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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-01

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 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 draft-ietf-ccamp-flexi-grid-fwk

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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Status of This Memo

This Internet-Draft will expire on September 14, 2017.

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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 avaiable 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 draft-ietf-ccamp-dwdm-if-mng-ctrl-fwk and draft-many-coherent-DWDM-if-control.

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

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

2. The Internet-Standard Management Framework

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

This memo specifies a Yang model for optical interfaces.

3. Conventions

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

4. Overview

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

```
          +-------------------------------------------------+
       Ss |              DWDM Network Elements              | Rs
   +--+ | |  | \                                       / |  |  | +--+
   Tx L1--|->|   \    +------+            +------+   /   |--|-->Rx L1
   +---+  |  |    |   |      |  +------+  |      |  |    |  |    +--+
   +---+  |  |    |   |      |  |      |  |      |  |    |  |    +--+
   Tx L2--|->| OM |-->|------|->| OADM |--|------|->| OD |--|-->Rx L2
   +---+  |  |    |   |      |  |      |  |      |  |    |  |    +--+
   +---+  |  |    |   |      |  +------+  |      |  |    |  |    +--+
   Tx L3--|->|   /    | DWDM |    |  ^    | DWDM |   \   |--|-->Rx L3
   +---+  |  | /      | Link +----|--|----+ Link |     \ |  |    +--+
          +-----------+           |  |           +----------+
                               +--+  +--+
                               |        |
                            Rs v        | Ss
                            +-----+  +-----+
                            |RxLx |  |TxLx |
                            +-----+  +-----+
   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
   OADM = Optical Add Drop Mux


   from Fig. 5.1/G.698.2
```

Figure 1: External transponder in WDM netwoks

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 treshold 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:dharinih@juniper.net>";

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

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        as authors of the code.  All rights reserved.

        Redistribution and use in source and binary forms, with or
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        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 "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 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 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]. he 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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A YANG model to manage the optical interface parameters for an external transponder in a WDM network
draft-dharini-ccamp-dwdm-if-param-yang-02

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 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 draft-ietf-ccamp-flexi-grid-fwk

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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Table of Contents

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 avaiable 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 draft-ietf-ccamp-dwdm-if-mng-ctrl-fwk and draft-many-coherent-DWDM-if-control.

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

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

2. The Internet-Standard Management Framework

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

This memo specifies a Yang model for optical interfaces.

3. Conventions

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

4. Overview

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

```
       +---------------------------------------------------+
    Ss |              DWDM Network Elements                | Rs
+--+ | |  | \                                          / |  |  | +--+
Tx L1--|->|   \    +------+           +------+   /   |--|-->Rx L1
+---+  |  |    |   |      |  +-------+  |      |  |    |  |    +--+
+---+  |  |    |   |      |  |       |  |      |  |    |  |    +--+
Tx L2--|->| OM |-->|------|->|ROADM |--|------|->| OD |--|-->Rx L2
+---+  |  |    |   |      |  |       |  |      |  |    |  |    +--+
+---+  |  |    |   |      |  +-------+  |      |  |    |  |    +--+
Tx L3--|->|   /    | DWDM |    |  ^    | DWDM |   \   |--|-->Rx L3
+---+  |  | /      | Link +----|--|----+ Link |     \ |  |    +--+
       +------------+          |  |          +-----------+
                            +--+  +--+
                            |        |
                         Rs v        | Ss
                         +-----+  +-----+
                         |RxLx |  |TxLx |
                         +-----+  +-----+
```

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 netwoks

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 treshold 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:dharinih@juniper.net>";

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

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

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           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 "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 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 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]. he 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-03

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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Table of Contents

1. Introduction

This extension addresses the use cases described by "draft-kdkgall-ccamp-dwdm-if-mng-ctrl-fwk-00". 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-galikunze-ccamp-dwdm-if-snmp-mib-01" and "draft-dharini-ccamp-dwdm-if-yang-00".

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 (OADM).

```
          +-------------------------------------------------+
       Ss |              DWDM Network Elements              | Rs
   +--+ | |  | \                                       / |  |  | +--+
   Tx L1--|->|   \    +------+            +------+   /   |--|-->Rx L1
   +---+  |  |    |   |      |  +------+  |      |  |    |  |    +--+
   +---+  |  |    |   |      |  |      |  |      |  |    |  |    +--+
   Tx L2--|->| OM |-->|------|->| OADM |--|------|->| OD |--|-->Rx L2
   +---+  |  |    |   |      |  |      |  |      |  |    |  |    +--+
   +---+  |  |    |   |      |  +------+  |      |  |    |  |    +--+
   Tx L3--|->|   /    | DWDM |    |  ^    | DWDM |   \   |--|-->Rx L3
   +---+  |  | /      | Link +----|--|----+ Link |     \ |  |    +--+
          +-----------+           |  |           +----------+
                               +--+  +--+
                               |        |
                            Rs v        | Ss
                            +-----+  +-----+
                            |RxLx |  |TxLx |
                            +-----+  +-----+
```

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
OADM = Optical Add Drop Mux

from Fig. 5.1/G.698.2

Figure 1: Linear Single Channel approach

Figure 2 Extended LMP Model (from [RFC4209])

```
         +------+ Ss    +------+       +------+    Rs +------+
         |      | ----- |      |       |      | ----- |      |
         | OXC1 | ----- | OLS1 | ===== | OLS2 | ----- | OXC2 |
         |      | ----- |      |       |      | ----- |      |
         +------+       +------+       +------+       +------+
           ^  ^             ^              ^             ^  ^
           |  |             |              |             |  |
           |  +-----LMP-----+              +-----LMP-----+  |
           |                                                |
           +----------------------LMP-----------------------+
```

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-kdkgall-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 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_ApplicationIdentier   (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-01" and "draft-dharini-ccamp-dwdm-if-yang-00" 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:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type       |    Length     |         (Reserved)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Central Frequency                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Number of Application                |                      |
|   Identifiers Supported                |     (Reserved)       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Single-channel|  A.I. Type    |         A.I. length           |
| Application   |   in use      |                               |
| Identifier    |               |                               |
| Number in use |               |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Single-channel Application Identifier in use        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Single-channel Application Identifier in use        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Single-channel Application Identifier in use        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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 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 identifiers this entry - 8 bits

3. Application Indentifier 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:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type       |    Length     |         (Reserved)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Number of Application               |                       |
|   Identifiers Supported               |     (Reserved)        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Single-channel|  A.I. Type    |         A.I. length           |
| Application   |               |                               |
| Identifier    |               |                               |
| Number        |               |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Single-channel Application Identifier           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Single-channel Application Identifier           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Single-channel Application Identifier           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
//              ....                                           //
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Single-channel|               |         A.I. length           |
| Application   |   A.I. Type   |                               |
| Identifier    |               |                               |
| Number        |               |                               |
|               |               |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
|                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-galikunze-ccamp-dwdm-if-snmp-mib-01" 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:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type       |    Length     |         (Reserved)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Output Power                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type       |    Length     |                    (Reserved) |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Current Input Power                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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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October 30, 2017

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-05

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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Table of Contents

1. Introduction

This extension addresses the use cases described by "draft-ietf-ccamp-dwdm-if-mng-ctrl-fwk-07". 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-03".

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 (OADM).

```
          +-------------------------------------------------+
       Ss |              DWDM Network Elements              | Rs
   +--+ | |  | \                                       / |  |  | +--+
   Tx L1--|->|   \    +------+            +------+   /   |--|-->Rx L1
   +---+  |  |    |   |      |  +------+  |      |  |    |  |    +--+
   +---+  |  |    |   |      |  |      |  |      |  |    |  |    +--+
   Tx L2--|->| OM |-->|------|->|ROADM |--|------|->| OD |--|-->Rx L2
   +---+  |  |    |   |      |  |      |  |      |  |    |  |    +--+
   +---+  |  |    |   |      |  +------+  |      |  |    |  |    +--+
   Tx L3--|->|   /    | DWDM |    |  ^    | DWDM |   \   |--|-->Rx L3
   +---+  |  | /      | Link +----|--|----+ Link |     \ |  |    +--+
          +-----------+           |  |           +----------+
                               +--+  +--+
                               |        |
                            Rs v        | Ss
                            +-----+  +-----+
                            |RxLx |  |TxLx |
                            +-----+  +-----+
```

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])

```
          +------+ Ss    +------+       +------+    Rs +------+
          |      | ----- |      |       |      | ----- |      |
          | OXC1 | ----- | OLS1 | ===== | OLS2 | ----- | OXC2 |
          |      | ----- |      |       |      | ----- |      |
          +------+       +------+       +------+       +------+
            ^  ^             ^              ^             ^  ^
            |  |             |              |             |  |
            |  +-----LMP-----+              +-----LMP-----+  |
            |                                                |
            +----------------------LMP-----------------------+
```

```
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_ApplicationIdentier     (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-01" and "draft-dharini-ccamp-dwdm-if-yang-00" 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:

