SHOULD be reported to the user via normal network management mechanisms, e.g., user interface or error logging.

4. Compatibility

The data items defined in this document will only be used when extensions require their use.

5. Security Considerations

This document introduces credit window control and flow mechanisms to DLEP. These mechanisms do not inherently introduce any additional threats above those documented in [RFC8175]. The approach taken to Security in that document applies equally to the mechanism defined in this document.

6. IANA Considerations

This document requests the assignment of several values by IANA. All assignments are to registries defined by [RFC8175].

6.1. Message Values

This document requests 2 new assignments to the DLEP Message Registry named "Message Values" in the range with the "Specification Required" policy. The requested values are as follows:

Type Code	Description
TBA2	Credit Control
TBA3	Credit Control Response

Table 1: Requested Message Values

6.2. Data Item Values

This document requests the following new assignments to the DLEP Data Item Registry named "Data Item Type Values" in the range with the "Specification Required" policy. The requested values are as follows:

Type Code	Description
TBA1	Traffic Classification
TBA4	Credit Window Initialization
TBA5	Credit Window Association
TBA6	Credit Window Grant
TBA7	Credit Window Status
TBA8	Credit Window Request

Table 2: Requested Data Item Values

6.3. DLEP Traffic Classification Sub Data Item Registry

Upon approval of this document, IANA is requested to create a new DLEP registry, named "Traffic Classification Sub Data Item Type Values". The registry shall identify the type code value, the Data Item which may use the value, and a description of the value. While the same value may be reused in different Data Items, this is not recommended at this time.

The following table provides initial registry values and the [RFC8126] defined policies that should apply to the registry:

Type Code	Description
0	Reserved
1	DiffServ Traffic Classification
2	Ethernet Traffic Classification
3-65407	Specification Required
65408-65534	Private Use
65535	Reserved

Table 3: Initial Registry Values

7. References

7.1. Normative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.
- [RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <<https://www.rfc-editor.org/info/rfc8174>>.
- [RFC8175] Ratliff, S., Jury, S., Satterwhite, D., Taylor, R., and B. Berry, "Dynamic Link Exchange Protocol (DLEP)", RFC 8175, DOI 10.17487/RFC8175, June 2017, <<https://www.rfc-editor.org/info/rfc8175>>.

7.2. Informative References

- [I-D.ietf-manet-credit-window] Ratliff, S., "Credit Windowing extension for DLEP", draft-ietf-manet-credit-window-07 (work in progress), November 2016.
- [I-D.ietf-manet-dlep-da-credit-extension] Cheng, B., Wiggins, D., and L. Berger, "DLEP DiffServ Aware Credit Window Extension", draft-ietf-manet-dlep-da-credit-extension-05 (work in progress), May 2018.
- [I-D.ietf-manet-dlep-pause-extension] Cheng, B., Wiggins, D., and L. Berger, "DLEP Control Plane Based Pause Extension", draft-ietf-manet-dlep-pause-extension-03 (work in progress), March 2018.
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- [RFC8126] Cotton, M., Leiba, B., and T. Narten, "Guidelines for Writing an IANA Considerations Section in RFCs", BCP 26, RFC 8126, DOI 10.17487/RFC8126, June 2017, <<https://www.rfc-editor.org/info/rfc8126>>.

Appendix A. Acknowledgments

The sub Data Item format was inspired by Rick Taylor's "Data Item Containers". He also proposed the separation of credit windows from traffic classification at IETF98. Many useful comments were received from contributors to the MANET working group. This document was derived from [I-D.ietf-manet-dlep-da-credit-extension] as a result of discussions at IETF101.

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DLEP DiffServ Aware Credit Window Extension
draft-ietf-manet-dlep-da-credit-extension-05

Abstract

This document defines an extension to the DLEP protocol that enables a DiffServ aware credit-window scheme for destination-specific and shared flow control.

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 Dynamic Link Exchange Protocol (DLEP) is defined in [RFC8175]. It provides the exchange of link related control information between DLEP peers. DLEP peers are comprised of a modem and a router. DLEP defines a base set of mechanisms as well as support for possible extensions. This document defines one such extension.

The base DLEP specification does not include any flow control capability. There are various flow control techniques theoretically possible with DLEP. For example, a credit-window scheme for destination-specific flow control which provides aggregate flow control for both modem and routers has been proposed in [I-D.ietf-manet-credit-window].

This document defines a DLEP extension which provides a flow control mechanism for traffic sent from a router to a modem. Flow control is provided using one or more logical "Credit Windows", each of which will typically be supported by an associated virtual or physical queue. Traffic sent by a router will use traffic flow classification information provided by the modem to identify which traffic is associated with each credit window. (For general background on traffic classification see [RFC2475] Section 2.3.) Credit windows may be shared or dedicated on a per flow basis. The extension is structured to allow for reuse of the defined credit window based flow control with different traffic classification techniques.

This document uses the traffic classification and credit window control mechanisms defined in [I-D.ietf-manet-credit-flow-control] to provided credit window based flow control based on on DLEP destination and DiffServ [RFC2475] DSCPs (differentiated services codepoints). The defined mechanism allows for credit windows to be shared across traffic sent to multiple DLEP destinations and DSCPs,

or used exclusively for traffic sent to a particular destination and/or DSCP. The extension also supports the "wildcard" matching of any DSCP.

The extension defined in this document is referred to as "DiffServ Aware Credit Window" or, more simply, the "DA Credit" extension. The reader should be familiar with both the traffic classification and credit window control mechanisms defined in [I-D.ietf-manet-credit-flow-control].

This document defines a new DLEP Extension Type Value in Section 2 which is used to indicate support for the extension.

1.1. Key Words

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

2. Extension Usage and Identification

The extension defined in this document is composed of the mechanisms and processing defined in [I-D.ietf-manet-credit-flow-control]. To indicate that the DiffServ Aware Credit Window Extension is to be used, an implementation MUST include the DiffServ Aware Credit Window Type Value in the Extensions Supported Data Item. The Extensions Supported Data Item is sent and processed according to [RFC8175]. Any implementation that indicates use of the DiffServ Aware Credit Window Extension MUST support all Messages, Data Items, the DiffServ Traffic Classification Sub Data Item, and all related processing defined in [I-D.ietf-manet-credit-flow-control].

The DiffServ Aware Credit Window Extension Type Value is TBA1, see Section 5.

3. Management Considerations

This section provides several network management guidelines to implementations supporting the DiffServ Aware Credit Window Extension.

The use of the extension defined in this document SHOULD be configurable on both modems and routers.

Modems SHOULD support the configuration of DSCP to credit window (queue) mapping.

Modems MAY support the configuration of the number of credit windows (queues) to advertise to a router.

Routers may have limits on the number of queues that they can support and, perhaps, even limits in supported credit window combinations, e.g., if per destination queues can even be supported at all. When modem-provided credit window information exceeds the capabilities of a router, the router MAY use a subset of the provided credit windows. Alternatively, a router MAY reset the session and indicate that the extension is not supported. In either case, the mismatch of capabilities SHOULD be reported to the user via normal network management mechanisms, e.g., user interface or error logging.

4. Security Considerations

This document defines a DLEP extension that uses base DLEP mechanisms and the credit window control and flow mechanisms defined in [I-D.ietf-manet-credit-flow-control]. The use of those mechanisms, and the introduction of a new extension, do not inherently introduce any additional threats above those documented in [RFC8175]. The approach taken to Security in that document applies equally to the mechanism defined in this document.

5. IANA Considerations

This document requests one assignment by IANA. All assignments are to registries defined by [RFC8175].

5.1. Extension Type Value

This document requests 1 new assignment to the DLEP Extensions Registry named "Extension Type Values" in the range with the "Specification Required" policy. The requested value is as follows:

Code	Description
TBA1	DiffServ Aware Credit Window

Table 1: Requested Extension Type Value

6. References

6.1. Normative References

- [I-D.ietf-manet-credit-flow-control]
IETF, "DLEP Credit-Based Flow Control Messages and Data Items", April 2018.
- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.
- [RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <<https://www.rfc-editor.org/info/rfc8174>>.
- [RFC8175] Ratliff, S., Jury, S., Satterwhite, D., Taylor, R., and B. Berry, "Dynamic Link Exchange Protocol (DLEP)", RFC 8175, DOI 10.17487/RFC8175, June 2017, <<https://www.rfc-editor.org/info/rfc8175>>.

6.2. Informative References

- [I-D.ietf-manet-credit-window]
Ratliff, S., "Credit Windowing extension for DLEP", draft-ietf-manet-credit-window-07 (work in progress), November 2016.
- [RFC2475] Blake, S., Black, D., Carlson, M., Davies, E., Wang, Z., and W. Weiss, "An Architecture for Differentiated Services", RFC 2475, DOI 10.17487/RFC2475, December 1998, <<https://www.rfc-editor.org/info/rfc2475>>.

Appendix A. Acknowledgments

The sub data item format was inspired by Rick Taylor's "Data Item Containers". He also proposed the separation of credit windows from traffic classification at IETF98. Many useful comments were received from contributors to the MANET working group.

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February 21, 2018

DLEP Latency Range Extension
draft-ietf-manet-dlep-latency-extension-03

Abstract

This document defines an extension to the DLEP protocol to provide the range of latency that may be experienced on a link.

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 Dynamic Link Exchange Protocol (DLEP) is defined in [RFC8175]. It provides the exchange of link related control information between DLEP peers. DLEP peers are comprised of a modem and a router. DLEP defines a base set of mechanisms as well as support for possible extensions. This document defines one such extension.

The base DLEP specification includes the Latency metric which provides a single latency value on a link, which is implementation dependent. This document adds the ability to relay the minimum and maximum latency range seen on a link. The extension defined in this document is referred to as "Latency Range".

This document defines a new DLEP Extension Type Value in Section 2 which is used to indicate the use of the extension, and one new DLEP Data Item in Section 3.

1.1. Key Words

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

2. Extension Usage and Identification

The use of the Latency Range Extension SHOULD be configurable. To indicate that the Latency Range Extension is to be used, an implementation MUST include the Latency Range Extension Type Value in the Extensions Supported Data Item. The Extensions Supported Data Item is sent and processed according to [RFC8175].

Note: the usage of the extension defined in this document does not impact processing associated with the Latency Data Item defined in [RFC8175].

The Latency Range Extension Type Value is TBA1, see Section 5.

3. Latency Range Data Item

The Latency Range Data Item serves much the same purpose as the Latency Data Item defined in [RFC8175] with the addition of being able to communicate the latency range that may be experienced by traffic on a link. The Latency Range Data Item MAY be carried in any message where the Latency Data Item [RFC8175] is allowed and is carried as an additional data item. When present, the Latency Range Data Item MUST be processed according to the same rules as the Latency Data Item defined in [RFC8175].

The format of the Latency Range Data Item is:

```

      0               1               2               3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
| Data Item Type                                     | Length |
+-----+-----+-----+-----+-----+-----+-----+-----+
|                                     Maximum Latency                                     :
+-----+-----+-----+-----+-----+-----+-----+-----+
:                                     Maximum Latency                                     |
+-----+-----+-----+-----+-----+-----+-----+-----+
|                                     Minimum Latency                                     :
+-----+-----+-----+-----+-----+-----+-----+-----+
:                                     Minimum Latency                                     |
+-----+-----+-----+-----+-----+-----+-----+-----+

```

Data Item Type: TBA2

Length: 16

Maximum Latency:

A 64-bit unsigned integer, representing the longest transmission delay, in microseconds, that a packet encounters as it is transmitted over the link.

Minimum Latency:

A 64-bit unsigned integer, representing the shortest transmission delay, in microseconds, that a packet encounters as it is transmitted over the link.

4. Security Considerations

The extension introduces a new Data Item for the DLEP protocol. The extension does not inherently introduce any additional threats above those documented in [RFC8175]. The approach taken to Security in that document applies equally when running the extension defined in this document.

5. IANA Considerations

This document requests the assignment of 2 values by IANA. All assignments are to registries defined by [RFC8175].

5.1. Extension Type Value

This document requests one new assignment to the DLEP Extensions Registry named "Extension Type Values" in the range with the "Specification Required" policy. The requested value is as follows:

Code	Description
TBA1	Latency Range

Table 1: Requested Extension Type Value

5.2. Data Item Value

This document requests one new assignment to the DLEP Data Item Registry named "Data Item Type Values" in the range with the "Specification Required" policy. The requested values are as follows:

Type	Code	Description
TBA2		Latency Range

Table 2: Requested Data Item Values

6. Normative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.

- [RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <<https://www.rfc-editor.org/info/rfc8174>>.
- [RFC8175] Ratliff, S., Jury, S., Satterwhite, D., Taylor, R., and B. Berry, "Dynamic Link Exchange Protocol (DLEP)", RFC 8175, DOI 10.17487/RFC8175, June 2017, <<https://www.rfc-editor.org/info/rfc8175>>.

Appendix A. Acknowledgments

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February 20, 2018

DLEP Multi-Hop Forwarding Extension
draft-ietf-manet-dlep-multi-hop-extension-05

Abstract

This document defines an extension to the DLEP protocol that enables the reporting and control of Multi-Hop Forwarding by DLEP capable modems.

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 Dynamic Link Exchange Protocol (DLEP) is defined in [RFC8175]. It provides the exchange of link related control information between DLEP peers. DLEP peers are comprised of a modem and a router. DLEP defines a base set of mechanisms as well as support for possible extensions. This document defines one such extension.

Some modem technologies support connectivity to destinations via multi-hop forwarding. DLEP Destination messages can be used to report such connectivity, see [RFC8175], but do not provide any information related to the number or capacity of the hops. The extension defined in this document enables modems to inform routers when multi-hop forwarding is being used, and routers to request that modems change multi-hop forwarding behavior. The extension defined in this document is referred to as "Multi-Hop Forwarding".

This document defines a new DLEP Extension Type Value in Section 2 which is used to indicate the use of the extension, and three new DLEP Data Items in Section 3.

1.1. Key Words

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

2. Extension Usage and Identification

The use of the Multi-Hop Forwarding Extension SHOULD be configurable. To indicate that the extension is to be used, an implementation MUST include the Multi-Hop Forwarding Extension Type Value in the Extensions Supported Data Item. The Extensions Supported Data Item is sent and processed according to [RFC8175].

The Multi-Hop Forwarding Extension Type Value is TBA1, see Section 5.

3. Extension Data Items

Three data items are defined by this extension. The Hop Count Data Item is used by a modem to provide the number of network hops traversed to reach a particular destination. The Hop Control Data Item is used by a router to request that a modem alter connectivity to a particular destination. The Suppress Forwarding Data Item is used by a router to request that a modem disable multi-hop forwarding on either a device or destination basis.

3.1. Hop Count

The Hop Count Data Item is used by a modem to indicate the number of physical hops between the modem and a specific destination. In other words, each hop represents a transmission and the number of hops is equal to the number of transmissions required to go from a router connected modem to the destination's connected modem. The minimum number of hops is 1, which represents transmission to destinations that are directly reachable via the router's locally connected modem.

The data item also contains an indication of when a destination which currently has a hop count of greater than one (1) could be made directly reachable by a modem, e.g., by re-aiming an antenna.

The Hop Count Data Item SHOULD be carried in the Destination Up, Destination Update, Destination Announce Response, and Link Characteristics Response Messages when the Hop Count to a destination is greater than one (1).

A router receiving a Hop Count Data Item MAY use this information in its forwarding and routing decisions, and specific use is out of scope of this document. The absence of the Hop Count Data Item MUST be interpreted by the router as a Hop Count value of one (1).

The format of the Hop Count Data Item is:

```

      0               1               2               3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
| Data Item Type | Length |
+-----+-----+-----+-----+-----+-----+-----+-----+
| P | Reserved  | Hop Count |
+-----+-----+-----+-----+-----+-----+-----+

```

Data Item Type: TBA2

Length: 4

P:

The P-bit indicates that a destination is potentially directly reachable. When the P-bit is set, the router MAY request a direct link to the associated destination using the Hop Control Data Item described below.

Reserved:

MUST be set to zero by the sender (a modem) and ignored by the receiver (a router).

Hop Count:

An unsigned 8-bit integer indicating the number of network hops required (i.e., number of times a packet will be transmitted) to reach the destination indicated in the message. The special value of 255 (0xFF) is used to indicate that the number of hops is an unknown number greater than one (1). This field MUST contain a value of at least one (1) if the associated destination is reachable.

A value of zero (0) is used to indicate that processing of a Hop Control action, see Section 3.2, has resulted in a destination no longer being reachable. A zero value MUST NOT be used in any message other than a Link Characteristics Response Message.

3.2. Hop Control

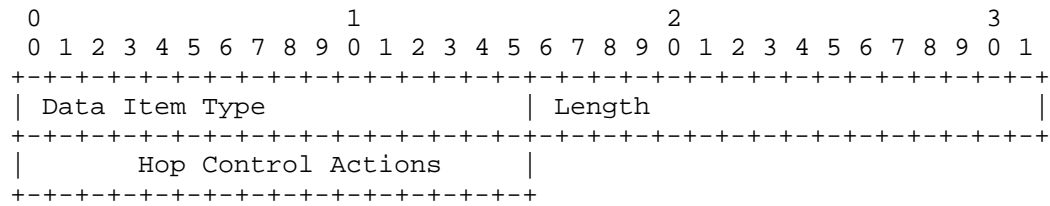
The Hop Control Data Item is used by a router to request a change in connectivity to a particular destination, or in multi-hop processing on a device wide basis. A router can request multi-hop reachable destination be changed to a single hop. A router can also indicate that the modem terminates a previous direct connectivity request to a particular destination.

The Hop Control Data Item MAY be carried in a Session Update Message sent by a router when the control applies to the whole device, or a Link Characteristics Request Message when the control applies to a particular destination.

A modem that receives the Hop Control Data Item in a Link Characteristics Request Message SHOULD attempt to make the change indicated by the data item for the associated destination MAC address. Once the change is made, fails or is rejected, the modem MUST respond with a Link Characteristics Response Message containing an updated Hop Count Data Item. Note that other destinations can be impacted as a result of the change and such changes are reported in Destination Down and Destination Update Messages. The modem MUST notify the router of each destination that is not identified in the Link Characteristics Response Message and is no longer reachable via a Destination Down Message. The modem MUST also notify the router of each destination that is not identified in the Link Characteristics Response Message and has a changed Hop Count impacted via a Destination Update Message.

A modem that receives the Hop Control Data Item in a Session Update Message SHOULD attempt to make the change indicated by the data item for all known destinations. Once the change is made, or fails or is rejected, the modem MUST respond with a Session Update Response Message with an appropriate Status Code. Destination specific impact resulting from the processing of a Hop Control Data Item in a Session Update Message is provided via Destination Down and Destination Update Messages. The modem MUST notify the router of each destination that is no longer reachable via a Destination Down Message. The modem MUST notify the router of any changes in Hop Counts via Destination Update Messages.

The format of the Hop Control Data Item is:



Data Item Type: TBA3

Length: 4

Hop Control Actions:

An unsigned 16-bit value with the following meaning:

Value	Action
0	Reset
1	Terminate
2	Direct Connection
3	Suppress Forwarding

Table 1: Hop Control Actions Values

3.2.1. Reset

The Reset Action requests that the default behavior be restored. When received in a Session Update Message message, a modem SHOULD clear all control actions that have previously been processed on a device wide basis, and revert to its configured behavior. When received in a Link Characteristics Request Message, a modem SHOULD clear all control actions that have previously been processed for the destination indicated in the message.

3.2.2. Terminate

The Terminate Action is only valid on a per destination basis and MUST NOT be sent in a Session Update Message message. It indicates that a direct connection is no longer needed with the destination identified in the message. This request has no impact for multi-hop destinations and may fail even in a single hop case, i.e. MAY result

in the Hop Count to the destination not being impacted by the processing of the request.

3.2.3. Direct Connection

The Direct Connection is only valid on a per destination basis and MUST NOT be sent in a Session Update Message message. It indicates that the modem SHOULD attempt to establish a direct connection with the destination identified in the message. This action SHOULD only be sent for destinations for which the Hop Count is greater than 1 and has the P-Bit set in the previously received Hop Count Data Item. Results of the request for the destination identified in the message are provided as described above. If any other destination is impacted in the processing of this action, the modem MUST send a Destination Update Message for each impacted destination.

3.2.4. Suppress Forwarding

The Suppress Forwarding Action is used by a router to indicate to its peer that multi-hop forwarding performed by the modem is to be suppressed. A router may request that multi-hop forwarding may be suppressed on a device wide or destination specific basis.

A modem which receives the Suppress Forwarding Data Item in a Session Update Message MUST suppress multi-hop forwarding on a device wide basis. This means that data traffic originating from the modem's peer router SHALL only be sent by the modem to destinations that are one modem hop away, and that any data traffic received by the modem from another modem that is not destined to the peer router SHALL be dropped. Impact to destination hop counts are provided to the router by the modem as described above.

A modem which receives the Suppress Forwarding Data Item in a Link Characteristics Request Message MUST suppress multi-hop forwarding for only the destination indicated in the message. This means that data traffic originating from the modem's peer router SHALL be sent by the modem to the destination indicated in the Link Characteristics Request Message only when it is one modem hop away. Notably, data traffic received by the modem from another modem MAY be forwarded by the modem per its normal processing. Results are provided as described above.

4. Security Considerations

The extension enables the reporting and control of forwarding information by DLEP capable modems. The extension does not inherently introduce any additional threats above those documented in

[RFC8175]. The approach taken to Security in that document applies equally when running the extension defined in this document.

5. IANA Considerations

This document requests the assignment of 3 values by IANA. All assignments are to registries defined by [RFC8175]. It also requests creation of one new registry.

5.1. Extension Type Value

This document requests 1 new assignment to the DLEP Extensions Registry named "Extension Type Values" in the range with the "Specification Required" policy. The requested value is as follows:

Code	Description
TBA1	Multi-Hop Forwarding

Table 2: Requested Extension Type Value

5.2. Data Item Values

This document requests 2 new assignments to the DLEP Data Item Registry named "Data Item Type Values" in the range with the "Specification Required" policy. The requested values are as follows:

Type Code	Description
TBA2	Hop Count
TBA3	Hop Control

Table 3: Requested Data Item Values

5.3. Hop Control Actions Registry

Upon approval of this document, IANA is requested to create a new DLEP registry, named "Hop Control Actions Values". The following table provides initial registry values and the [RFC8126]. defined policies that should apply to the registry:

Value	Action/Policy
0	Reset
1	Terminate
2	Direct Connection
3	Suppress Forwarding
4-65519	Specification Required
65520-65534	Private Use
65535	Reserved

Table 4: Hop Control Actions Values

6. References

6.1. Normative References

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- [RFC8175] Ratliff, S., Jury, S., Satterwhite, D., Taylor, R., and B. Berry, "Dynamic Link Exchange Protocol (DLEP)", RFC 8175, DOI 10.17487/RFC8175, June 2017, <<https://www.rfc-editor.org/info/rfc8175>>.

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Appendix A. Acknowledgments

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DLEP Control Plane Based Pause Extension
draft-ietf-manet-dlep-pause-extension-04

Abstract

This document defines an extension to the DLEP protocol that enables a modem to use DLEP messages to pause and resume data traffic coming from its peer router.

Status of This Memo

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1. Introduction

The Dynamic Link Exchange Protocol (DLEP) is defined in [RFC8175]. It provides the exchange of link related control information between DLEP peers. DLEP peers are comprised of a modem and a router. DLEP defines a base set of mechanisms as well as support for possible extensions. This document defines one such extension.

The base DLEP specification does not include any data plane flow control capability. Various flow control methods are possible, e.g., see [I-D.ietf-manet-credit-window]. The extension defined in this document supports flow control of data traffic based on explicit messages sent via DLEP by a modem to indicate when a router should hold off sending traffic, and when it should resume. The extension also optionally supports DSCP (differentiated services codepoint) aware, see [RFC2475], flow control. The extension defined in this document is referred to as "Control Plane Based Pause". Note that this mechanism only controls traffic that is to be transmitted on the modem's attached data channel and not to DLEP control messages themselves.

This document defines a new DLEP Extension Type Value in Section 2 which is used to indicate the use of the extension, and three new DLEP Data Items in Section 3.

1.1. Key Words

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

2. Extension Usage and Identification

The use of the Control Plane Based Pause Extension SHOULD be configurable. To indicate that the Control Plane Based Pause Extension is to be used, an implementation MUST include the Control Plane Based Pause Extension Type Value in the Extensions Supported Data Item. The Extensions Supported Data Item is sent and processed according to [RFC8175].

The Control Plane Based Pause Extension Type Value is TBA1, see Section 5.

3. Extension Data Items

Three data items are defined by this extension. The Queue Parameters Data Item is used by a modem to provide information on the DSCPs it uses in forwarding. The Pause Data Item is used by a modem to indicate when a router should cease sending packets and the Restart Data Item is used by a modem to indicate when a router can resume sending packets.

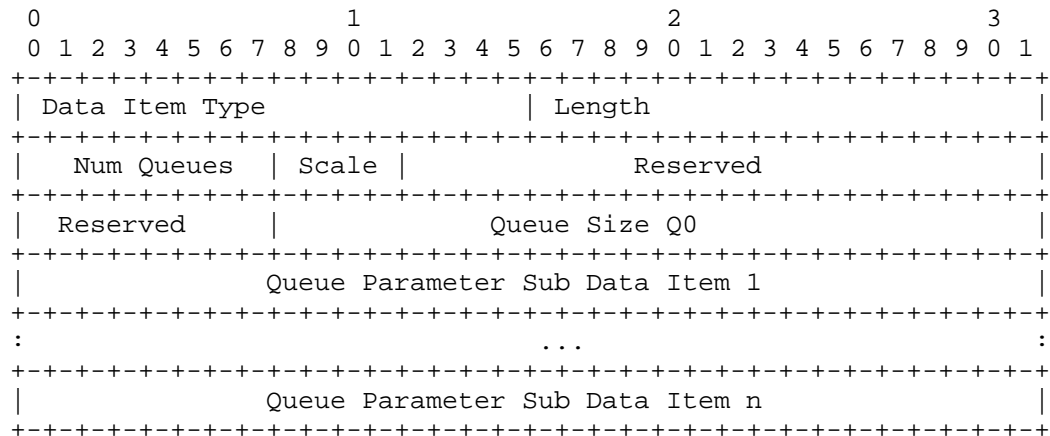
3.1. Queue Parameters

The Queue Parameters Data Item is used by a modem to indicate DSCP values that may be independently paused. This data item MUST be included in a Session Initialization Response Message that also contains the Control Plane Based Pause Extension Type Value in the Extensions Supported Data Item. Updates to these parameters MAY be sent by a modem by including the data item in Session Update Messages.