```
  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
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |    Type       |    Length     |         (Reserved)            |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                    Central Frequency                          |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |   Number of Application                |                      |
 |   Identifiers Supported                |     (Reserved)       |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 | Single-channel|  A.I. Type    |         A.I. length           |
 | Application   |   in use      |                               |
 | Identifier    |               |                               |
 | Number in use |               |                               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |          Single-channel Application Identifier in use         |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |          Single-channel Application Identifier in use         |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |          Single-channel Application Identifier in use         |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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 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 identifiers this entry - 8 bits

3. Application Indentifier 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:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type       |    Length     |         (Reserved)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Number of Application                 |                     |
|   Identifiers Supported                 |     (Reserved)      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Single-channel|  A.I. Type    |         A.I. length           |
| Application   |               |                               |
| Identifier    |               |                               |
| Number        |               |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Single-channel Application Identifier           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Single-channel Application Identifier           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Single-channel Application Identifier           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
//              ....                                           //
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Single-channel|               |         A.I. length           |
| Application   |   A.I. Type   |                               |
| Identifier    |               |                               |
| Number        |               |                               |
|               |               |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
    |                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-03" 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:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type       |    Length     |         (Reserved)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Output Power                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type       |    Length     |                   (Reserved)  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Current Input Power                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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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A YANG model to manage the optical optical parameters for in a WDM network
draft-galimbe-ccamp-iv-yang-02

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 tu 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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Status of This Memo

This Internet-Draft will expire on September 14, 2017.

Copyright Notice

Table of Contents

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 SND controller features is tu support multi vendor network and support the service calculation and deployment in multilayer topologies, for the DWDM mayer it is fundamentad 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.

For the optical impairments related to the DWDM Transceiver the 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 refer 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 algoritms, not being exhaustive the information can give a acceptable or even good approximation in therm of connection feasibility. This may not be true for legacy compensated network.

6. Properties

For the signal properties this traft refers the 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 |                   DWDM Network                  | Rs
   +--+ | |  | \                                       / |  |  | +--+
   Tx L1--|->|   \                                   /   |--|-->Rx L1
   +---+  |  |    |             +------+            |    |  |    +--+
   +---+  |  |    |             |      |            |    |  |    +--+
   Tx L2--|->| OM |------------>| OADM |-- -------->| OD |--|-->Rx L2
   +---+  |  |    |    DWDM     |      |    DWDM    |    |  |    +--+
   +---+  |  |    |    Link     +------+    Link    |    |  |    +--+
   Tx L3--|->|   /               |  ^               \   |--|-->Rx L3
   +---+  |  | /                 |  |                 \ |  |    +--+
          +-----------------------|--|----------------------+
                               +--+  +--+
                               |        |
                            Rs v        | Ss
                            +-----+  +-----+
                            |RxLx |  |TxLx |
                            +-----+  +-----+
   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
   OADM = Optical Add Drop Mux


   from Fig. 5.1/G.698.2
```

Figure 1: External transponder in WDM netwoks

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. 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
      +--rw gain-degrade-high?   dbm-t
   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 channel-t
      |  +--rw grid?              uint32
      |  +--rw channel-spacing?   uint32
      |  +--rw identifier?        uint32
      |  +--rw n?                 uint32
      +--rw channel-n-m
         +--rw grid?              uint32
         +--rw channel-spacing?   uint32
         +--rw n?                 uint32
         +--rw m?                 uint32
```

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 "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";
     }

     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";
         }
        }
     }

      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;
        description "High Gain Degrade Value";
```

```
      }
    }


    grouping noise {
      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";
      }
      description "Noise feasibility";
    }

    grouping noise-sigma {
      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";
      }
      description "Noise Sigma feasibility";
    }

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

    grouping 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";
       }
       description "Chromatic Dispersion (CD) Slope feasibility";
     }

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

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

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

     grouping drop-power-sigma {
       leaf drop-power-sigma {
         type decimal64 {
           fraction-digits 2;
         }
         units "db";
```

```
         description "Drop Power Sigma value at the DWDM Transceiver
         RX side";
       }
       description "Drop Power Sigma feasibility";
     }

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

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

       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 {
       leaf dgd {
         type decimal64 {
           fraction-digits 2;
         }
         units "db";
         description "differential group delay";
       }
       description "differential group delay";
     }

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

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

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

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

       grouping att-coefficient {
       leaf att {
         type decimal64 {
```

```
           fraction-digits 2;
         }
         units "db";
         description "Attenuation coefficient (for a fibre segment)";
       }
       description "Attenuation coefficient (for a fibre segment)";
      }


       }


   }
```

<CODE ENDS>

10. Security Considerations

The YANG module defined in this memo is designed to be accessed via the NETCONF protocol [RFC6241]. he 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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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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June 30, 2017

A YANG model to manage the optical parameters for in a WDM network
draft-galimbe-ccamp-iv-yang-03

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 tu 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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Status of This Memo

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Table of Contents

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 SND controller features is tu support multi vendor network and support the service calculation and deployment in multilayer topologies, for the DWDM mayer it is fundamentad 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.

For the optical impairments related to the DWDM Transceiver the 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 refer 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 algoritms, not being exhaustive the information can give a acceptable or even good approximation in therm of connection feasibility. This may not be true for legacy compensated network.

6. Properties

For the signal properties this traft refers the 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 |                   DWDM Network                  | Rs
   +--+ | |  | \                                       / |  |  | +--+
   Tx L1--|->|   \                                   /   |--|-->Rx L1
   +---+  |  |    |             +------+            |    |  |    +--+
   +---+  |  |    |             |      |            |    |  |    +--+
   Tx L2--|->| OM |------------>|ROADM |-- -------->| OD |--|-->Rx L2
   +---+  |  |    |     DWDM    |      |    DWDM    |    |  |    +--+
   +---+  |  |    |     Link    +------+    Link    |    |  |    +--+
   Tx L3--|->|   /                |  ^               \   |--|-->Rx L3
   +---+  |  | /                  |  |                 \ |  |    +--+
          +-----------------------|--|----------------------+
                               +--+  +--+
                               |        |
                            Rs v        | Ss
                            +-----+  +-----+
                            |RxLx |  |TxLx |
                            +-----+  +-----+
   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 netwoks

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. 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
    +--rw gain-degrade-high?   dbm-t
  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
```

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 "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";
      }

      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";
```

```
         }
        }
     }

      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;
        description "High Gain Degrade Value";
      }
    }


    grouping noise {
      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";
      }
      description "Noise feasibility";
    }

    grouping noise-sigma {
```

```
       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";
       }
       description "Noise Sigma feasibility";
     }

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

     grouping 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";
       }
       description "Chromatic Dispersion (CD) Slope feasibility";
     }

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

     grouping pdl {
```

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

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

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

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

       grouping ch-noise-figure {
       list ch-noise-figure {
```

```
         description "Channel signal-spontaneous noise figure";

        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 {
        leaf dgd {
          type decimal64 {
            fraction-digits 2;
          }
          units "db";
          description "differential group delay";
        }
        description "differential group delay";
      }

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

        leaf ad-ch-isol {
            type decimal64 {
              fraction-digits 2;
            }
```

```
           units "dB";
           description "adjecent channel isolation";
         }

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

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

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


       }


   }

   <CODE ENDS>
```

10. Security Considerations

The YANG module defined in this memo is designed to be accessed via the NETCONF protocol [RFC6241]. he 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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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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October 30, 2017

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-03

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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Table of Contents

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 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 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-T so this document can jast 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 (OADM).

```
          +--------------------------------------------------+
       Ss |             DWDM Network Elements                | Rs
   +--+ | |  | \                                          / |  |  | +--+
   Tx L1--|->|   \    +------+          +------+   /   |--|-->Rx L1
   +---+  |  |    |   |      |  +------+  |      |  |     |  |    +--+
   +---+  |  | FX |   |      |  | FLEX |  |      |  | FX |  |    +--+
   Tx L2--|->| OM |-->|------|->|ROADM |--|------|->| OD |--|-->Rx L2
   +---+  |  |    |   |      |  |      |  |      |  |     |  |    +--+
   +---+  |  |    |   |      |  +------+  |      |  |     |  |    +--+
   Tx L3--|->|   /    | DWDM |     |  ^    | DWDM |   \   |--|-->Rx L3
   +---+  |  | /      | Link +----|--|----+ Link |     \ |  |    +--+
          +-----------+          |  |          +-----------+
                               +--+  +--+
                               |        |
                            Rs v        | Ss
                            +-----+  +-----+
                            |RxLx |  |TxLx |
                            +-----+  +-----+
```

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])

```
        +------+ Ss    +------+       +------+    Rs +------+
        |      | ----- |      |       |      | ----- |      |
        | OXC1 | ----- | OLS1 | ===== | OLS2 | ----- | OXC2 |
        |      | ----- |      |       |      | ----- |      |
        +------+       +------+       +------+       +------+
          ^  ^             ^              ^             ^  ^
          |  |             |              |             |  |
          |  +-----LMP-----+              +-----LMP-----+  |
          |                                                |
          +----------------------LMP-----------------------+
```

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 paramentes exchanged between is to support the Spectrum Switched Optical Network in therms 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.

The general parameters are

1. Modulation identifier: indicates the Transceiver capabilities to support a single or multiple modulation format like: BPSK (1), 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: number of symbols rate, besically this identify the channel frequency
4. Num Carriers: number of subcarriers 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. Sub-carrier OSNR robustness

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

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type       |    Length     |          (Reserved)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|S|I|         Modulation ID     |               FEC             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        baud rate  (Symbol Rate)               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Number of subcarriers    |           Bit/Symbol          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          subcarrier band      |          guard band           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      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 BSPSK, 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
```

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-00

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. This document extends the GMPLS Lambda label format in accordance and extending the parameters defined in ITU-T Recommendation G.694.1.[ITU.G694.1] and its extensions.

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1. Introduction

Generalised Multiprotocol Label Switched (GMPLS) is widely used in Wavelength Switched Optical Network (WSON) 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 by Spectrum Switched Optical Network (SSON), 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 routed with it and keep the backward compatibility with the WSON signalling. In particular this memo wants do address the use cases where the SSON 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 [RFC7699] The contents and the parameters reflect the experimental activity on IP over SSON recently done.

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. |       | C.N. | /         /\ | C.N. |       | E.N. |
   |  OTS1| ----- |      ||        |  ||      | ----- |OTS1  |
 ==|  OTS2| ----- |      || Media  |  ||      | ----- |OTS2  |==
 ==|  OTS3| ----- |      || Channel|  ||      | ----- |OTS3  |==
   |  OTS4| ----- |      ||        |  ||      | ----- |OTS4  |
   |      |       | ROADM| \________\/ | ROADM|       |      |
   +------+       +------+             +------+       +------+
         ^         ^                         ^         ^
         |         |                         |         |
         +---UNI---+                         +---UNI---+
```

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 = Signallig interface

from Fig. 5.1/G.698.2

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" and "k" values 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 on 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). .

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.

3. Use Cases

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

4. Signalling Extensions

The extension to the RFC7699 includes the parameter listed above. The above parameters could be added also to [RFC4208]. 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 want 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.

Total bandwidth request:
   e.g. 200Gb, 400Gb, 1Tb

Policy (strict/loose):
   Strict/loose referred to B/W and subcarrier number.

Subcarrier bandwidth tunability:
   (optional) e.g. 34Ghz, 48GHz.

Figure 2: The format of the this sub-object (Type = TBA, Length = TBA) is as follows:

```
 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|B|     Number of Carriers    |        Client bandwidth       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             Subcarrier frequency tunability (optional)        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Sub-Transponder Mod Format: In the Value Field (96 bits) it is specified
S strict number of subcarrier (No = 0, Yes = 1)
B strict client bandwidth (No = 0, Yes = 1)
- Num Carriers
- Client bandwidth (100Gb, 150Gb, 200Gb, 400Gb, 1Tb, etc)
- Subcarrier frequency tunability (optional)

Figure 2: SSON LSP set-up request

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 paramenters:

Media Channel:
   (Grid, C.S., Identifier and n).

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):
   Grid, Identifiers, central frequency and granularity.

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 on 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). .

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.

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].

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

```
  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|I|         Modulation ID     |               FEC             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         baud rate  (Symbol Rate)              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Grid | C.S.  | M.C. Identifier |              n                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Grid| carrier Identifier      |               j               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                               k                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        sub-carrier power                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Sub-Transponder Mod Format:

- S: standardized format;
- I: input / output (1 / 0)
- Modulation IDs: BPSK (1), DC DP BSPSK, QPSK, DP QPSK, 8QAM 16QAM, 64QAM, etc.
- FEC ......
- Symbol Rate: IEEE float in bauds/s
- Number of Carriers in the Media channel
- Bits/symbol
- Sub-carrier Power
- Media channel Grid

Grid	Value
ITU-T Flex	3

- C.S.
- n Media channel central frequency
- Sub carrier identifier field: sub-carrier identifier inside the mediachannel
- 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 S.C. Position inside the Media Channel, J can be set at default value = 0.1GHz.

```
                                    m=8
     +-------------------------------X------------------------------+
     |                               |                              |
     |           sub-carrier                    sub-carrier         |
     |     +----------X----------+   |   +----------X----------+    |
     |     |        OTSi         |       |        OTSi         |    |
     |     |          o          |   |   |          o          |    |
     |     |          |          |       |          |          |    |
    -4  -3  -2  -1   0   1   2   3   4   5   6   7   8   9   10  11  12
   --+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+-
                      |             n=4             |
                      K1    -236     |     +236     k2

     <------------------------ Media Channel ----------------------->
```

Figure 3: OCh_General

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 as specific extensions of the SENDER_TSPEC/FLOW_SPEC object for Flexi-Grid networks (see [RFC7792])

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

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Intended status: Experimental   Cisco
Expires: May 3, 2018   A. Zanardi, Ed.
                                                              L. Galvagni
                                                            FBK-CreateNet
                                                         October 30, 2017

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-02

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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Status of This Memo

Table of Contents

1. Introduction

Generalised Multiprotocol Label Switched (GMPLS) is widely used in Wavelength Switched Optical Network (WSON) 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 (SSON), 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 WSON signalling. In particular this memo wants do address the use cases where the SSON 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. |       | C.N. | /         /\ | C.N. |       | E.N. |
     |  OTS1| ----- |      ||          |  ||      | ----- |OTS1  |
   ==|  OTS2| ----- |      || Media    |  ||      | ----- |OTS2  |==
   ==|  OTS3| ----- |      || Channel|  ||      | ----- |OTS3  |==
     |  OTS4| ----- |      ||          |  ||      | ----- |OTS4  |
     |      |       | ROADM| \_________\/ | ROADM|       |      |
     +------+       +------+              +------+       +------+
           ^         ^                          ^         ^
           |         |                          |         |
           +---UNI---+                          +---UNI---+
```

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

from Fig. 5.1/G.698.2

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 pover suppotred 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 in 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 want 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.

Total bandwidth request:
  e.g. 200Gb, 400Gb, 1Tb

Policy (strict/loose):
  Strict/loose referred to B/W and subcarrier number.

Subcarrier bandwidth tunability:
  (optional) e.g. 34Ghz, 48GHz.

Figure 2: The format of the this sub-object is as follows:

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

```
 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|B|     Reserved              |         Carrier Number        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Total Bandwidth                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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 Bandwith 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 paramenters:

Media Channel:
   (Grid, C.S., Identifier m and n).

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 (see G.694.1 Table 1):
Grid, Identifiers, central frequency and granularity.

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 on the carrier or sub-carriers.

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 must be used by the Transceivers (not mentioned in G.698). .

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

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].

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

The TLV defines the carriers signal configuration.
All carriers in a Media Channel MUST have the same configuration.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|        Modulation Format      |              FEC              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         baud rate  (Symbol Rate)              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3: OCh_General

```
Traffic Type
    - Modulation Format: is the modulation type:
          BPSK, DC DP BSPSK, 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 request from the Head UNI-C node can specify only a subset of the parameters (e.g. the Modulation and the baud rate but not the FEC) but setting to 0 the undefined parameters.
- 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

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

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

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Carrier Identifier       |               j               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                               k                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            sub-TLVs                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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)
- 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.

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

```
                                    m=8
     +-------------------------------X------------------------------+
     |                               |                              |
     |           sub-carrier                    sub-carrier         |
     |     +----------X----------+   |   +----------X----------+    |
     |     |        OTSi         |       |         OTSi        |    |
     |     |          o          |   |   |          o          |    |
     |     |          |          |       |          |          |    |
    -4  -3  -2  -1   0   1   2   3   4   5   6   7   8   9   10  11  12
   --+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+-
                      |             n=4             |
                      K1    -236     |     +236     K2