The Queue Parameters Data Item identifies DSCPs based on groups of logical queues, each of which is referred to via a "Queue Index". The number of logical queues, or queue indexes, is variable as is the number of DSCPs associated with each queue. A queue size (in bytes) is provided for informational purposes. Queue Indexes are numbered sequentially from zero, where queue index zero is a special case covering DSCPs which are not otherwise associated with Queue Index.

An implementation that does not support DSCPs would indicate 1 queue with 0 DSCPs, and the number of bytes that may be in its associated link transmit queue. Additional logical queues are represented in a variable series of Queue Parameter sub data items.

The format of the Queue Parameters Data Item is:



Data Item Type: TBA2

Length: Variable

Per [RFC8175] Length is the number of octets in the data item, excluding the Type and Length fields.

Num Queues:

An 8-bit unsigned integer indicating the number of queues represented in the data item. This field MUST contain a value of at least one (1), and is equal to one greater than the number of included Queue Parameter Sub Data Items.

Scale:

An 4-bit unsigned integer indicating the scale used in the Queue Size fields. The valid values are:

Value	Scale
0	B - Bytes (Octets)
1	KB - Kilobytes (B/1024)
2	MB - Megabytes (KB/1024)
3	GB - Gigabytes (MB/1024)

Reserved:

MUST be set to zero by the sender (a modem) and ignored by the receiver (a router).

Queue Size Q0:

A 24-bit unsigned integer representing the size, in the octet scale indicated by the Scale field, of queue index zero.

3.1.1. Queue Parameter Sub Data Item

Queue Parameter Sub Data Items are an unordered list composed of sub data items with a common format. The first sub data item is assigned a Queue Index value of 1, and subsequent data items are numbered incrementally. The format of the Queue Parameter Sub Data Item is patterned after the standard DLEP data item format, see [RFC8175] Section 11.3. Any errors or inconsistencies encountered in parsing Sub Data Items are handled in the same fashion as any other Data Item parsing error encountered in DLEP.

The format of the Queue Parameter Sub Data Item is:

```

      0                               1                               2                               3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Sub Data Item Type (1)          | Length                               |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                               Value...                               |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+

```

and Value has the format:

```

      0                               1                               2                               3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Queue Index | Queue Size Qn                                         |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Num DSCPs Qn | DS Field Qn | ...                                     |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
:               ...           | DS Field Qn |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+

```

Sub Data Item Type:

A 16-bit unsigned integer that indicates the type and corresponding format of the Sub Data Item's Value field. Sub Data Item Types are scoped within the Data Item in which they are

carried, i.e., the Sub Data Item Type field MUST be used together with the Data Item Type to identify the format of the Sub Data Item. This field MUST be set to one (1) for the Queue Parameter Sub Data Item.

Length: Variable

Copying [RFC8175], Length is the number of octets in the sub data item, excluding the Type and Length fields.

Queue Index:

An 8-bit field indicating the queue index of the queue parameter represented in the sub data item. Only the first instance a particular Queue Index value is meaningful. Subsequent sub data items containing the same Queue Index values, if present, MAY be logged via a management interface and MUST otherwise be ignored.

Queue Size Qn:

A 24-bit unsigned integer representing the size, in the octet scale indicated by the Scale field, of the queue supporting traffic with the DSCPs associated with the queue index.

Num DSCPs Qn:

An 8-bit unsigned integer indicating the number of DSCPs associated with the queue index associated with the sub data item. This field MUST contain a value of at least one (1).

DS Field Qn:

The data item contains a sequence of 8 bit DS Fields. The position in the sequence identifies the associated queue index. The number of DS Fields present should equal the sum of all Num DSCPs field values.

The DS Field structure is the same as [RFC2474].

0	1	2	3	4	5	6	7
+-----+-----+-----+-----+-----+-----+-----+-----+							
DSCP				CU			
+-----+-----+-----+-----+-----+-----+-----+-----+							

DSCP: differentiated services codepoint
CU: currently unused, MUST be zero

3.2. Pause

The Pause Data Item is used by a modem to indicate to its peer that traffic is to be suppressed. An example of when a modem might send this data item is when an internal queue length exceeds a particular threshold.

A modem may indicate that traffic is to be suppressed on a device wide or destination specific basis. An example of when a modem might use device wide indications is when output queues are shared across all destinations, and destination specific might be used when per destination queuing is used. To indicate that suppression applies to all destinations, a modem MAY send the Pause Data Item in a Session Update Message. To indicate that suppression applies to a particular destination a modem MAY send the Pause Data Item in a Destination Update Message.

Each Pause Data Item identifies the traffic to be suppressed by the Queue Index defined by Section 3.1, which in turn indicates a set of traffic identified by DSCPs. The special value of 255 is used to indicate that all traffic is to be suppressed.

While there is no restriction on the number of Messages containing Pause Data Item that may be sent by a modem, a modem SHOULD include multiple queue indexes in the same message when possible.

A router which receives the Pause Data Item MUST cease sending the identified traffic to the modem. This may of course translate into the router's queues exceeding their own thresholds. If a received Pause Data Item contains a Queue Index value other than 0, 255, or a queue index established by a Session Initialization or Session Update Message, the router MUST terminate the session with a Status Data Item indicating Invalid Data.

The format of the Pause Data Item is:

```

      0               1               2               3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
| Data Item Type | Length |
+-----+-----+-----+-----+-----+-----+-----+-----+
| Queue Index | ... :
+-----+-----+-----+-----+-----+-----+-----+-----+
: ... | Queue Index |
+-----+-----+-----+-----+-----+-----+-----+-----+

```

Data Item Type: TBA3

Length: Variable

Per [RFC8175] Length is the number of octets in the data item, excluding the Type and Length fields. It will equal the number of Queue Index fields carried in the data item.

Queue Index:

One or more 8-bit fields used to indicate a queue index defined by a Queue Parameters Data Item. The special value of 255 indicates all traffic is to be suppressed to the modem, when the data item is carried in a Session Update Message, or a destination, when the data item is carried in Destination Update Message.

3.3. Restart

The Restart Data Item is used by a modem to indicate to its peer that transmission of previously suppressed traffic may be resumed. An example of when a modem might send this data item is when an internal queue length drops below a particular threshold.

The sending of this data item parallels the Pause Data Item, see the previous section, and follows the same rules. This includes that to indicate that transmission can resume to all destinations, a modem MAY send the Restart Data Item in a Session Update Message. It also includes that to indicate that transmission can resume to a particular destination a modem MAY send the Pause Restart Item in a Destination Update Message. Finally, the same rules apply to queue indexes.

A router which receives the Restart Data Item SHOULD resume transmission of the identified traffic to the modem.

The format of the Restart Data Item matches the Pause Data Item and is:

```

      0               1               2               3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
| Data Item Type | Length |
+-----+-----+-----+-----+-----+-----+-----+-----+
| Queue Index | ... :
+-----+-----+-----+-----+-----+-----+-----+-----+
: ... | Queue Index |
+-----+-----+-----+-----+-----+-----+-----+-----+

```

Data Item Type: TBA4

Length: See Section 3.2.

Queue Index: See Section 3.2.

4. Security Considerations

The extension introduces a new mechanism for flow control between a router and modem using the DLEP protocol. The extension does not inherently introduce any additional threats above those documented in [RFC8175]. The approach taken to Security in that document applies equally when running the extension defined in this document.

5. IANA Considerations

This document requests the assignment of 4 values by IANA. All assignments are to registries defined by [RFC8175].

5.1. Extension Type Value

This document requests 1 new assignment to the DLEP Extensions Registry named "Extension Type Values" in the range with the "Specification Required" policy. The requested value is as follows:

Code	Description
TBA1	Control Plane Based Pause

Table 1: Requested Extension Type Value

5.2. Data Item Values

This document requests 3 new assignments to the DLEP Data Item Registry named "Data Item Type Values" in the range with the "Specification Required" policy. The requested values are as follows:

Type Code	Description
TBA2	Queue Parameters
TBA3	Pause
TBA4	Restart

Table 2: Requested Data Item Values

6. References

6.1. Normative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.
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Appendix A. Acknowledgments

The sub data item format was inspired by Rick Taylor's "Data Item Containers".

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Finite state machine YANG model augmentation for Transponder
Reconfiguration
draft-sambo-ccamp-yang-fsm-transponder-reconf-01

Abstract

YANG enables to compile a set of consistent vendor-neutral data models for optical networks and components based on actual operational needs emerging from heterogeneous use cases. A YANG model has been also proposed to describe finite state machine to program network elements that are modeled with YANG. This document augments the more generic YANG model for finite state machine [I-D.sambo-netmod-yang-fsm], in order to pre-instruct an optical transponder on the actions to be performed (e.g., code adaptation) in case some events, such as physical layer degradations, occur.

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1. Introduction

Networks are evolving toward more programmability, flexibility, and multi-vendor interoperability. Multi-vendor interoperability can be applied in the context of nodes, i.e. a node composed of components provided by different vendors (named fully disaggregated white box) is assembled under the same control system. This way, operators can optimize costs and network performance without the need of being tied to single vendor equipment. NETCONF protocol RFC6241 [RFC6241] based on YANG data modeling language RFC6020 [RFC6020] is emerging as a candidate Software Defined Networking (SDN) enabled protocol. First, NETCONF supports both control and management functionalities, thus permits high programmability. Then, YANG enables data modeling in a vendor-neutral way. Some recent works have provided YANG models to describe attributes of links (e.g., identification), nodes (e.g., connectivity matrix), media channels, and transponders (e.g., supported forward error correction - FEC) of networks

([I-D.ietf-i2rs-yang-network-topo] [I-D.vergara-ccamp-flexigrid-yang] [I-D.zhang-ccamp-ll-topo-yang]), also including optical technologies. A YANG model [I-D.sambo-netmod-yang-fsm] has been also proposed to describe finite state machines (FSMs) in order to program actions based on conditions and events in YANG-described devices. Such draft mainly refers to elastic optical networks (EONs), i.e. optical networks based on flexible grid where circuits with different bandwidth requirements are switched. EONs are expected to employ flexible transponders, i.e. transponders supporting multiple bit rates, multiple modulation formats, and multiple codes. Such transponders permits the (re-) configuration of the bit rate value based on traffic requirements, as well as the configuration of the modulation format and code based on the physical characteristics of a path (e.g., quadrature phase shift keying is more robust than 16 quadrature amplitude modulation). This document augments the YANG model for FSM [I-D.sambo-netmod-yang-fsm] to be applied in programming reconfiguration of transponders in EONs based on physical layer conditions. In particular, the model enables a centralized remote network controller (managed by a network operator) to instruct a transponder controller about the actions to perform when certain events (e.g., failures) occur. The actions to be taken and the events can be re-programmed on the device.

2. Conventions used in this document

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

3. Terminology

ABNO: Application-Based Network Operations

BER: Bit Error Rate

EON: Elastic Optical Network

FEC: Forward Error Correction

FSM: Finite State Machine

NETCONF: Network Configuration Protocol

OAM: Operation Administration and Maintenance

SDN: Software Defined Network

YANG: Yet Another Network Generator

4. Flexible Transponders

Flexible transponders enable several parameters' configurations, through the support of multiple modulation formats, baud rate, and forward error correction (FEC) schemes. This way, transmission parameters can be (re-)configured based on the physical layer conditions. The YANG model presented in this draft enables to pre-program reconfiguration settings of data plane devices in case of changes in the physical layer conditions. In particular, soft failures can be assumed. Soft failures imply transmission performance degradation, in turns a bit error rate (BER) increase, e.g. due to the ageing of some network devices. Without losing generality, the ABNO architecture is assumed for the control and management of EONs (RFC7491 [RFC7491]). Considering the state of the art, when pre-FEC BER passes above a predefined threshold, it is expected that an alarm is sent to the OAM Handler, which communicates with the ABNO controller that may trigger an SDN controller (that could be the Provisioning Manager of ABNO RFC7491 [RFC7491]) for computing new transmission parameters. The involved ABNO modules are shown in the simplified ABNO architecture of Fig. 1. Then, transponders are reconfigured. When alarms related to several connections impacted by the soft failure are generated, this procedure may be particularly time consuming. The related workflow for transponder reconfiguration is shown in Fig. 2. The proposed model enables an SDN controller to instruct the transponder about reconfiguration of new transmission parameters values if a soft failure occurs. This can be done before the failure occurs (e.g., during the connection instantiation phase or during the connection service), so that data plane devices can promptly reconfigure themselves without querying the SDN controller to trigger an on-demand recovery. This is expected to speed up the recovery process from soft failures. The related flow chart is shown in Fig. 3.