     <------------------------ Media Channel ----------------------->
```

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

The defined sub-TLVs are:

Port Identifier

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Type (TBA)         |          Length (TBD)         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Port Identifier                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5: Port Identifier

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

Notes:

- 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.

- The association of a carrier to a local link optical port is a local link association (depending on the local ports physical configuration), the sub-TLV value MUST be set by head/tail nodes (with transit nodes not signaling its value).
  The local port identifier is the identifier of the local link port on the upstream node (with respect to the LSP nominal direction):
  - UNI-C port in head UNI link
  - UNI-N port in tail UNI link

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

Figure 6: The format of this sub-object (Type = TBA, Length = TBD) is as follows:

Carrier Power:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Type (TBA)         |           Length (TBD)        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          carrier power                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 6: Carrier Power

Carrier Port: 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

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A framework for Management and Control of DWDM optical interface parameters

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Abstract

To ensure an efficient data transport, meeting the requirements requested by today’s IP-services the control and management of DWDM interfaces is a precondition for enhanced multilayer networking and for an further automation of network provisioning and operation. This document describes use cases and requirements for the control and management of optical interfaces parameters according to different types of single channel DWDM interfaces. The focus is on automating the network provisioning process irrespective on how it is triggered i.e. by EMS, NMS or GMPLS. This document covers management as well as control plane considerations in different management cases of single channel DWDM interfaces. The purpose is to identify the necessary information elements and processes to be used by control or management systems for further processing.

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1. Introduction

The usage of the single channel DWDM interfaces (e.g. in routers) connected to a DWDM Network (which include ROADMs and optical amplifiers) adds a further networking option for operators allowing new scenarios and requiring more control/management plane integration.

Carriers deploy their networks today as a combination of transport and packet infrastructures to ensure high availability and flexible data transport. Both network technologies are usually managed by different operational units using different management concepts. This is the status quo in many carrier networks today. In the case of deployments, where the optical transport interface moves into the client device (e.g. , router), it is necessary to coordinate the management of the optical interface at the client domain with the optical transport domain. There are different levels of coordination, which are specified in this framework.

The objective of this document is to provide a framework that describes the solution space for the control and management of single channel interfaces and providing use cases on how to manage these solutions. In particular, it examines topological elements and related network management measures. From an architectural point of view, the network can be considered as a set of pre- configured/ qualified unidirectional, single-fiber, network connections between reference points S and R shown in figure 2. The optical transport network is managed and controlled in order to provide optical connections at the intended centre frequencies and the optical interfaces are managed and controlled to generate signals of the intended centre frequencies and further parameters as specified for example in ITU-T Recommendations G.698.2 and G.798. The management or control plane of the client and DWDM network is aware of the parameters of the interfaces to properly set up the optical link. This knowledge can be used furthermore, to support fast fault detection.

Optical routing and wavelength assignment based on WSON is out of scope although can benefit of the way the optical parameters are exchanged between the Client and the DWDM Network.

Additionally, the wavelength ordering process and the process how to determine the demand for a new wavelength from A to Z is out of scope.

Note that the Control and Management Planes are two separate entities that are handling the same information in different ways. This document covers management as well as control plane considerations in different management cases of single channel DWDM interfaces.

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. Terminology and Definitions

The current generation of WDM netwoks are single vendor networks where the optical line system and the transponders are tightly integrated. The DWDM interfaces migration from the transponders to the colored interfaces changes this scenario, by introducing a standardized interface at the level of OCh between the DWDM interface and the DWDM network.

Black Link: The Black Link [ITU.G698.2] allows supporting an optical transmitter/receiver pair of a single vendor or from different vendors to provide a single optical channel interface and transport it over an optical network composed of amplifiers, filters, add-drop multiplexers which may be from a different vendor. Therefore the standard defines the ingress and egress parameters for the optical interfaces at the reference points Ss and Rs.

Single Channel DWDM Interface: The single channel interfaces to DWDM systems defined in G.698.2, which currently include the following features: channel frequency spacing: 50 GHz and wider (defined in [ITU-T G.694.1]); bit rate of single channel: Up to 10 Gbit/s. Future revisions are expected to include application codes for bit rates up to 40 Gb/s.

Forward error correction (FEC): FEC is a way of improving the performance of high-capacity optical transmission systems. Employing FEC in optical transmission systems yields system designs that can accept relatively large BER (much more than 10-12) in the optical transmission line (before decoding).

Administrative domain [G.805]: For the purposes of this Recommendation an administrative domain represents the extent of resources which belong to a single player such as a network operator, a service provider or an end-user. Administrative domains of different players do not overlap amongst themselves.

Intra-domain interface (IaDI) [G.872]: A physical interface within an administrative domain.

Inter-domain interface (IrDI) [G.872]: A physical interface that represents the boundary between two administrative domains.

Management Plane [G.8081]: The management plane performs management functions for the transport plane, the control plane and the system as a whole. It also provides coordination between all the planes. The following management functional areas are performed in the management plane: performance management; fault management; configuration management; accounting management and security management.

Control Plane[G.8081]: The control plane performs neighbour discovery, call control and connection control functions. Through signalling, the control plane sets up and releases connections, and may restore a connection in case of a failure. The control plane also performs other functions in support of call and connection control, such as neighbour discovery and routing information dissemination.

Transponder: A Transponder is a network element that performs O/E/O (Optical /Electrical/Optical) conversion. In this document it is referred only transponders with 3R (rather than 2R or 1R regeneration) as defined in [ITU.G.872].

Client DWDM interface: A Transceiver element that performs E/O (Electrical/Optical) conversion. In this document it is referred as the DWDM side of a transponder as defined in [ITU.G.872].

3. Solution Space

The solution space of this document is focusing on aspects related to the management of single-channel optical interface parameters of physical point-to-point and ring DWDM applications on single-mode optical fibres and allows the direct connection of a wide variety of equipment using a DWDM link, for example

1. A digital cross-connect with multiple optical interfaces, supplied by a different vendor from the line system

2. Devices as routing, switching or compute nodes, each from a different vendor, supplying one channel each

3. A combination of the above

3.1. Comparison of approaches for transverse compatibility

This section describes two ways to achieve transverse compatibility. Section 3.1.1 describes the classic model based on well defined inter-domain interfaces. Section 3.1.2 defines a model ensuring interoperability on the line side of the optical network.

3.1.1. Multivendor DWDM line system with transponders

As illustrated in Figure 1, for this approach interoperability is achieved via the use of optical transponders providing OEO (allowing conversion to appropriate parameters). The optical interfaces can then be any short reach standardized optical interface that both vendors support, such as those found in [ITU-T G.957] [ITU-T G.691], [ITU-T G.693], [ITU-T G.959.1], etc.

```
               IrDI                            IaDI
                |                                |
                .                                .
                |   +----------------------------|----+
                .   |     +    WDM Domain     +  .    |
                |   |     |\                 /|  |    |
   +------+     .   |     | \     |\        / |  .    |       +------+
   |  TX/ |-->--+---+--T/-|OM|----|/-------|OD|--+-\T-+---->--| RX/  |
   |  RX  |--<--+---+--T/-|  |----- /|-----|  |--.-\T-+----<--| TX   |
   +------+     |   |     | /       \|      \ |  |    |       +------+
                .   |     |/                 \|  .    |
                |   |     +                   +  |    |
                .   +----------------------------.----+
                |                                |


           TX/RX = Single channel non-DWDM interfaces
           T/ = Transponder
           OM = Optical Mux
           OD = Optical Demux
```

Figure 1: Inter and Intra-Domain Interface Identification

In the scenario of Figure 1 the administrative domain is defined by the Interdomain Interface (IrDI). This interface terminates the DWDM domain. The line side is characterized by the IaDI. This interface specifies the internal parameter set of the optical administrative domain. In the case of a client DWDM interface deployment this interface moves into the client device and extends the optical and administrative domain towards the client node. ITU-T G.698.2 for example specifies the parameter set for a certain set of applications.

This document elaborates only the IaDI Interface as shown in Figure 1 as transversely compatible and multi-vendor interface within one administrative domain controlled by the network operator.

3.1.2. Integrated single channel DWDM deployments on the client site

In case of a deployment as shown in Figure 2, through the use of single channel DWDM interfaces, multi-vendor interconnection can also be achieved while removing the need for one short reach transmitter and receiver pair per channel (eliminating the transponders).

Figure 2 shows a set of reference points, for single-channel connection (Ss and Rs) between transmitters (Tx) and receivers (Rx). Here the DWDM network elements include an optical multiplexer (OM) and an optical demultiplexer (OD) (which are used as a pair with the peer element), one or more optical amplifiers and may also include one or more OADMs.