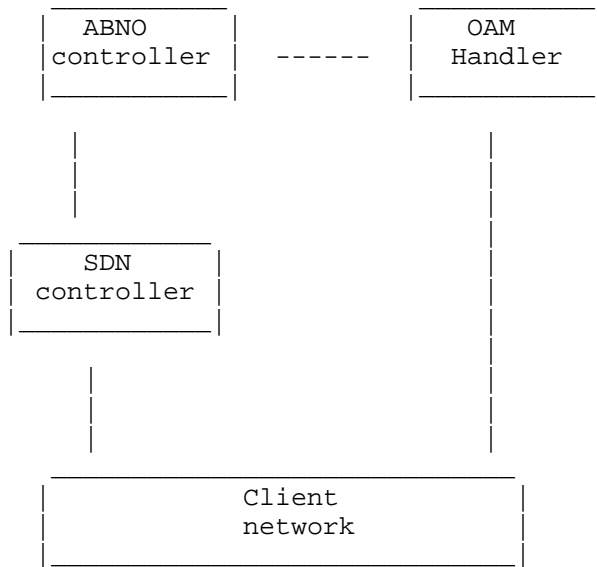


Figure 1: Assumed ABNO functional modules

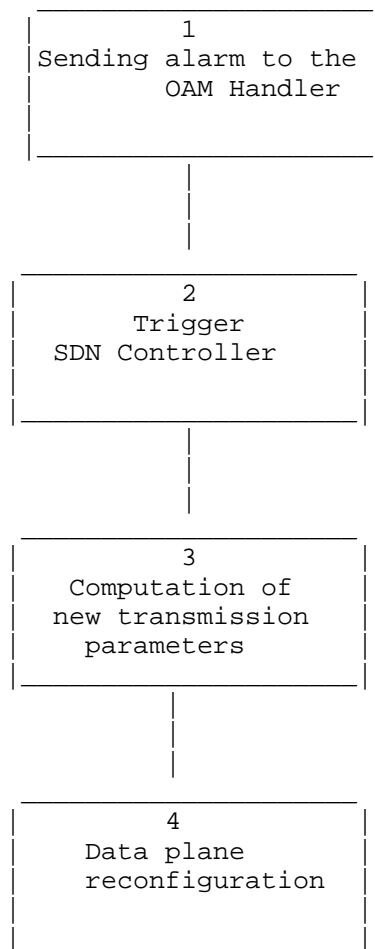


Figure 2: Flow chart of the expected state-of-the-art approach

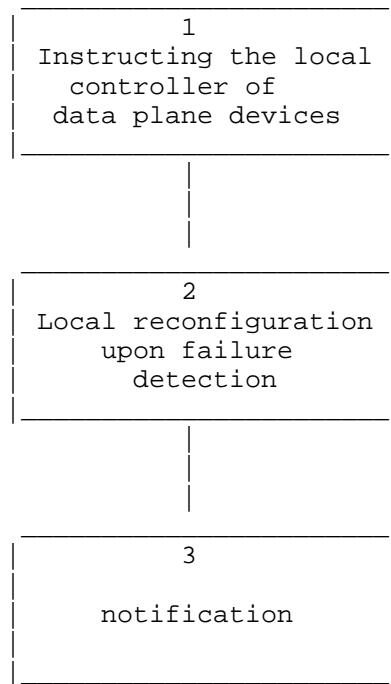


Figure 3: Flow chart of the approach exploiting YANG models in this draft

5. Augmenting the FSM YANG model for transponder reconfiguration

This section augments the FSM YANG model presented in [I-D.sambo-netmod-yang-fsm] to address the specific use case of transponder reconfiguration triggered by physical layer changes. The FSM is installed by the SDN controller in the local controller of the transponder and then runs there. The installation of the FSM can be enabled through a NETCONF <edit-config> message. Through FSM, the SDN controller instructs the transponder about the possible events (e.g., BER above a threshold) and reactions (e.g., change of modulation format) by setting the thresholds (e.g., BER threshold) and the reconfiguration settings. The FSM model is based on the following main attributes: states, transitions (corresponding to some specific event), and actions. In particular, more specifically with respect to [I-D.sambo-netmod-yang-fsm], in such a use case, a state corresponds to a specific configuration of transponder transmission parameters: e.g., given by the modulation format and the FEC. A transition is triggered when the pre-FEC BER (or another parameter such as the OSNR) is below or above a threshold. To this purpose,

with respect to [I-D.sambo-netmod-yang-fsm], the attribute <filter> is expressed by the definition of thresholds and operators. The action mainly consists of the change of modulation format and/or FEC.

The Tree of the YANG model for transponder reconfiguration (augmentation of the YANG model for FSM) is reported below.

```

module: ietf-treconf
  +--rw current-state?   leafref
  +--rw states
    +--rw state [id]
      +--rw id                state-id-type
      +--rw description?     string
      +--rw transitions
        +--rw transition [name]
          +--rw name                string
          +--rw description?        string
          +--rw threshold-parameter? decimal64
          +--rw threshold-operator? string
          +--rw transition-action
            +--rw action [id]
              +--rw id                transition-id-type
              +--rw type                enumeration
              +--rw simple
                +--rw execute
                +--rw next-action?     transition-id-type
                +--rw next-state?     Leafref

```

More specifically, the attribute <state> is a list defining all the transponder states. <transitions> is an attribute defining a list of events that may trigger the change of transponder state (e.g., BER change). <threshold-parameter> defines a threshold value, while <threshold-operator> defines the operator <, >, <=, >=. Thus, if the event BER>TH has to be modeled, the attribute <threshold-parameter> has to be set to "TH" while <threshold-operator> to ">". <actions> defines a list of actions to take during the transition (e.g. change of modulation format) <next-state> defines the next transponder state when an action is executed (e.g., new modulation format and FEC).

For more details about the other model attributes, the reader can refer to [I-D.sambo-netmod-yang-fsm].

In such a use case, we assume that an event (e.g., BER>TH) is revealed by the digital signal processing (DSP) of the receiver. Once the event is recognized, the modulation format and/or the FEC have to be changed, both at the receiver and the transmitter. Thus, the list of actions to be executed includes the change of

transmission parameters at the receiver side. Moreover, transmission and receiver must be synchronized about the transmission settings (modulation format and so on) for a proper transmission. Thus, when the transponder at the receiver side decides to change its state, the remote transponder at the transmitter side has to do the same state transition. To this purpose, the list of actions also includes this coordination. In particular, the transponder at the receiver side sends a message to the transmitter to synchronize about the transmission parameters to be adopted. This message can be sent over a control channel. This way both the transmitter and receiver operates with the same transmission parameters: e.g. the format, FEC, and so on.

Such transponder reconfiguration based on FSM has been successfully demonstrated by integrating control and data planes in a lab and field trials.

Finally, a last consideration concerns the impact on transmission bit rate when changing some transmission parameters. When passing from a more spectral efficient modulation format (but less robust with respect to physical impairments) to a less spectral efficient modulation format (more robust) such that could be polarization multiplexing 16 quadrature phase shift keying (PM-16QAM) and PM quadrature phase shift keying (PM-QPSK) the bit rate is reduced (halved in the case of PM-16QAM and PM-QPSK). This means that part of the traffic cannot be recovered through FSM, but needs of other restoration mechanisms (e.g., dynamic restoration). As an example, the gain of the proposed FSM mechanism promptly recovering part of the bit rate can be applied to high-priority traffic so that its recovery can be faster without involving central controller, while other classical recovery mechanisms (involving the sending of alarms, their processing, new computations and setup) can be adopted for best effort traffic (as the traffic that cannot be recovered when passing from PM-16QAM to PM-QPSK). The same happens changing the code rate: at fixed baud rate and modulation format, if the code redundancy is increased, the net bit rate is decreased. Again, part of the traffic can be promptly recovered through FSM, while the other by relying on classical recovery mechanisms. A future version of the draft will expand the list of actions also including the mechanism for recovery the remaining traffic.

6. Code of the YANG model for transponder reconfiguration

The related code is reported below.

```
<CODE BEGINS> file "ietf-treconf@2016-03-15.yang"
```

```
module ietf-treconf {
  namespace "http://sssup.it/fsm";
  prefix fsm;

  organization
    "Scuola Superiore Sant'Anna Network and Services Laboratory";

  contact
    " Editor: Matteo Dallaglio
      <mailto:m.dallaglio@sssup.it>
    ";

  description
    "This module contains a YANG definitions of a generic finite state
      machine.";

  revision 2016-03-15 {
    description "Initial Revision.";
    reference
      "RFC xxxx:";
  }

  identity TRANSITION {
    description "Base for all types of event";
  }

  identity ON_CHANGE {
    base TRANSITION;
    description
      "The event when the database changes.";
  }

  // typedef statements

  typedef transition-type {
    description "it defines the transition type";
    type identityref {
      base TRANSITION;
    }
  }

  typedef transition-id-type {
    description "it defines the transition id type";
    type uint32;
  }
```

```
// grouping statements
grouping action-block {
    description "it defines the grouping action";
    leaf id {
        description "it defines the id of the transition";
        type transition-id-type;
    }
    leaf type {
        description "it defines if the action has to be simply executed
or if a conditional statement has to be checked before execution";

        type enumeration {
            enum "CONDITIONAL_OP" {
description "it defines the type CONDITIONAL OPERATION to check a
statement before execution. In this draft, at the moment, only SIMPLE
will be assumed";

            }
            enum "SIMPLE_OP" {
description "it defines the type SIMPLE OPERATION: i.e., an operation
to be directly executed;
            }
            mandatory true;
        }
    }

    grouping execution-top {
        description "it defines the execution attribute";
        anyxml execute {
            description "Represent the action to perform";
        }
        leaf next-action {
            type transition-id-type;
            description "the id of the next action to execute";
        }
    }
}

container simple {
    when "../type = 'SIMPLE_OP'";
    description
        "Simple execution of an action without checking any condition";
    uses execution-top;
}

grouping action-top {
    description "it defines the grouping of action";
```

```
list action {
    description "it defines the list of actions";
    key "id";

    ordered-by user;
    uses action-block;
}

grouping on-change {
    description
        "Event occurring when a modification of one or more
        objects occurs";

    leaf threshold-parameter {
        description "it defines the threshold of an event determined by
        a threshold exceed";
        type decimal64;
    }

    leaf threshold-operator {
        description "it defines the operator to check the threshold
        exceed: <, > <=, >=";
        type string;
    }
}

grouping transition-top {
    description "it defines the grouping transition";
    leaf name {
        description "it defines the transition name";
        type string;
        mandatory true;
    }

    leaf description {
        description "it describes the transition with a string";
        type string;
    }

    // list of all possible events
    uses on-change {
        when "type = 'ON_CHANGE'";
    }
}
```

```
    container transition-action {
        description "it defines the container actions to take during the
            transition";
        uses action-top;
    }
}

grouping transitions-top {
    description "it defines the grouping transition";
    container transitions {
        description "it defines the container transitions";
        list transition {
            description "it defines the list of transitions";
            key "name";
            uses transition-top;
        }
    }
}

// data definition statements

uses transitions-top;

// extension statements

// feature statements

// augment statements

// rpc statements

// notification statements

// identity statements

// typedef statements

typedef state-id-type {
    description "it defines the id type of the states";
    type uint32;
}

// grouping statements
grouping state-top {
    description "it defines the grouping state";
```

```
leaf id {
    description "it defines the id of the state";
    type state-id-type;
}

leaf description {
    description "it describes the state with a string";
    type string;
}

grouping next-state-top {
    description "it defines the grouping next state";
    leaf next-state {
        type leafref {
            path "../states/state/id";
        }
        description "Id of the next state";
    }
}

uses transitions-top {
    augment "transitions/transition/transition-action/action/simple" {
        //uses next-state-top;
        leaf next-state {
            type leafref {
                path "../states/state/id";
            }
            description "Id of the next state";
        }
    }
}

grouping states-top {
    description "it defines the attributes of state-top";
    leaf current-state {
        description "it defines the current state";
        type leafref {
            description "it refers to its id";
            path "../states/state/id";
        }
    }
}

container states {
```

```
        description "it defines the container states";
    list state {
        description "it defines the list of states";
        key "id";
        uses state-top;
    }
}

// data definition statements

uses states-top;

// extension statements

// feature statements

// augment statements.

// rpc statements

// notification statements

} // module fsm

<CODE ENDS>
```

7. Acknowledgements

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8. Security Considerations

TBD

9. IANA Considerations

TBD

10. References

10.1. Normative References

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A YANG Data Model for Microwave Topology
draft-ye-ccamp-mw-topo-yang-01

Abstract

This document defines a YANG data model to describe the topologies of microwave/millimeter.

Requirements Language

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

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1. Terminology and Definitions

The following acronyms are used in this document:

PNC Provisioning Network Controller

MDSC Multi Domain Service Coordinator

2. Introduction

This document defines a YANG data model to describe the topologies of microwave/millimeter(hereafter microwave is used to simplify the text). The microwave topology model augments the TE topology model defines in [I-D.ietf-teas-yang-te-topo].

The microwave topology model is expected to be used between a Provisioning Network Controller(PNC) and a Multi Domain Service

Coordinator(MDSC)([I-D.ietf-teas-actn-framework])). Possible use cases of microwave topology models include:

1. The microwave link frequency could be used to understand the current frequency usage, enabling a whole view of the network topology information, and as an input for network frequency planning.
2. The microwave radio link could change its bandwidth according to the environments under the adaptive modulation mode, e.g., the bandwidth will degrade when there's a heavy rain. To get to know of current microwave link bandwidth is important for path computation and service provisioning across different technologies/networks.
3. Due to bandwidth changing feature, availability is normally used to describe the microwave radio link characteristic. [RFC8330] defines a mechanism to report bandwidth-availability information through OSPF-TE. It's also necessary to include the information in the YANG data model to optimize the path/route computation.

3. YANG Data Model (Tree Structure)

3.1. The YANG Tree

```

module: ietf-microwave-topology
  augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
    +--rw mw-topology!
  augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes:
    +--rw mw-link-frequency?          uint32
    +--rw mw-link-channel-separation?  uint32
    +--ro mw-link-nominal-bandwidth?   rt-types:bandwidth-ieee-float32
    +--ro mw-link-current-bandwidth?   rt-types:bandwidth-ieee-float32
    +--rw mw-unreserved-bandwidth      rt-types:bandwidth-ieee-float32
    +--rw mw-link-availability* [availability]
      +--rw mw-link-availability      rt-types:percentage
      +--ro mw-link-bandwidth         rt-types:bandwidth-ieee-float32
  augment /nw:networks/nw:network/nw:node/nt:termination-point /tet:te:
    +-- mp interface-root

```

3.2. Relationship with microwave interface YANG model

The microwave topology model is expected to be used between a PNC and a MDSC. [I-D.ietf-ccamp-mw-yang] defines an interface YANG model for microwave radio link which is used between the PNC and the physical device for device configuration. The PNC is able to convert the

information received from the topology model into the interface model. For example, the link frequency in the topology model is mapped to the tx-frequency of the carrier termination in the interface model.

If the purpose is to access more information of the microwave interface YANG model through the microwave topology model, a schema mount mechanism could be used, see the "interface-root" in the microwave topology model. [I-D.ietf-netmod-schema-mount] defines a mechanism to add the schema trees defined by a set of YANG modules onto a mount point defined in the schema tree in some YANG module. The current defined schema mount mechanism allows mounting of complete data models only. If complete mounting of the microwave interface YANG model is not necessary, a deviation model could be created to remove unneeded schema in the microwave interface model, and be mounted to the topology model.

4. YANG Module

<CODE BEGINS> file "ietf-microwave-topology.yang"

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

  prefix "mwtopo";

  import ietf-network {
    prefix "nw";
  }

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

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

  import ietf-routing-types {
    prefix "rt-types";
  }

  import ietf-yang-schema-mount {
    prefix yangmnt;
    reference "draft-ietf-netmod-schema-mount: YANG Schema Mount";
  }
}
```

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

  ID-draft authors:
  Min Ye (amy.yemin@huawei.com);
  Aihua Guo (aihuaguo@huawei.com);
  Jonas Ahlberg (jonas.ahlberg@ericsson.com);
  Xi Li (Xi.Li@neclab.eu);
  Daniela Spreafico (daniela.spreafico@nokia.com)
  ";

description
  "This is a module for microwave topology.";

  revision 2018-06-30 {
    description
      "Updated version to add mount point to the interface model.";
    reference "";
  }

  revision 2018-03-05 {
    description
      "Initial version.";
    reference "";
  }

/*
 * Groupings
 */
grouping mw-link-attributes {
  description "Microwave link attributes";

  leaf mw-link-frequency {
    type uint32;
    units "kHz";
    description "Frequency of the link";
  }

  leaf mw-link-channel-separation {
    type uint32;
    units "kHz";
    description "The distance
      between adjacent channels in a radio frequency channel
      arrangement used in this link";
```

```
    reference "ETSI EN 302 217-1";
  }

  leaf mw-link-nominal-bandwidth {
    type rt-types:bandwidth-ieee-float32;
    units "Mbps";
    config false;
    description "The nominal bandwidth of the link";
  }

  leaf mw-link-current-bandwidth {
    type rt-types:bandwidth-ieee-float32;
    units "Mbps";
    config false;
    description "The current bandwidth of the link";
  }

  leaf mw-unreserved-bandwidth {
    type rt-types:bandwidth-ieee-float32;
    units "Mbps";
    description "the unreserved bandwidth of the link";
  }

  list mw-link-availability{
    key "availability";
    description "List of availability and corresponding
                link bandwidth";

    leaf availability {
      type rt-types:percentage;
      description "availability level of the link";
    }

    leaf mw-link-bandwidth {
      type rt-types:bandwidth-ieee-float32;
      units "Mbps";
      config false;
      description "The link bandwidth corresponding
                  to the availability level";
    }
  }

  container "interface-root" {
    description
      "Container for mount point.";
    yangmnt:mount-point "interface-root" {
      description
```



```

        "Root for microwave rado interface model.
          It could contain an interface instance.";
    }
}

}

/*
 * Data nodes
 */
augment "/nw:networks/nw:network/nw:network-types/"
+ "tet:te-topology" {
    container mw-topology {
        presence "indicates a topology type of microwave.";
        description "microwave topology type";
    }
    description "augment network types to include microwave network";
}

augment "/nw:networks/nw:network/nt:link/tet:te/"
+ "tet:te-link-attributes" {
    when "../.../nw:network-types/tet:te-topology/"
+ "mwtopo:mw-topology" {
        description "This augment is only valid for microwave.";
    }
    description "Microwave link augmentation";

    uses mw-link-attributes;
}

}
<CODE ENDS>

```

5. Security Considerations

The YANG module specified in this document defines a schema for data that is designed to be accessed via network management protocols such as NETCONF [RFC6241] or RESTCONF [RFC8040][RFC8040]. The lowest NETCONF layer is the secure transport layer, and the mandatory-to-implement secure transport is Secure Shell (SSH) [RFC6242]. The lowest RESTCONF layer is HTTPS, and the mandatory-to-implement secure transport is TLS [RFC5246].

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

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

TBD.(list subtrees and data nodes and state why they are sensitive)

Some of the readable data nodes in this YANG module may be considered sensitive or vulnerable in some network environments. It is thus important to control read access (e.g., via get, get-config, or notification) to these data nodes. These are the subtrees and data nodes and their sensitivity/vulnerability:

TBD.(list subtrees and data nodes and state why they are sensitive)

6. IANA Considerations

IANA has assigned a new URI from the "IETF XML Registry" [RFC3688].

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

IANA has recorded a YANG module name in the "YANG Module Names" registry [RFC6020] as follows:

Name: ietf-microwave-topology
Namespace: urn:ietf:params:xml:ns:yang:ietf-microwave-topology
Prefix: mwtopo
Reference: RFC xxxx

7. References

7.1. Normative References

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- [I-D.ietf-netmod-schema-mount]
Bjorklund, M. and L. Lhotka, "YANG Schema Mount", draft-ietf-netmod-schema-mount-10 (work in progress), April 2018.
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[I-D.ietf-teas-yang-te-topo]

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[RFC8330]

Long, H., Ye, M., Mirsky, G., D'Alessandro, A., and H. Shah, "OSPF Traffic Engineering (OSPF-TE) Link Availability Extension for Links with Variable Discrete Bandwidth", RFC 8330, DOI 10.17487/RFC8330, February 2018, <<https://www.rfc-editor.org/info/rfc8330>>.

Appendix A. Appendix A Examples of microwave topology

A.1. Appendix A.1 A topology with single microwave radio link

Microwave is a transport technology which can be used to transport client services, such as ETH. When an ETH service is transported by a single microwave radio link, the topology could be shown as the Figure 3. Note that the figure just shows an example, there might be other possibilities to demonstrate the topology.

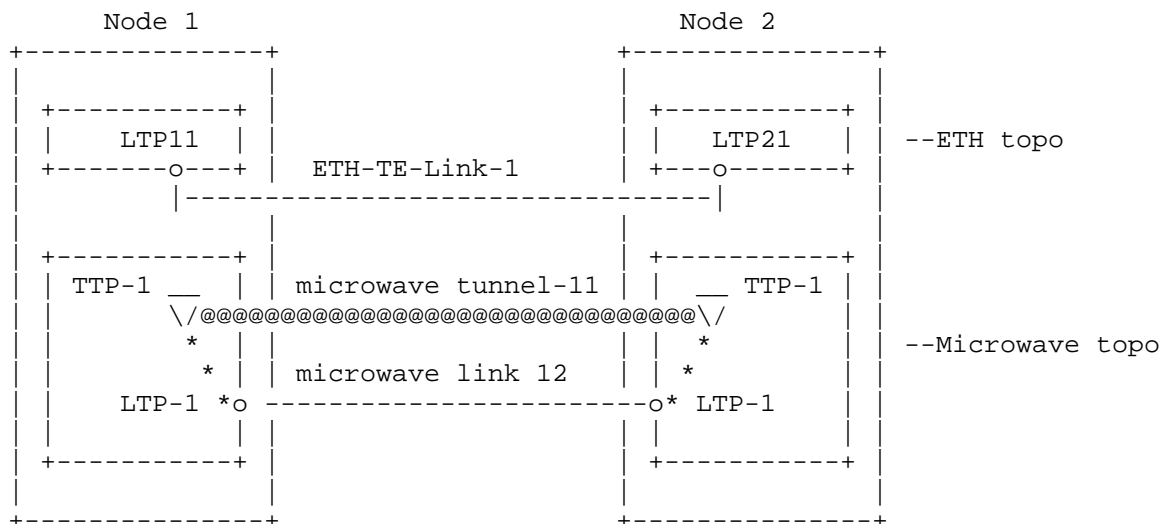


Figure 3: ETH transported on a single microwave radio link

In the above ETH topology, the ETH-TE-link is encoded in JSON as below:

```

...
"ietf-network-topology:link": [
  {
    "link-id": "N1,LTP11,N2,LTP21",
    "source": {
      "source-node": "N1",
      "source-tp": "LTP11"
    }
    "destination": {
      "dest-node": "N2",
      "dest-tp": "LTP21"
    }
  }
]
"ietf-te-topology:link/te/te-link-attributes/": [
  {
    "enabled": true,
    "primary-path": {
      "path-element": {
        "path-element-id": "MW-11"
        //no backup-path
        //no protection-type
      }
    }
    "tunnel-termination-points": {
      "source": "N1/TTP-1",
      "destination": "N2/TTP-1"
    }
    "tunnels": {
      "sharing": "false",
      "tunnel": {
        "tunnel-name": "MW-11",
        "sharing": "false"
      }
    }
  }
]

```

Note that the example above just shows the particular ETH link, not the full ETH topology.

In the microwave topology, the microwave link is encoded in JSON as below:

```
...
"ietf-network-topology:link": [
  {
    "link-id": "N1,LTP1,N2,LTP1",
    "source": {
      "source-node": "N1",
      "source-tp": "LTP1"
    }
    "destination": {
      "dest-node": "N2",
      "dest-tp": "LTP1"
    }
  }
]
"ietf-te-topology:link/te/te-link-attributes/underlay": [
  {
    "mw-link-frequency": 10728000,
    "mw-link-channel-separation": "28000",
    "mw-link-actual-tx-cm": "qam-512",
    "mw-link-nominal-bandwidth": "1000",
    "mw-link-current-bandwidth": "1000",
    "mw-link-availability": {
      "mw-link-availability": "0.9999",
      "mw-link-bandwidth": "1000"
    }
  }
]
```

A.2. Appendix A.2 A topology with microwave radio links bundling

When a ETH service is transported over two microwave radio links, the topologies could be shown as in Figure 4. Note that the figure just shows one example, there might be other possibilities to demonstrate the topology.

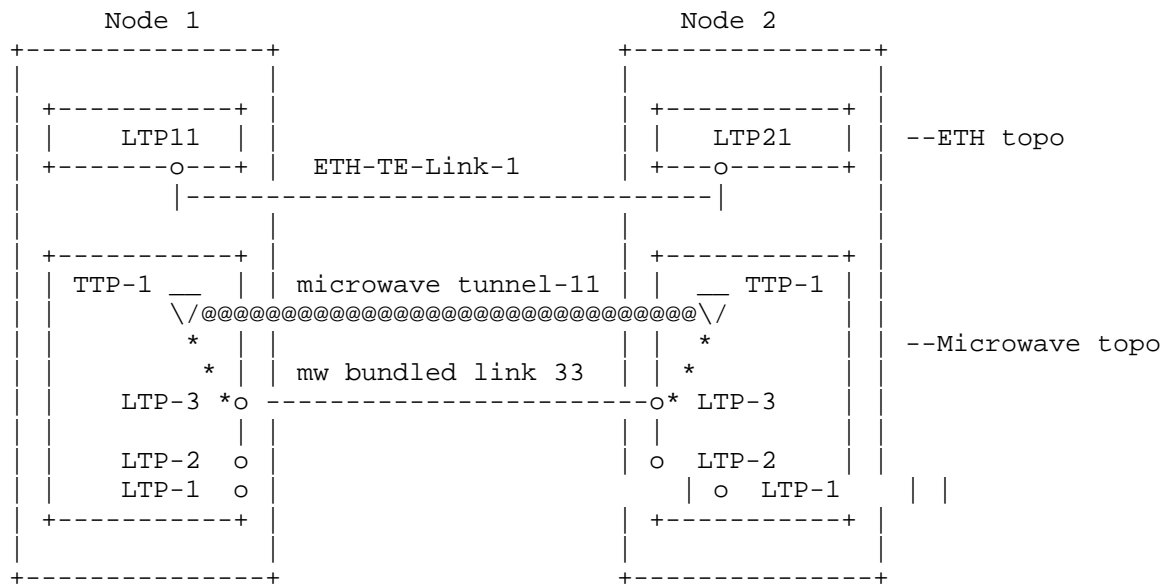


Figure 4: ETH transported on single microwave radio links

In the ETH topology, the ETH-TE-link is encoded in JSON as below:

```

...
"ietf-network-topology:link": [
  {
    "link-id": "N1,LTP11,N2,LTP21",
    "source": {
      "source-node": "N1",
      "source-tp": "LTP11"
    }
    "destination": {
      "dest-node": "N2",
      "dest-tp": "LTP21"
    }
  }
]
"ietf-te-topology:link/te/te-link-attributes/": [
  {
    "enabled": true,
    "primary-path": {
      "path-element": {
        "path-element-id": "MW-33"
        //no backup-path
        //no protection-type
      }
    }
    "tunnel-termination-points": {
      "source": "N1/TTP-1",
      "destination": "N2/TTP-1"
    }
    "tunnels": {
      "sharing": "false",
      "tunnel": {
        "tunnel-name": "MW-11",
        "sharing": "false"
      }
    }
  }
]

```

Note that the example above just shows the specific ETH link, not the full ETH topology.