```
        |==================== Black Link ========================|

           +-------------------------------------------------+
        Ss |  |           DWDM Network Elements           |  | Rs
   +---+ | |  | \                                       / |  | | +---+
   Tx L1---|->|   \    +------+            +------+   /   |--|-->Rx L1
   +---+   |  |    |   |      |  +------+  |      |  |    |  |   +---+
   +---+   |  |    |   |      |  |      |  |      |  |    |  |   +---+
   Tx L2---|->| OM |-|>|------|->| OADM |--|------|->| OD |--|-->Rx L2
   +---+   |  |    |   |      |  |      |  |      |  |    |  |   +---+
   +---+   |  |    |   |      |  +------+  |      |  |    |  |   +---+
   Tx L3---|->|   /    | DWDM |    |  ^    | DWDM |   \   |--|-->Rx L3
   +---+   |  | /      | Link +----|--|----+ Link |     \ |  |   +---+
           +-----------+           |  |           +----------+
                                +--+  +--+
                                |        |
                                v        |
                              +---+    +---+
                               RxLx     TxLx
                              +---+    +---+
```

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
OADM = Optical Add Drop Mux

Linear DWDM network as per ITU-T G.698.2

Figure 2: Linear Black Link

As shown in Figure 2, the administrative domain may consists of several vendor domains. Even a in that case a common north bound management interface is required to ensure a consistent management of the entire connection.

The following documents[DWDM-interface-MIB], [YANG], [LMP] define such a protocol- FIX-THE-REFERENCE specific information using SNMP/SMI, Yang models and LMP TLV to support the direct exchange of information between the client and the network control plane.

4. Solutions for managing and controlling single channel optical interface

Operation and management of WDM systems is traditionally seen as a homogenous group of tasks that could be carried out best when a single management system or an umbrella management system is used. Currently each WDM vendor provides an Element Management System (EMS) that also administers the wavelengths.

Therefore from the operational point of view the following approaches will be considered to manage and operate optical interfaces.

1. Separate operation and management of client device and the transport network whereas the single channel interface of the client belongs to the administrative domain of the transport network and will be managed by the transport group. This results in two different approaches to send information to the management system

   a.Direct connection from the client to the management system,ensuring a management of the single channel of the optical network (e.g. EMS, NMS)

   b.Indirect connection to the management system of the optical network using a protocol (LMP) between the client device and the directly connected WDM system node to exchange management information with the optical domain

2. Common operation and management of client device including the single channel DWDM part and the Transport network

The first option keeps the status quo in large carrier networks as mentioned above. In that case it must be ensured that the full FCAPS Management (Fault, Configuration, Accounting, Performance and Security) capabilities are supported. This means from the management staff point of view nothing changes. The transceiver/receiver optical interface will be part of the optical management domain and will be managed from the transport management staff.

The second solution addresses the case where underlying WDM transport network is mainly used to interconnect a homogeneous set of client nodes (e.g. IP routers or digital crossconnects). Since the service creation and restoration could be done by the higher layers (e.g.

IP), this may lead to an efficient network operation and a higher level of integration.

4.1. Separate Operation and Management Approaches

4.1.1. Direct connection to the management system

As depicted in Figure 3 (case 1a) one possibility to manage the optical interface within the client domain is a direct connection to the management system of the optical domain. This ensures manageability as usual.

```
                        +-----+
                        | NMS |
                        |_____|
                        /_____/
                           |
                           |
                           |
                       +---+---+
                +----->+  EMS  |
               /       |       |
              /        +-------+
             /             | MI SNMP or Yang
       SNMP / or Yang      |                DCN Network
       --------------------+-------------------------------
          /         +------+-----------------------+
         /          |     +|     WDM Domain   +    |
        /           |     |\               /|    |
   +---+--+         |     | \     |\      / |    |          +------+
   |  CL  |-/C------+-----|OM|----|/-------|OD|----+-------/C-|  CL  |
   |      |-/C------+-----|  |----- /|-----|  |----+-------/C-|      |
   +------+         |     | /       \|     \ |    |          +------+
                    |     |/               \|    |
                    |     +                 +    |
                    +------------------------------+

           CL = Client Device
           /C = Single Channel Optical Interface
           OM = Optical Mux
           OD = Optical Demux
           EMS = Element Management System
           MI= Management Interface
```

Figure 3: Connecting Single Channel optical interfaces to the Transport Management system

The exchange of management information between client device and the management system assumes that some form of a direct management communication link exists between the client device and the DWDM management system (e.g. EMS). This may be an Ethernet Link or a DCN connection (management communication channel MCC).

It must be ensured that the optical network interface can be managed in a standardised way to enable interoperable solutions between different optical interface vendors and vendors of the optical network management application. RFC 3591 [RFC3591] defines managed objects for the optical interface type but needs further extension to cover the optical parameters required by this framework document. Therefore an extension to this MIB for the optical interface has been drafted in [DWDM-interface-MIB]. SNMP is used to read parameters and get notifications and alarms, netconf and Yang models are needed to easily provision the interface with the right parameter set as described in [YANG]

Note that a software update of the optical interface components of the client nodes must not lead obligatory to an update of the software of the EMS and vice versa.

4.1.2. Direct connection to the DWDM management system

An alternative as shown in Figure 4 can be used in cases where a more integrated relationship between transport node (e.g. OM or OD) and client device is aspired. In that case a combination of control plane features and manual management will be used.

```
                        +-----+
                        | NMS |
                        |_____|
                        /_____/
                           |
                           |
                       +---+---+
                       | EMS   |
                       |       |
                       +-------+
                           | MI  SNMP or Yang
                           |
           LMP      +------+-----------------------+
       +------------+---+ +|                  +    |
       |            |   | |\                 /|    |
   +---+--+         |   +-+ \     |\        / |    |          +------+
   |  CL  |-/C------+--- -|OM|----|/-------|OD|--- +-------/C-|  CL  |
   |      |-/C------+--- -|  |----- /|-----|  |----+-------/C-|      |
   +------+         |     | /       \|      \ |    |          +------+
                    |     |/                 \|    |
                    |     +                   +    |
                    +------------------------------+