In the microwave topology, the microwave link is encoded in JSON as below:


```

...
"ietf-network-topology:link": [
  {
    "link-id": "N1,LTP1,N2,LTP1",
    "source": {
      "source-node": "N1",
      "source-tp": "LTP3"
    }
    "destination": {
      "dest-node": "N2",
      "dest-tp": "LTP3"
    }
  }
]
"ietf-te-topology:link/te/te-link-config": [
  {
    "bundle-stack-level":{
      "component" {
        "component-links-1": {
          "sequence": "mw-11",
          "src-tp-ref": "N1-LTP1",
          "des-tp-ref" : "N2-LTP1"
        }
        "component-links-2": {
          "sequence": "mw-22",
          "src-tp-ref": "N1-LTP2",
          "des-tp-ref" : "N2-LTP2"
        }
      }
    }
  }
]

```

Note that the example above just shows the microwave component links, it doesn't show the full microwave topology.

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A YANG Data Model for Transport Network Client Signals
draft-zheng-ccamp-client-signal-yang-00

Abstract

A transport network is a server-layer network to provide connectivity services to its client. The topology and tunnel information in the transport layer has already been defined by Traffic-engineered models and OTN models, however, the access to the network has not been described. These information is useful to both client and provider.

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

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1. Introduction

A transport network is a server-layer network designed to provide connectivity services for a client-layer network to carry the client traffic transparently across the server-layer network resources. Currently there has been topology and tunnel model defined for transport network, such as [I-D.ietf-ccamp-otn-topo-yang] and [I-D.ietf-ccamp-otn-tunnel-model], which has described the network model between PEs. However, there is a missing piece for the mapping

between the PE and the CE, which is expected to be solved in this document.

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

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

The YANG model defined in this document is independent of control plane protocols and captures topology related information. Furthermore, it is not a stand-alone model, but augmenting from the TE topology YANG model defined in [I-D.ietf-teas-yang-te-topo].

2. Terminology and Notations

A simplified graphical representation of the data model is used in this document. The meaning of the symbols in the YANG data tree presented later in this document is defined in [I-D.ietf-netmod-yang-tree-diagrams]. They are provided below for reference.

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

3. Transport Network Client Signal Overview

The transport network is usually a server-layer network designed to provide connectivity services for a client-layer network to carry the client traffic opaquely across the server-layer network resources. A transport network may be constructed from equipments utilizing any of a number of different transport technologies such as the evolving optical transport infrastructure (SONET/SDH and OTN) or packet transport as epitomized by the MPLS Transport Profile (MPLS-TP).

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

It is also worth noting that some client signal can be carried over multiple types of transport networks. For example, the Ethernet services can be carried over either OTN or Ethernet TE tunnels (over optical or microwave networks). The model specified in this document allows the support from networks with different technologies.

4. YANG Model for Transport Network Client Signal

4.1. YANG Tree for Ethernet Service

```
module: ietf-eth-tran-service
  +--rw etht-svc
    +--rw globals
      +--rw etht-svc-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-descr?        string
  +--rw etht-svc-type?          etht-types:service-type
  +--rw access-provider-id?     te-types:te-global-id
  +--rw access-client-id?       te-types:te-global-id
  +--rw access-topology-id?     te-types:te-topology-id
+--rw etht-svc-access-ports* [access-port-id]
  +--rw access-port-id          uint16
  +--rw access-node-id?         te-types:te-node-id
  +--rw access-ltp-id?          te-types:te-tp-id
  +--rw service-classification-type? identityref
  +--rw (service-classification)?
    +--:(port-classification)
    +--:(vlan-classification)
      +--rw outer-tag!
        +--rw tag-type?          etht-types:eth-tag-classify
        +--rw (individual-bundling-vlan)?
          +--:(individual-vlan)
          | +--rw vlan-value?     etht-types:vlanid
          +--:(vlan-bundling)
          +--rw vlan-range?      etht-types:vid-range-type
      +--rw second-tag!
        +--rw tag-type?          etht-types:eth-tag-classify
        +--rw (individual-bundling-vlan)?
          +--:(individual-vlan)
          | +--rw vlan-value?     etht-types:vlanid
          +--:(vlan-bundling)
          +--rw vlan-range?      etht-types:vid-range-type
  +--rw split-horizon-group?    string
  +--rw (direction)?
    +--:(symmetrical)
    | +--rw ingress-egress-bandwidth-profile-name? string
    +--:(asymmetrical)
    +--rw ingress-bandwidth-profile-name? string
    +--rw egress-bandwidth-profile-name? string
+--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 second-tag!
          +--rw tag-type?        etht-types:eth-tag-type
          +--rw vlan-value?      etht-types:vlanid

```

```

    +---:(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 second-tag!
              +---rw tag-type?  etht-types:eth-tag-type
              +---rw vlan-value? etht-types:vlanid
          +---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 second-tag!
                +---rw tag-type?  etht-types:eth-tag-type
                +---rw vlan-value? etht-types:vlanid
+---rw etht-svc-tunnels* [tunnel-name]
  +---rw tunnel-name      string
  +---rw (svc-multiplexing-tag)?
    +---:(other)
    +---:(none)
    +---:(vlan-tag)
    +---:(pw)
  +---rw src-split-horizon-group?  string
  +---rw dst-split-horizon-group?  string
+---rw pm-config
  +---rw pm-enable?              boolean
  +---rw sending-rate-high?      uint64
  +---rw sending-rate-low?       uint64
  +---rw receiving-rate-high?    uint64
  +---rw receiving-rate-low?     uint64
+---rw admin-status?            identityref
+---ro state
  +---ro operational-state?       identityref
  +---ro provisioning-state?      identityref
  +---ro creation-time?           yang:date-and-time
  +---ro last-updated-time?       yang:date-and-time
  +---ro sending-rate-too-high?   uint32
  +---ro sending-rate-too-low?   uint32
  +---ro receiving-rate-too-high? uint32
  +---ro receiving-rate-too-low?  uint32

```


4.2. YANG Tree for other Transport Network Client Signal Model

```

module: ietf-trans-client-service
  +--rw client-svc
    +--rw client-svc-instances* [client-svc-name]
      +--rw client-svc-name      string
      +--rw client-svc-descr?    string
      +--rw access-provider-id?  te-types:te-global-id
      +--rw access-client-id?    te-types:te-global-id
      +--rw access-topology-id?  te-types: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 svc-tunnels* [tunnel-name]
        | +--rw tunnel-name      string
      +--ro operational-state?    identityref
      +--ro provisioning-state?   identityref

```

5. YANG Code for Transport Network Client Signal

5.1. The ETH Service YANG Code

<CODE BEGINS> file "ietf-eth-tran-service@2018-03-01.yang"

```

module ietf-eth-tran-service {

  namespace "urn:ietf:params:xml:ns:yang:ietf-eth-tran-service";

  prefix "ethtsvc";

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

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

```

```
import ietf-eth-tran-types {
  prefix "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);
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      Aihua Guo (aihuaguo@huawei.com);
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      Xufeng Liu (Xufeng_Liu@jabil.com);
      Giuseppe Fioccola (giuseppe.fioccola@telecomitalia.it);
  ";

description
  "This module defines a YANG data model for describing
  the Ethernet transport services.";

  revision 2018-03-01 {
    description
      "Initial revision";
    reference
      "draft-zheng-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-t-types:eth-tag-classify;
    description
      "The tag type used for VLAN classification.";
  }
  choice individual-bundling-vlan {
    description
      "VLAN based classification can be individual
      or bundling.";
  }
}
```

```
    case individual-vlan {
      leaf vlan-value {
        type etht-types:vlanid;
        description
          "VLAN ID value.";
      }
    }

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

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

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

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 = "s-vlan-tag-type"
    'tag-type = "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 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 the ingress
      and the egress bandwidth profile.";

    leaf ingress-egress-bandwidth-profile-name {
      type "string";
      description
        "Name of the bandwidth profile.";
    }
  }
  case asymmetrical {
    description
      "Ingress and egress bandwidth profiles can be specified.";
    leaf ingress-bandwidth-profile-name {
      type "string";
      description
        "Name of the bandwidth profile used in
        the ingress direction.";
    }
    leaf egress-bandwidth-profile-name {
      type "string";
      description
        "Name of the bandwidth profile used in
        the egress direction.";
    }
  }
}

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

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

```

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

choice service-classification {
    description
        "Access classification can be port-based or
        VLAN based.";

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

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

            uses vlan-classification;
        }
        container second-tag {
            must
                ' ../outer-tag/tag-type = "classi
fy-s-vlan" and ' +
                'tag-type = "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
        "include parameters for vlan-operation";
    choice direction {
        description
            "Whether the VLAN operations are symmetrical or
            asymmetrical";
        case symmetrical {
            container symmetrical-operation {
                uses vlan-operations;
                description
                    "Symmetrical operations.
                    Expressed in the ingress direction, but
                    the reverse operation is applied to egress traffic";
            }
        }
        case asymmetrical {
            container asymmetrical-operation {
                description "Asymmetrical operations";
                container ingress {
                    uses vlan-operations;
                    description "Ingress operations";
                }
                container egress {
                    uses vlan-operations;
                }
            }
        }
    }
}

```

```
        description "Egress operations";
    }
}
}
}
}

grouping etht-svc-tunnel-parameters {
    description
        "ETH transport services tunnel parameters";

    leaf tunnel-name {
        type string;
        description
            "TE service tunnel instance name.";
    }
    choice svc-multiplexing-tag {
        description
            "Service multiplexing is optional and flexible.";

        case other {
            /*
             * placeholder to support proprietary multiplexing
             * (for further discussion)
             */
        }

        case none {
            /* no additional information is needed */
        }

        case vlan-tag {
            /*
             * No additional information is needed
             * The C-Tag or S-Tag used for service mulitplexing is defined
             * by the VLAN classification and operations configured in the
             * etht-svc-access-parameters grouping
             */
        }

        case pw {
            /* to be completed (for further discussion) */
        }
    }
}

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



```

*/
        leaf src-split-horizon-group {
            type string;
            description "Identify a split horizon group at the Tunnel
1 source TTP";
        }
        leaf dst-split-horizon-group {
            type string;
            description "Identify a split horizon group at the Tunnel
1 destination TTP";
        }
    }

    grouping te-topology-identifier {
        description
            "An identifier to uniquely identify the TE topology.";
        leaf access-provider-id {
            type te-types:te-global-id;
            description
                "An identifier to uniquely identify a provider.";
        }
        leaf access-client-id {
            type te-types:te-global-id;
            description
                "An identifier to uniquely identify a client.";
        }
        leaf access-topology-id {
            type te-types:te-topology-id;
            description
                "Identifies the topology the
                service access ports belong to.";
        }
    }

    grouping etht-svc-pm-threshold_config {
        description
            "Configuration parameters for Ethernet service PM thresh
olds.";

        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 etht-svc-instance_config {
    description
        "Configuraiton parameters for Ethernet services.";

    leaf etht-svc-name {
        type string;
        description
            "Name of the p2p ETH transport service.";
    }

    leaf etht-svc-descr {
        type string;
```

```
        description
            "Description of the ETH transport service.";
    }

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

    uses te-topology-identifier;

    list etht-svc-access-ports {
        key access-port-id;
        min-elements "1";
/*
        Open Issue:
            Is it possible to limit the max-elements only for p2p services?

        max-elements "2";
*/
    }
    description
        "List of the ETH transport services access port instances.";

    leaf access-port-id {
        type uint16;
        description
            "ID of the service access port instance";
    }
    uses etht-svc-access-parameters;
}
list etht-svc-tunnels {
    key tunnel-name;
    description
        "List of the TE Tunnels supporting the ETH
        transport service.";

    uses etht-svc-tunnel-parameters;
}

    container pm-config {
        description
            "ETH service performance monitoring";

        leaf pm-enable {
            type boolean;
            description
                "Boolean value indicating whether PM is
enabled.";

```

```
        }
        uses etht-svc-pm-threshold_config;
    }
    leaf admin-status {
        type identityref {
            base te-types:tunnel-state-type;
        }
        default te-types:tunnel-state-up;
        description "ETH service administrative state.";
    }
}

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

    leaf operational-state {
        type identityref {
            base te-types:tunnel-state-type;
        }
        default te-types:tunnel-state-up;
        description "ETH service operational state.";
    }
    leaf provisioning-state {
        type identityref {
            base te-types:lsp-state-type;
        }
        description "ETH service provisioning state.";
    }
    leaf creation-time {
        type yang:date-and-time;
        description
            "Time of ETH service creation.";
    }
    leaf last-updated-time {
        type yang:date-and-time;
        description
            "Time of ETH service last update.";
    }
    uses etht-svc-pm-stats;
}

/*
Data nodes
*/

container etht-svc {
    description
```

```
    "ETH transport services.";

    container globals {
        description
            "ETH profile information.";
        list etht-svc-bandwidth-profiles {
            key bandwidth-profile-name;
            description
                "List of bandwidth profile templates used by
                Ethernet services.";

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

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

        uses etht-svc-instance_config;

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

            uses etht-svc-instance_state;
        }
    }
}
```