           CL = Client Device
           /C = Single Channel optical Interface
           OM = Optical Mux
           OD = Optical Demux
           EMS= Element Management System
           MI= Management Interface
```

Figure 4: Direct connection between peer node and first optical network node

For information exchange between the client node and the direct connected node of the optical transport network LMP as specified in RFC 4209 [RFC4209] should be used. This extension of LMP may be used between a peer node and an adjacent optical network node as depicted in Figure 4.

The LMP based on RFC 4209 does not yet support the transmission of configuration data (information). This functionality must be added to the existing extensions of the protocol. The use of LMP-WDM assumes that some form of a control channel exists between the client node and the WDM equipment. This may be a dedicated lambda, an Ethernet Link, or other signalling communication channel (SCC or IPCC).

4.2. Control Plane Considerations

The concept of integrated single channel DWDM interfaces equally applies to management and control plane mechanisms. The general GMPLS control plane for wavelength switched optical networks is work under definition in the scope of WSON. One important aspect of the BL is the fact that it includes the wavelength that is supported by the given link. Thus a BL can logically be considered as a fiber that is transparent only for a single wavelength. In other words, the wavelength becomes a characteristic of the link itself. Nevertheless the procedure to light up the fiber may vary depending on the implementation. Since the implementation is unknown a priori, different sequences to light up a wavelength need to be considered:

1. Interface first, interface tuning: The transmitter is switched on and the link is immediately transparent to its wavelength. This requires the transmitter to carefully tune power and frequency not overload the line system or to create transients.

2. Interface first, OLS tuning: The transmitter is switched on first and can immediately go to the max power allowed since the OLS performs the power tuning. This leads to an intermediate state where the receiver does not receive a valid signal while the transmitter is sending out one. Alarm suppression mechanisms shall be employed to overcome that condition.

3. OLS first, interface tuning: At first the OLS is tuned to be transparent for a given wavelength, then transponders need to be tuned up. Since the OLS in general requires the presence of a wavelength to fine-tune it is internal facilities there may be a period of time where a valid signal is transmitted but the receiver is unable to detect it. This equally need to be covered by alarm suppression mechanisms.

4. OLS first, OLS tuning: The OLS is programmed to be transparent for a given wavelength, then the interfaces need to be switched on and further power tuning takes place. The sequencing of enabling the link needs to be covered as well.

The preferred way to address these in a Control Plane enabled network is neighbour discovery including exchange of link characteristics and link property correlation. The general mechanisms are covered in RFC4209 [LMP-WDM] and RFC 4204[LMP] which provides the necessary protocol framework to exchange those characteristics between client and black link. LMP-WDM is not intended for exchanging routing or signaling information but covers:

1. Control channel management

2. Link property correlation

3. Link verification

4. Fault management

Extensions to LMP/LMP-WDM covering the code points of the BL definition are needed. Additionally when client and server side are managed by different operational entities, link state exchange is required to align the management systems.

4.2.1. Considerations using GMPLS UNI

The deployment of single channel optical interfaces is leading to some functional changes related to the control plane models and has therefore some impact on the existing interfaces especially in the case of an overlay model where the edge node requests resources from the core node and the edges node do not participate in the routing protocol instance that runs among the core nodes. RFC 4208 [RFC4208] defines the GMPLS UNI that will be used between edge and core node. In case of integrated interfaces deployment additional functionalities are needed to setup a connection.

It is necessary to differentiate between topology/signalling information and configuration parameters that are needed to setup a wavelength path. RSVP-TE could be used for the signalling and the reservation of the wavelength path. But there are additional information needed before RSVP-TE can start the signalling process. There are three possibilities to proceed:

a. Using RSVP-TE only for the signalling and LMP as described above to exchange information to configure the optical interface within the edge node or

b. RSVP-TE will be used to transport additional information

c. Leaking IGP information instead of exchanging this information needed from the optical network to the edge node (overlay will be transformed to a border-peer model)

Furthermore following issues should be addressed:

a) The Communication between peering edge nodes using an out of band control channel. The two nodes have to exchange their optical capabilities. An extended version of LMP is needed to exchange FEC Modulation scheme, etc. that must be the same. It would be helpful to define some common profiles that will be supported. Only if the profiles match with both interface capabilities it is possible start signalling.

b) Due to the bidirectional wavelength path that must be setup it is obligatory that the upstream edge node inserts a wavelength value into the path message for the wavelength path towards the upstream node itself. But in the case of an overlay model the client device may not have full information which wavelength must/should be selectedand this information must be exchanged between the edge and the core node.

5. Use cases

A Comparison with the traditional operation scenarios provides an insight of similarities and distinctions in operation and management of single channel optical interfaces. The following use cases provide an overview about operation and maintenance processes.

5.1. Service Setup

It is necessary to differentiate between two operational issues for setting up a light path (a DWDM connection is specific in having defined maximum impairments) within an operational network. The first step is the preparation of the connection if no optical signal is applied. Therefore it is necessary to define the path of the connection.

The second step is to setup the connection between the client DWDM interface and the ROADM port. This is done using the NMS of the optical transport network. From the operation point of view the task is similar in a Black Link scenario and in a traditional WDM environment. The Black Link connection is measured by using BER tester which use optical interfaces according to G.698.2. These measurements are carried out in accordance with [ITU-TG.692]. When needed further connections for resilience are brought into service in the same way.

In addition some other parameters like the transmit optical power, the received optical power, the frequency, etc. must be considered.

If the optical interface moves into a client device some of changes from the operational point of view have to be considered. The centre frequency of the Optical Channel was determined by the setup process.

The optical interfaces at both terminals are set to the centre frequency before interconnected with the dedicated ports of the WDM network. Optical monitoring is activated in the WDM network after the terminals are interconnected with the dedicated ports in order to monitor the status of the connection. The monitor functions of the optical interfaces at the terminals are also activated in order to monitor the end to end connection.

Furthermore it should be possible to automate this last step. After connecting the client device towards the first control plane managed transport node a control connection may e.g. be automatically established using LMP to exchange configuration information.

If tunable interfaces are used in the scenario it would be possible to define a series of backup wavelength routes for restoration that could be tested and stored in backup profile. In fault cases this wavelength routes can be used to recover the service.

5.2. Link monitoring Use Cases

The use cases described below are assuming that power monitoring functions are available in the ingress and egress network element of the DWDM network, respectively. By performing link property correlation it would be beneficial to include the current transmit power value at reference point Ss and the current received power value at reference point Rs. For example if the Client transmitter power (OXC1) has a value of 0dBm and the ROADM interface measured power (at OLS1) is -6dBm the fiber patch cord connecting the two nodes may be pinched or the connectors are dirty. More, the interface characteristics can be used by the OLS network Control Plane in order to check the Optical Channels feasibility. Finally the OXC1 transceivers parameters (Application Code) can be shared with OXC2 using the LMP protocol to verify the transceivers compatibility. The actual route selection of a specific wavelength within the allowed set is outside the scope of LMP. In GMPLS, the parameter selection (e.g. central frequency) is performed by RSVP-TE.

G.698.2 defines a single channel optical interface for DWDM systems that allows interconnecting network-external optical transponders across a DWDM network. The optical transponders are considered to be external to the DWDM network. This so-called 'black link' approach illustrated in Figure 5-1 of G.698.2 and a copy of this figure is provided below. The single channel fiber link between the Ss/Rs reference points and the ingress/egress port of the network element on the domain boundary of the DWDM network (DWDM border NE) is called access link in this contribution. Based on the definition in G.698.2 it is considered to be part of the DWDM network. The access link typically is realized as a passive fiber link that has a specific optical attenuation (insertion loss). As the access link is an integral part of the DWDM network, it is desirable to monitor its attenuation. Therefore, it is useful to detect an increase of the access link attenuation, for example, when the access link fiber has been disconnected and reconnected (maintenance) and a bad patch panel connection (connector) resulted in a significantly higher access link attenuation (loss of signal in the extreme case of an open connector or a fiber cut). In the following section, two use cases are presented and discussed:

1) pure access link monitoring
2) access link monitoring with a power control loop

These use cases require a power monitor as described in G.697 (see section 6.1.2), that is capable to measure the optical power of the incoming or outgoing single channel signal. The use case where a power control loop is in place could even be used to compensate an increased attenuation as long as the optical transmitter can still be operated within its output power range defined by its application code.

Figure 5 Access Link Power Monitoring

```
                                +---------------------------+
                                |    P(in) = P(Tx) - a(Tx) |
                                |     ___                   |
 +----------+                   |    \ /   Power Monitor    |
 |          | P(Tx)             |     V    P(in)            |
 |  +----+  | Ss    //\\        |     |    |\               |
 |  | TX |----|-----\\//------------------>| \              |
 |  +----+  | Access Link (AL-T) |       .  |  |            |
 |          | attenuation a(Tx)  |       .  |  |==============>
 |          |                    |       .  |  |            |
 | External |                    |      --->| /             |
 | Optical  |                    |          |/              |
 |Transpond.|                    |    P(out)                |
 |          |                    |     ___                  |
 |          |                    |    \ /   Power Monitor   |
 |          | P(Rx)              |     V    P(out)          |
 |  +----+  | Rs    //\\         |     |    |\              |
 |  | RX |<---|-----\\//-------------------| \              |
 |  +----+  | Access Link (AL-R) |       .  |  |            |
 |          | Attenuation a(Rx)  |       .  |  |<==============
 +----------+                    |       .  |  |            |
                                 |      <---| /             |
 P(Rx) = P(out) - a(Rx)          |          |/              |
                                 |                          |
                                 |          ROADM           |
                                 +--------------------------+
```

 - For AL-T monitoring: P(Tx) and a(Tx) must be known
 - For AL-R monitoring: P(RX) and a(Rx) must be known

An alarm shall be raised if P(in) or P(Rx) drops below a configured threshold (t [dB]):

- P(in) < P(Tx) - a(Tx) - t (Tx direction)
- P(Rx) < P(out) - a(Rx) - t (Rx direction)
- a(Tx) =| a(Rx)

Figure 5: Extended LMP Model

5.2.1. Pure Access Link (AL) Monitoring Use Case

Figure 6 illustrates the access link monitoring use case and the different physical properties involved that are defined below:

- Ss, Rs: Single Channel reference points
- P(Tx): current optical output power of transmitter Tx
- a(Tx): access link attenuation in Tx direction (external transponder point of view)
- P(in): measured current optical input power at the input port of border DWDM NE
- t: user defined threshold (tolerance)
- P(out): measured current optical output power at the output port of border DWDM NE
- a(Rx): access link attenuation in Rx direction (external transponder point of view)
- P(Rx): current optical input power of receiver Rx

Description:

- The access link attenuation in both directions (a(Tx), a(Rx)) is known or can be determined as part of the commissioning process. Typically, both values are the same.
- A threshold value t has been configured by the operator. This should also be done during commissioning.
- A control plane protocol (e.g. this draft) is in place that allows to periodically send the optical power values P(Tx) and P(Rx) to the control plane protocol instance on the DWDM border NE. This is illustrated in Figure 3.
- The DWDM border NE is capable to periodically measure the optical power Pin and Pout as defined in G.697 by power monitoring points depicted as yellow triangles in the figures below.

Access Link monitoring process:

- Tx direction: the measured optical input power Pin is compared with the expected optical input power P(Tx) - a(Tx). If the measured optical input power P(in) drops below the value (P(Tx) - a(Tx) - t) a low power alarm shall be raised indicating that the access link attenuation has exceeded a(Tx) + t.
- Rx direction: the measured optical input power P(Rx) is compared with the expected optical input power P(out) - a(Rx). If the measured optical input power P(Rx) drops below the value (P(out) - a(Rx) - t) a low power alarm shall be raised indicating that the access link attenuation has exceeded a(Rx) + t.
- to avoid toggling errors, the low power alarm threshold shall be lower than the alarm clear threshold.

Figure 6 Use case 1: Access Link monitoring

```
+----------+                    +--------------------------+
| +------+ |    P(Tx), P(Rx)    |  +-------+               |
| |      | | =================> |  |       |               |
| | LMP  | |    P(in), P(out)   |  |  LMP  |               |
| |      | | <================= |  |       |               |
| +------+ |                    |  +-------+               |
|          |                    |                          |
|          |                    |    P(in) - P(Tx) - a(Tx) |
|          |                    |    ___                   |
|          |                    |    \ /  Power Monitor    |
|          | P(Tx)              |     V                    |
|  +----+  | Ss    //\\         |     |    |\              |
|  | TX |----|-----\\//------------------->| \             |
|  +----+  | Access Link (AL-T) |       .  |  |            |
|          | attenuation a(Tx)  |       .  |  |==============>
|          |                    |       .  |  |            |
| External |                    |      --->| /             |
| Optical  |                    |          |/              |
|Transpond.|                    |    P(out)                |
|          |                    |    ___                   |
|          |                    |    \ /  Power Monitor    |
|          | P(Rx)              |     V                    |
|  +----+  | Rs    //\\         |     |    |\              |
|  | RX |<---|-----\\//--------------------| \             |
|  +----+  | Access Link (AL-R) |       .  |  |            |
|          | Attenuation a(Rx)  |       .  |  |<==============
+----------+                    |       .  |  |            |
                                |      <---| /             |
P(Rx) = P(out) - a(Rx)          |          |/              |
                                |                          |
                                |           ROADM          |
                                +--------------------------+

 - For AL-T monitoring: P(Tx) and a(Tx) must be known
 - For AL-R monitoring: P(RX) and a(Rx) must be known
 An alarm shall be raised if P(in) or P(Rx) drops below a
 configured threshold  (t [dB]):
 -  P(in) < P(Tx) - a(Tx) - t (Tx direction)
 -  P(Rx) < P(out) - a(Rx) - t (Rx direction)
 -  a(Tx) = a(Rx)
```

Figure 6: Extended LMP Model

5.2.2. Power Control Loop Use Case

This use case is based on the access link monitoring use case as described above. In addition, the border NE is running a power control application that is capable to control the optical output power of the single channel tributary signal at the output port of the border DWDM NE (towards the external receiver Rx) and the optical output power of the single channel tributary signal at the external transmitter Tx within their known operating range. The time scale of this control loop is typically relatively slow (e.g. some 10s or minutes) because the access link attenuation is not expected to vary much over time (the attenuation only changes when re-cabling occurs).

From a data plane perspective, this use case does not require additional data plane extensions. It does only require a protocol extension in the control plane (e.g. this LMP draft) that allows the power control application residing in the DWDM border NE to modify the optical output power of the DWDM domain-external transmitter Tx within the range of the currently used application code. Figure 5 below illustrates this use case utilizing the LMP protocol with extensions defined in this draft.

Figure 7 Use case 2: Power Control Loop

```
     +----------+                       +--------------------------+
     | +------+ | P(Tx),P(Rx),Set(Pout) |  +-------+   +--------+  |
     | |      | | ====================> |  |       |   | Power  |  |
     | | LMP  | | P(in),P(out),Set(PTx) |  |  LMP  |   |Control |  |
     | |      | | <==================== |  |       |   | Loop   |  |
     | +------+ |                       |  +-------+   +--------+  |
     |     |    |                       |                          |
     | +------+ |                       |    P(in) = P(Tx) - a(Tx) |
     | |C.Loop| |                       |    ___                   |
     | +------+ |                       |    \ /  Power Monitor    |
     |     |    | P(Tx)                 |     V                    |
     | +------+ | Ss    //\\            |     |    |\              |
     | | TX |>----|-----\\//---------------------->| \             |
     | +------+ | Access Link (AL-T)    |       .  |  |            |
     |  VOA(Tx) | attenuation a(Tx)     |       .  |  |==============>
     |          |                       |       .  |  |            |
     | External |                       |     --->| /              |
     | Optical  |                       |          |/              |
     |Transpond.|                       |    P(out)                |
     |          |                       |    ___                   |
     |          |                       |    \ /  Power Monitor    |
     |          | P(Rx)                 |     V                    |
     |  +----+  | Rs    //\\            |     |  VOA(out) |\       |
     |  | RX |<---|-----\\//---------------------<|-------| \      |
     |  +----+  | Access Link (AL-R)    |              .  |  |      |
     |          | attenuation a(Rx)     |              .  |  |<=======
     +----------+                       |        VOA(out) |  |      |
                                        |      <--<|-------| /      |
     P(Rx) = P(out) - a(Rx)             |                 |/       |
                                        |                          |
                                        |            ROADM         |
                                        +--------------------------+
```

Figure 7: Power control loop

- The Power Control Loops in Transponder and ROADM controls the Variable Optical Attenuators (VOA) to adjust the proper power in base of the ROADM and Receiver caracteristics and the Access Link attenuation

6. Requirements

Even if network architectures becomes more complex the management and operation as well as the provisioning process should have a higher degree of automation or should be fully automated. Simplifying and automating the entire management and provisioning process of the network in combination with a higher link utilization and faster restoration times will be the major requirements that has been addressed in this section.

Data Plane interoperability as defined for example in [ITU.G698.2] is a precondition to ensure plain solutions and allow the usage of standardized interfaces between network and control/management plane.

The following requirements are focusing on the usage of integrated single channel interfaces.

1 To ensure a lean management and provisioning process of single channel interfaces management and control plane of the client and DWDM network must be aware of the parameters of the interfaces and the optical network to properly setup the optical connection.

2 A standard-based northbound API (to network management system) based on Netconf should be supported, alternatively SNMP should be supported too.

3 A standard-based data model for single channel interfaces must be supported to exchange optical parameters with control/management plane.

4 Netconf should be used also for configuration of the single channel interfaces including the power setting

5 LMP should be extended and used in cases where optical parameters need to be exchanged between peer nodes to correlate link characteristics and adopt the working mode of the single channel interface.

6 LMP may be used to adjust the output power of the single channel DWDM interface to ensure that the interface works in the right range.

7 Parameters e.g. PRE-FEC BER should be used to trigger a FRR mechanism on the IP control plane to reroute traffic before the link breaks.

8 Power monitoring functions at both ends of the DWDM connection should be implemented to further automate the setup and shoutdown process of the optical interfaces.

9 A standardized procedure to setup an optical connection should be defined and implemented in DWDM and client devices (containing the single channel optical interface).LMP should be used to ensure that the process follows the right order.

10 Pre-tested and configured backup paths should be stored in so called backup profiles. In fault cases this wavelength routes should be used to recover the service.

11 LMP may be used to monitor and observe the access link.

7. Acknowledgements

The authors would like to thank all who supported the work with fruitful discussions and contributions.

8. IANA Considerations

This memo includes no request to IANA.

9. Security Considerations

The architecture and solution space in scope of this framework imposes no additional requirements to the security models already defined in RFC5920 for packet/optical networks using GMPLS, covering also Control Plane and Management interfaces. Respective security mechanisms of the components and protocols, e.g. LMP security models, can be applied unchanged.

As this framework is focusing on the single operator use case, the security concerns can be relaxed to a subset compared to a setup where information is exchanged between external parties and over external interfaces.

Concerning the access control to Management interfaces, security issues can be generally addressed by authentication techniques providing origin verification, integrity and confidentiality. Additionally, access to Management interfaces can be physically or logically isolated, by configuring them to be only accessible out-of-band, through a system that is physically or logically separated from the rest of the network infrastructure. In case where management interfaces are accessible in-band at the client device or within the optical transport netork domain, filtering or firewalling techniques can be used to restrict unauthorized in-band traffic. Authentication techniques may be additionally used in all cases.

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A framework for Management and Control of DWDM optical interface parameters
draft-ietf-ccamp-dwdm-if-mng-ctrl-fwk-07

Abstract

To ensure an efficient data transport, meeting the requirements requested by today's IP-services the control and management of DWDM interfaces are a precondition for enhanced multilayer networking and for a further automation of network provisioning and operation. This document describes use cases, requirements and solutions for the control and management of optical interfaces parameters according to different types of single channel DWDM interfaces. The focus is on automating the network provisioning process irrespective on how it is triggered i.e. by EMS, NMS or GMPLS. This document covers management as well as control plane considerations in different management cases of single channel DWDM interfaces. The purpose is to identify the necessary information elements and processes to be used by control or management systems for further processing.

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Table of Contents

1. Introduction

The usage of the single channel DWDM interfaces (e.g. in routers) connected to a DWDM Network (which include ROADMs and optical amplifiers) adds a further networking option for operators allowing new scenarios but require harmonised control and management plane interaction between different network domains.

Carriers deploy their networks today based on transport and packet network infrastructures as domains to ensure high availability and a high level of redundancy. Both network domains were operated and managed separately. This is the status quo in many carrier networks today. In the case of deployments, where the optical transport interface moves into the client device (e.g. router) an interaction between those domains becomes necessary.

This framework specifies different levels of control and management plane interaction to support the usage of single channel optical interfaces in carrier networks in an efficient manner.

The objective of this document is to provide a framework for the control and management of transceiver interfaces based on the corresponding use cases and requirements to ensure an efficient and optimized data transport.

Although Optical routing and wavelength assignment based on WSON is out of scope, they can benefit from the optical parameters that are exchanged between the Client and the DWDM Network. Also, the wavelength ordering process and the process how to determine the demand for a new wavelength path through the network is out of scope.

Note that the Control and Management Planes are two separate entities that are handling the same information in different ways.

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. Terminology and Definitions

The current generation of WDM netwoks are single vendor networks where the optical line system and the transponders are tightly integrated. The DWDM interface migration from the transponders to the colored interfaces change this scenario, by introducing a standardized interface at the level of OCh between the DWDM interface and the DWDM network.

Black Link: The Black Link [ITU.G698.2] allows supporting an optical transmitter/receiver pair of a single vendor or from different vendors to provide a single optical channel interface and transport it over an optical network composed of amplifiers, filters, add-drop multiplexers which may be from a different vendor. Therefore the standard defines the ingress and egress parameters for the optical interfaces at the reference points Ss and Rs.

Single Channel DWDM Interface: The single channel interfaces to DWDM systems defined in G.698.2, which currently include the following features: channel frequency spacing: 50 GHz and wider (defined in [ITU-T G.694.1]); bit rate of single channel: Up to 10 Gbit/s. Future revisions are expected to include application codes for bit rates up to 40 Gb/s.

Forward error correction (FEC): FEC is a way of improving the performance of high-capacity optical transmission systems. Employing FEC in optical transmission systems yields system designs that can accept relatively large BER (much more than 10-12) in the optical transmission line (before decoding).

Administrative domain [G.805]: the extent of resources which belong to a single player such as a network operator, a service provider or an end-user. Administrative domains of different players do not overlap amongst themselves.

Intra-domain interface (IaDI) [G.872]: A physical interface within an administrative domain.

Inter-domain interface (IrDI) [G.872]: A physical interface that represents the boundary between two administrative domains.

Management Plane [G.8081]: The management plane performs management functions for the transport plane, the control plane and the system as a whole. It also provides coordination between all the planes. The following management functional areas are performed in the management plane: performance management, fault management, configuration management, accounting management and security management.

Control Plane[G.8081]: The control plane performs neighbour discovery, call control and connection control functions. Through signalling, the control plane sets up and releases connections, and may restore a connection in case of a failure. The control plane also performs other functions in support of call and connection control, such as neighbour discovery and routing information dissemination.

Transponder: A Transponder is a network element that performs O/E/O (Optical /Electrical/Optical) conversion. In this document it is referred only transponders with 3R (rather than 2R or 1R regeneration) as defined in [ITU.G.872].

Client DWDM interface: A Transceiver element that performs E/O (Electrical/Optical) conversion. In this document it is referred as the DWDM side of a transponder as defined in [ITU.G.872].

3. Solution Space

The solution space of this document is focusing on aspects related to the management and control of single-channel optical interface parameters of physical point-to-point and ring DWDM applications on single-mode optical fibres and allows the direct connection of a wide variety of equipment using a DWDM link, for example

1. A digital cross-connect with multiple optical interfaces, supplied by a different vendor from the line system

2. Devices as routing, switching or compute nodes, each from a different vendor, providing optical line interfaces

3. A combination of the above

3.1. Comparison of approaches for transverse compatibility

This section describes two ways to achieve transverse compatibility. Section 3.1.1 describes the classic model based on well defined inter-domain interfaces. Section 3.1.2 defines a model ensuring interoperability on the line side of the optical network.

3.1.1. Multivendor DWDM line system with transponders

As illustrated in Figure 1, for this approach interoperability is achieved via the use of optical transponders providing OEO (allowing conversion to appropriate parameters). The optical interfaces can then be any short reach standardized optical interface that both vendors support, such as those found in [ITU-T G.957] [ITU-T G.691], [ITU-T G.693], [ITU-T G.959.1], etc.