<CODE ENDS>

5.2. YANG Code for ETH transport type

```
<CODE BEGINS> file "ietf-eth-tran-types@2018-07-02.yang"
module iETF-eth-tran-types {
    namespace "urn:ietf:params:xml:ns:yang:ietf-eth-tran-types";
    prefix "etht-types";

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

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

ID-draft editor:
  Haomian Zheng (zhenghaomian@huawei.com);
  Italo Busi (italo.busi@huawei.com);
  Aihua Guo (aihuaguo@huawei.com);
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  Yang Zhao (zhaoyangyjy@chinamobile.com);
  Xufeng Liu (Xufeng_Liu@jabil.com);
  Giuseppe Fioccola (giuseppe.fioccola@telecomitalia.it);
";

description
  "This module defines the ETH transport types.";

revision 2018-05-24 {
  description
    "Initial revision";
  reference
    "draft-zheng-ccamp-client-signal-yang";
}

/*
 * Identities
 */

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

/*
 * 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.";
}

/*
 * Grouping Definitions
 */

grouping etht-bandwidth-profiles {
  description
    "Bandwidth profile configuration paramters.";

  leaf bandwidth-profile-name {
    type string;
    description
      "Name of the bandwidth profile.";
  }
  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;
  }
/*
 * Open Issue: 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;
    }
/*
 * Open issue: need to indicate that Coupling Flag is defined only for MEF 10
 *
 * must
 *   '../bw-profile-type = "mef-10-bwp"'
 */
    description
        "Coupling Flag.";
}

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

grouping eth-label-restriction {
    container eth-label-restriction {
        leaf tag-type {
            type eth-types:eth-tag-type;
            description "VLAN tag type.";
        }
        leaf priority {
            type uint8;
            description "priority.";
        }
    }
}
```

```
}  
  
grouping eth-label {  
  leaf vlanid {  
    type eth-types:vlanid;  
    description  
      "VLAN tag id.";  
  }  
}
```

<CODE ENDS>

5.3. Other Transport Network client signal YANG Code

```
<CODE BEGINS> file "ietf-trans-client-service@2018-02-09.yang"  
module ietf-trans-client-service {  
  /* TODO: FIXME */  
  //yang-version 1.1;  
  
  namespace "urn:ietf:params:xml:ns:yang:ietf-trans-client-service";  
  prefix "clntsvc";  
  
  import ietf-te-types {  
    prefix "te-types";  
  }  
  
  import ietf-otn-types {  
    prefix "otn-types";  
  }  
  
  organization  
    "Internet Engineering Task Force (IETF) CCAMP WG";  
  contact  
    "  
  
    ID-draft editor:  
      Aihua Guo (aihuaguo@huawei.com);  
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      Xufeng Liu (Xufeng_Liu@jabil.com);  
      Giuseppe Fioccola (giuseppe.fioccola@telecomitalia.it);  
    ";
```

```
description
  "This module defines a YANG data model for describing
  simple transport client services.";

revision 2018-02-09 {
  description
    "Initial version";
  reference
    "ADD REFERENCE HERE";
}

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

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

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

  leaf client-signal {
    type identityref {
      base otn-types:client-signal;
    }
    description
      "Identifiies the client signal type associated with this port";
  }
}

grouping client-svc-tunnel-parameters {
  description
    "Transport client services tunnel parameters";

  leaf tunnel-name {
    type string;
    description
```

```
        "TE service tunnel instance name.";
    }
}

grouping te-topology-identifier {
    description
        "description";
    leaf access-provider-id {
        type te-types:te-global-id;
        description
            "An identifier to uniquely identify a provider.";
    }

    leaf access-client-id {
        type te-types:te-global-id;
        description
            "An identifier to uniquely identify a client.";
    }

    leaf access-topology-id {
        type te-types:te-topology-id;
        description
            "Identifies the topology the service access ports belong to.";
    }
}

grouping client-svc-instance_config {
    description
        "Configuraiton parameters for client services.";

    leaf client-svc-name {
        type string;
        description
            "Name of the p2p transport client service.";
    }

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

    uses te-topology-identifier;

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

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

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

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

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

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

/*
 * Data nodes
 */

container client-svc {
```

```
description
  "Transport client services.";

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

    uses client-svc-instance_config;
    uses client-svc-instance_state;
  }
}
}

<CODE ENDS>
```

6. Considerations and Open Issue

Editor Notes: This section is used to note temporary discussion/conclusion that to be fixed in the future version, and will be removed before publication. We currently categorize all the client signal types into transparent and non-transparent, with separate models. There was consensus that no common model is needed for these two categories.

7. IANA Considerations

TBD.

8. Manageability Considerations

TBD.

9. Security Considerations

The data following the model defined in this document is exchanged via, for example, the interface between an orchestrator and a transport network controller. The security concerns mentioned in [I-D.ietf-teas-yang-te-topo] for using ietf-te-topology.yang model also applies to this document.

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

There are a number of data nodes defined in the YANG module which are writable/creatable/deletable (i.e., config true, which is the

default). These data nodes may be considered sensitive or vulnerable in some network environments. Write operations (e.g., POST) to these data nodes without proper protection can have a negative effect on network operations.

10. Acknowledgements

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Interworking of GMPLS Control and Centralized Controller System

draft-zheng-ccamp-gmpls-controller-inter-work-02

Abstract

Generalized Multi-Protocol Label Switching (GMPLS) control allows each network element (NE) to perform local resource discovery (e.g., LMP), routing (e.g., OSPF-TE) and signaling (e.g., RSVP-TE) in a distributed manner.

On the other hand, with the development of software-defined transport networking technology, a set of NEs can be controlled via centralized controller hierarchies to address the issue from multi-domain, multi-vendor and multi-technology. An example of such centralized architecture is ACTN controller hierarchy [I-D.ietf-teas-actn-framework].

Instead of competing with each other, both the distributed and the centralized control plane have their own advantage, and should be complementary in the system. This document describes how the GMPLS distributed control plane can interwork with a centralized controller system in a transport network.

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Conventions used in this document

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

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1. Introduction

Generalized Multi-Protocol Label Switching (GMPLS) [RFC3945] extends MPLS to support different classes of interfaces and switching capabilities such as Time-Division Multiplex Capable (TDM), Lambda Switch Capable (LSC), and Fiber-Switch Capable (FSC). Each network element (NE) running a GMPLS control plane collects network information from other NEs and supports service provisioning through signaling in a distributed manner.

On the other hand, Software-Defined Networking (SDN) technologies have been introduced to control the transport network in a centralized manner. Central controllers can collect network information from each node and provision services to corresponding nodes. One of the examples is the Abstraction and Control of Traffic Engineered Networks (ACTN) [I-D.ietf-teas-actn-framework], which defines a hierarchical architecture with PNC, MDSC and CNC as central controllers for different network abstraction levels.

In such centralized controller architectures, GMPLS can be applied for the NE-level control. A central controller may support GMPLS enabled domains and may interact with a GMPLS enabled domain where the GMPLS control plane does the service provisioning from ingress to egress. In this case the centralized controller sends the request to the ingress node and does not have to configure all NEs along the path through the domain from ingress to egress thus leveraging the GMPLS control plane. This document describes how GMPLS control interworks with centralized controller system in transport network.

2. Overview

In this section, overviews of GMPLS control plane and centralized controller system are discussed as well as the interactions between the GMPLS control plane and centralized controllers.

2.1. Overview of GMPLS Control Plane

GMPLS separates the control plane and the data plane to support time-division, wavelength, and spatial switching, which are significant in transport networks. For the NE level control in GMPLS, each node runs a GMPLS control plane instance. Functionalities such as service provisioning, protection, and restoration can be performed via GMPLS communication among multiple NEs. At the same time, the controller can also collect node and link resources in the network to construct the network topology and compute routing paths for serving service requests.

Several protocols have been designed for GMPLS control [RFC3945] including link management [RFC4204], signaling [RFC3471], and routing [RFC4202] protocols. The controllers applying these protocols communicate with each other to exchange resource information and establish LSP. In this way, controllers in different nodes in the network have the same network topology and provision services based on local policies.

2.2. Overview of Centralized Controller System

With the development of SDN technologies, a centralized controller architecture has been introduced to transport networks such as ACTN [I-D.ietf-teas-actn-framework]. In centralized controller system, a controller is aware of the network topology and is responsible for provisioning incoming service requests. In ACTN, multiple abstraction levels are designed and controllers at different levels implement different functions. This kind of abstraction enables multi-vendor, multi-domain, and multi-technology control.

For example in ACTN, an MDSC coordinates several PNCs controlling different domains. Each PNC provides a topological view of the domain it controls, which can be abstracted, to the MDSC, so that the MDSC learns the topology of the network encompassing multiple domains. When a multi-domain service request arrives at the MDSC, the MDSC first computes an end-to-end path based on the abstracted topology view provided by the PNCs. Then, the MDSC splits this path to multiple segment according to domain boundaries and allocate each segment to corresponding PNC for detailed path computation and LSP segment setup. When each PNC has reported the establishment of its LSP segment, the multi-domain service is established.

2.3. GMPLS Control Interwork with Centralized Controller System

The ACTN framework [I-D.ietf-teas-actn-framework] defines a hierarchical controller architecture and describes how these controllers communicate with each other in order to control a multi-domain transport network. The controllers at the different levels in the hierarchy typically perform network abstraction of the domain they control and provide an abstracted view of their domain to the controller at the next level in the hierarchy. The controllers at the different hierarchical levels also interact with each other during end-to-end service establishment, which can span multiple domains. Within each domain, GMPLS control can be applied to each NE. The bottom-level central controller like PNC can act as a NE to collect network information and initiate LSP. Following figure shows an example of GMPLS interworking with ACTN.

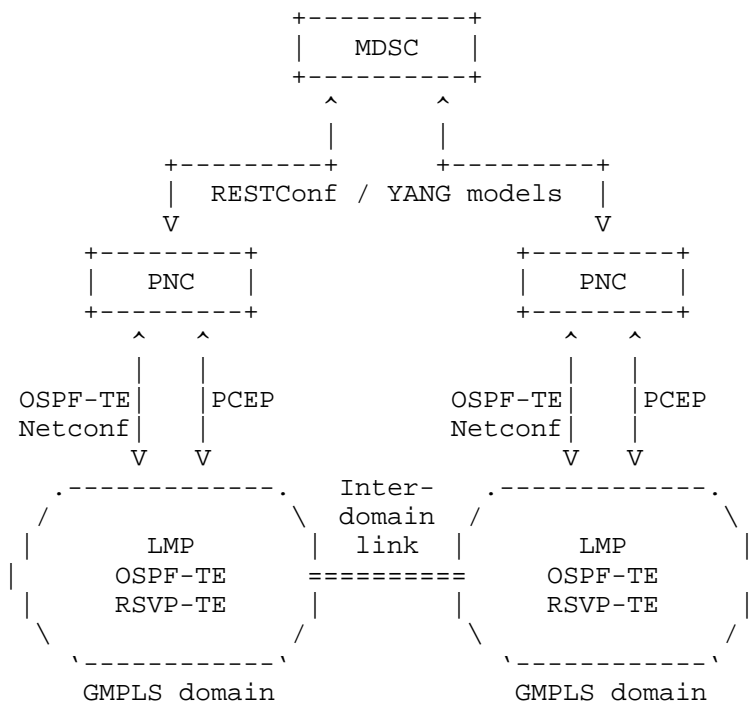


Figure 1: Example of GMPLS interworks with ACTN

In Figure 1, each domain has the GMPLS control plane enabled at the physical network level. The PNC can listen to the IGP routing

protocol messages (OSPF LSAs for example) that the GMPLS control plane instances are disseminating into the network and thus learn the network topology. For path computation in the domain with PNC implementing a PCE, PCCs (e.g. NEs, other controller/PCE) use PCEP to ask the PNC for a path and get replies. The MDSC communicates with PNCs using for example REST/RESTConf based on YANG data models. As a PNC has learned its domain topology, it can report the topology to the MDSC. When a service arrives, the MDSC computes the path and coordinates PNCs to establish the corresponding LSP segment.

Alternatively, the NETCONF protocol can be used to retrieve topology information utilizing the [TE-TOPO] Yang model and the technology-specific YANG model augmentations required for the specific network technology. The PNC can retrieve topology information from any NE (the GMPLS control plane instance of each NE in the domain has the same topological view), construct the topology of the domain and export an abstracted view to the MDSC. Based on the topology retrieved from multiple PNCs, the MDSC can create topology graph of the multi-domain network, and can use it for path computation. To setup a service, the MDSC can exploit Yang tunnel model together with the technology-specific YANG model augmentations.

3. Link Management Protocol

Link management protocol (LMP) [RFC4204] runs between a pair of nodes and is used to manage TE links. In addition to setup and maintain control channels, LMP can be used to verify the data link connectivity and correlate the link property. In this way, link resources, which are fundamental resources in the network, are discovered by both ends of the link.

4. Routing Options

In GMPLS control, link state information is flooded within the network as defined in [RFC4202]. Each node in the network can build the network topology according to the flooded link state information. Routing protocols such as OSPF-TE [RFC4203] and ISIS-TE [RFC5307] have been extended to support different interfaces in GMPLS.

In centralized controller system, central controller can be placed at the GMPLS network and passively receive the information flooded in the network. In this way, the central controller can construct and update the network topology.

4.1. OSPF-TE

OSPF-TE is introduced for TE networks in [RFC3630]. OSPF extensions have been defined in [RFC4203] to enable the capability of link

state information for GMPLS network. Based on this work, OSPF protocol has been extended to support technology-specific routing. The routing protocol for OTN, WSON and optical flexi-grid network are defined in [RFC7138], [RFC7688] and [I-D.ietf-ccamp-flexible-grid-ospf-ext], respectively.

4.2. ISIS-TE

ISIS-TE is introduced for TE networks in [RFC5305] and is extended to support GMPLS routing functions [RFC5307], and has been updated to [RFC7074] to support the latest GMPLS switching capability and Types fields.

4.3. Netconf/RESTconf

Netconf [RFC6241] and RESTconf [RFC8040] protocols are originally used for network configuration. Besides, these protocols can also be used for topology retrieval by using topology-related YANG models, such as [RFC8345] and [TE-topo]. These protocols provide a powerful mechanism for notification that permits to notify the client about topology changes.

5. Path Computation

Once a controller learn the network topology, it can utilize the available resources to serve service requests by performing path computation. Due to abstraction, the MDSC may not have sufficient information to compute the optimal path. In this case, the MDSC can interact with different domain controllers by sending Yang Path Computation requests [PAT-COMP] to compute a set of potential optimal paths and then, based on its own constraints, policy and specific knowledge (e.g. cost of access link) can choose the more feasible path for service e2e path setup.

Path computation is one of the key objectives in various types of controllers. In the given architecture, it is possible for different components that have the capability to compute the path.

5.1. Constraint-based Path Computing in GMPLS Control

In GMPLS control, a routing path is computed by the ingress node [RFC3473] and is based on the ingress node TED. Constraint-based path computation is performed according to the local policy of the ingress node.

5.2. Path Computation Element (PCE)

PCE has been introduced in [RFC4655] as a functional component that provides services to compute path in a network. In [RFC5440], the

path computation is accomplished by using the Traffic Engineering Database (TED), which maintains the link resources in the network. The emergence of PCE efficiently improve the quality of network planning and offline computation, but there is a risk that the computed path may be infeasible if there is a diversity requirement, because stateless PCE has no knowledge about the former computed paths.

To address this issue, stateful PCE has been proposed in [RFC8231]. Besides the TED, an additional LSP Database (LSP-DB) is introduced to archive each LSP computed by the PCE. In this way, PCE can easily figure out the relationship between the computing path and former computed paths. In this approach, PCE provides computed paths to PCC, and then PCC decides which path is deployed and when to be established.

In PCE Initiation [I-D.ietf-pce-pce-initiated-lsp], PCE is allowed to trigger the PCC to setup, maintenance, and teardown of the PCE-initiated LSP under the stateful PCE model. This would allow a dynamic network that is centrally controlled and deployed.

In centralized controller system, the PCE can be implement in a central controller, and the central controller performs path computation according to its local policies. On the other hand, the PCE can also be placed outside of the central controller. In this case, the central controller acts as a PCC to request path computation to the PCE through PCEP.

6. Signaling Options

Signaling mechanism is used to setup LSPs in GMPLS control. Messages are sent hop by hop between the ingress node and the egress node of the LSP to allocate labels. Once the labels are allocated along the path, the LSP setup is accomplished. Signaling protocols such as RSVP-TE [RFC3473] and CR-LDP [RFC3472] have been extended to support different interfaces in GMPLS.

6.1. RSVP-TE

RSVP-TE is introduced in [RFC3209] and extended to support GMPLS signaling in [RFC3473]. Several label formats are defined for a generalized label request, a generalized label, suggested label and label sets. Based on [RFC3473], RSVP-TE has been extended to support technology-specific signaling. The RSVP-TE extensions for OTN, WSON, optical flexi-grid network are defined in [RFC7139], [RFC7689], and [RFC7792], respectively.

6.2. CR-LDP

In order to support the label formats and signaling mechanism defined in [RFC3471], CR-LDP is extended in [RFC3472]. Several label formats are defined and bidirectional LSPs are supported.

7. Interworking Scenarios

7.1. Topology Collection & Synchronization

Topology information is necessary on both network elements and controllers. The topology on network element is usually raw information, while the topology on the controller can be either raw or abstracted. Three different abstraction method has been described in [I-D.ietf-teas-actn-framework], and different controllers can select the corresponding method depending on application.

When there are changes in the network topology, the impacted network element(s) need to report changes to all the other network elements, together with the controller, to sync up the topology information. The inter-NE synchronization can be achieved via protocols mentioned in section 3 and 4. The topology synchronization between NEs and controllers can either be achieved by routing protocols OSPF-TE/PCEP-LS in [PCEP-LS] or Netconf protocol with YANG model.

7.2. Multi-domain/layer Service Provisioning

Based on the topology information on controllers and network elements, service provisioning can be deployed. Plenty of methods have been specified for single domain service provisioning, such as using PCEP and RSVP-TE.

Multi-domain/layer service provisioning would request coordination among the controller hierarchies. Given the service request, the end-to-end delivery procedure may include interactions on MPI and SBI. The computation for a cross-domain/layer path is usually completed by MDSC, who has a global view of the topologies. Then the configuration is decomposed into lower layer controllers, including both MDSC and PNCs, to configure the network elements to set up the path.

A combination of the centralized and distributed protocols may be necessary for the interaction between network elements and controller. A typical example would be the PCE Initiation scenario, in which a PCE message (PCInitiate) is sent from the controller to the first-end node, and then trigger a RSVP procedure along the path. Similarly, the interaction between the controller and the ingress node of a domain can be achieved by Netconf protocol with

corresponding YANG models, and then completed by running RSVP among the network elements.

7.3. Recovery

The GMPLS recovery functions are described in [RFC4426]. Two models, span protection and end-to-end protection and restoration, are discussed with different protection schemes and message exchange requirements. Related RSVP-TE extensions to support end-to-end recovery is described in [RFC4872]. The extensions in [RFC4872] include protection, restoration, preemption, and rerouting mechanisms for an end-to-end LSP. Besides end-to-end recovery, a GMPLS segment recovery mechanism is defined in [RFC4873]. By introducing secondary record route objects, LSP segment can be switched to another path like fast reroute [RFC4090].

For the recovery with controllers, timely interaction between controller and network elements are required. Usually the re-routing can be decomposed into path computation and delivery, the controller can take some advantage in the path computation due to the global topology view. And the delivery can be achieved by the procedure described in section 7.2.

7.4. Controller Reliability

Given the important role in the network, the reliability of controller is critical. Once a controller is shut down, the network should operate as well. It can be either achieved by controller back up or functionality back up. There are several of controller backup or federation mechanisms in the literature. It is also more reliable to have some function back up in the network element, to guarantee the performance in the network.

8. Network Management

TBD.

9. Security Considerations

TBD.

10. IANA Considerations

This document requires no IANA actions.

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ISIS Extensions for Flex Ethernet Link Advertisement
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Abstract

This document specifies the extensions to the IS-IS routing protocol to carry and flood Flex Ethernet (FlexE) link state information. The FlexE link state information is necessary for a node or a controller to compute a path that is required to over FlexE links.

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].

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1. Introduction

Flex Ethernet (FlexE) [I-D.izh-ccamp-flexe-fwk] provides a generic mechanism for supporting a variety of Ethernet MAC rates that may or may not correspond to any existing Ethernet PHY rate. This includes MAC rates that are both greater than (through bonding) and less than (through sub-rate and channelization) the Ethernet PHY rates used to carry Ethernet traffic.

FlexE supports interface bonding, a bonded interface is consisted of from 1 to n 100GBASE-R Ethernet interfaces (other rates of interface will be supported in the future), the bonded interface is called FlexE interface in this document. FlexE also supports interface channelization, a FlexE interface can be channelized into multiple sub-interfaces, the sub-interface is called FlexE sub-interface in the rest of this document.

The FlexE mechanism operates using a calendar which assigns 66B block positions on sub-calendars on each PHY of a FlexE interface to each of the FlexE flows. The calendar has a granularity of 5G, and has a length of 20 slots for a 100G interface. Currently, only 100GBASE-R PHY and 5G granularity are supported in FlexE implementation agreement version 1.0 [FlexE], other types (e.g., 200G, 400G) of PHY and granularities (e.g., 25G) will be supported in the future.

A FlexE interface has a number of time slots resource. These time slots can be transparent to the upper layer application, the upper layer application (e.g., RSVP-TE) can just treat the FlexE interface as a normal Ethernet interface or the time slots can be allocated to form a FlexE sub-interface through configuration or some dynamic protocols. The later is called channelization. How to signal or configure the FlexE sub-interface is out of the scope of this document.

The logical link that connects two FlexE interfaces residing in two adjacent nodes is called FlexE link, and the logical link that connects two FlexE sub-interfaces residing in two adjacent nodes is called FlexE sub-link.

More details about FlexE can be found in FlexE framework document [I-D.izh-ccamp-flex-e-fwk].

This document defines extensions to ISIS protocol to advertise the FlexE link and sub-link state information.

2. FlexE Link

A FlexE link is a logical link that connects two FlexE interfaces, it looks like a LAG (Link Aggregation Group).

This document defines a new sub-TLV, which is referred to as FlexE Interface sub-TLV, to the extended IS reachability TLV [RFC5307]. It is defined to describe the resources and attributes of a FlexE interface. The format of FlexE Interface sub-TLV is as below:

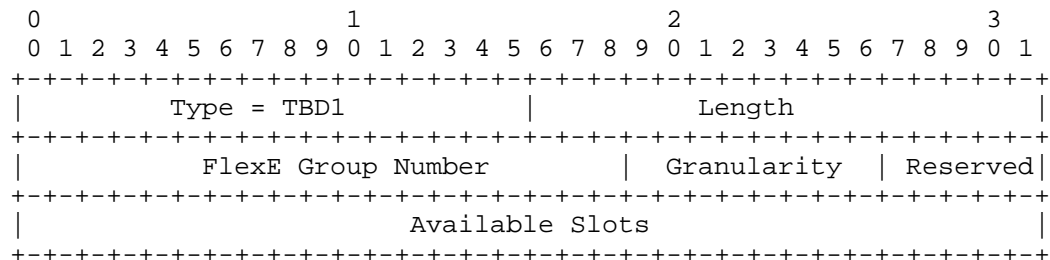


Figure 2: FlexE Interface sub-TLV

The Type field is 2 octets in length and the value is TBD1.

The Length field is 2 octets in length that indicates the total length of the TLV in octet.

FlexE Group Number field is 20 bits in length and carries the FlexE Group [FlexE]number of the FlexE Group that the FlexE interface belongs.

The Granularity is 1 octet in length and its value identifies the granularity of the FlexE time slots of a FlexE interface. Current OIF agreement only allows the "5G" granularity, other granularities may be defined in the future.

Value	Granularity
-----	-----
0	Reserved
1	5G
2-254	Unassigned
255	Reserved

For each PHY of a FlexE interface, there are two calendars, one is called Active calendar and the other is called Backup calendar. The two calendars are used to facilitate reconfiguration, for example, FlexE flow resizing can be achieved through calendar updates. More detail about FlexE calendar can be found [FlexE].

The Available Slots fields is 4-octet in length that indicates the maximum number of slots available on the active calendar of the FlexE interface.

For each PHY of a FlexE interface, there are two calendars, one is called Active calendar and the other is called Backup calendar. The two calendars are used to facilitate reconfiguration, for example, FlexE flow resizing can be achieved through calendar updates. More detail about FlexE calendar can be found [FlexE].

For a FlexE interface, 5G granularity is only supported in [FlexE], more granularities may be supported in the future. To support this, FlexE Interface sub-TLV can occur multiple times in an extended IS reachability TLV, but for each granularity, only one FlexE Interface sub-TLV can be included and it carries the available time slots of the granularity of the FlexE interface. When multiple FlexE Interface sub-TLVs for the same granularity occur, only the first FlexE Interface sub-TLV is considered to be valid, the rests MUST be ignored.

3. FlexE Sub-link

Through channelization, a FlexE interface can be sliced into a number of FlexE sub-interfaces, each FlexE sub-interface has dedicated bandwidth and is isolated from other FlexE sub-interfaces. A set of FlexE sub-interfaces can be allocated to a specific application/user

to form a sliced network. Or a series of FlexE sub-interfaces can be concatenated (e.g., through Segment Routing) to form a leased line.

A FlexE sub-link connects two FlexE sub-interfaces. From link characteristic point of view, a FlexE sub-link is same as an Ethernet link, it can be advertised and used as a normal link.

4. IANA Considerations

4.1. FlexE Interface Sub-TLV

IANA is requested to allocate the following new sub-TLV types of top-level TLV 22 that have been reflected in the IS-IS sub-TLV registry for TLV 22:

Value	sub-TLV Name	Reference
-----	-----	-----
TBD1	FlexE Interface	This document

5. Security Consideration

This document describes a mechanism for advertising FlexE link state information through IS-IS LSPs and does not introduce any new security issues.

6. Acknowledgements

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