```
               IrDI                            IaDI
                |                                |
                .                                .
                |   +----------------------------|----+
                .   |     +    WDM Domain     +  .    |
                |   |     |\                 /|  |    |
   +------+     .   |     | \     |\        / |  .    |       +------+
   |  TX/ |-->--+---+--T/-|OM|----|/-------|OD|--+-\T-+---->--| RX/  |
   |  RX  |--<--+---+--T/-|  |----- /|-----|  |--.-\T-+----<--| TX   |
   +------+     |   |     | /       \|      \ |  |    |       +------+
                .   |     |/                 \|  .    |
                |   |     +                   +  |    |
                .   +----------------------------.----+
                |                                |


           TX/RX = Single channel non-DWDM interfaces
           T/ = Transponder
           OM = Optical Mux
           OD = Optical Demux
```

Figure 1: Inter and Intra-Domain Interface Identification

In the scenario of Figure 1 the administrative domain is defined by the Interdomain Interface (IrDI). This interface terminates the DWDM domain. The line side is characterized by the IaDI. This interface specifies the internal parameter set of the optical administrative domain. In the case of a client DWDM interface deployment this interface moves into the client device and extends the optical and administrative domain towards the client node. ITU-T G.698.2 for example specifies the parameter set for a certain set of applications.

This document elaborates only the IaDI Interface as shown in Figure 1 as transversely compatible and multi-vendor interface within one administrative domain controlled by the network operator.

SNMP/SMI, Yang models and LMP TLV to support the direct exchange of information between the client and the network management and control plane will be specified in further documents.

3.1.2. Integrated single channel DWDM deployments on the client site

In case of a deployment as shown in Figure 2, through the use of DWDM interfaces, multi-vendor interconnection can also be achieved while removing the need for one short reach transmitter and receiver pair per channel (eliminating the transponders).

Figure 2 shows a set of reference points, for single-channel connection (Ss and Rs) between transmitters (Tx) and receivers (Rx). Here the DWDM network elements include an optical multiplexer (OM) and an optical demultiplexer (OD) (which are used as a pair with the peer element), one or more optical amplifiers and may also include one or more OADMs.

```
     |=================== Black Link ======================|


        +---------------------------------------------------+
     Ss |  |           DWDM Network Elements          |   | Rs
+---+ | |  | \                                      / |   | | +---+
Tx L1---|->|   \    +------+           +------+   /   |--|-->Rx L1
+---+   |  |    |   |      |  +------+  |      |  |     |  |   +---+
+---+   |  |    |   |      |  |      |  |      |  |     |  |   +---+
Tx L2---|->| OM |-|>|------|->| ROADM|--|------|->| OD |--|-->Rx L2
+---+   |  |    |   |      |  |      |  |      |  |     |  |   +---+
+---+   |  |    |   |      |  +------+  |      |  |     |  |   +---+
Tx L3---|->|   /    | DWDM |     |  ^    | DWDM |   \   |--|-->Rx L3
+---+   |  | /      | Link +----|--|----+ Link |     \ |  |   +---+
        +-----------+           |  |          +-----------+
                             +--+  +--+
     |==== Black Link ====|  |        |
                             v        |
                           +---+    +---+
                            RxLx     TxLx
                           +---+    +---+

  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


Linear DWDM network as per ITU-T G.698.2
```

Figure 2: Linear Black Link

The single administrative domain may consist of several vendor domains. Even in that case a common network management and control is required to ensure a consistent operation and provisioning of the entire connection.

SNMP/SMI, Yang models and LMP TLV to support the direct exchange of information between the client and the network management and control plane will be specified in further documents.

4. Solutions for managing and controlling single channel optical interface

Operation and management of WDM systems is traditionally seen as a homogenous group of tasks that could be carried out best when a single management system or an umbrella management system is used. Currently each WDM vendor provides an Element Management System (EMS) that also provisions the wavelengths. In a multi-vendor line system, such single-vendor EMS requirement is no more effective. New methods of managing and controlling line systems need to be looked at.

Therefore from the operational point of view the following approaches will be considered to manage and operate optical interfaces.

1. Separate operation and management of client device and the transport network whereas the interface of the client belongs to the administrative domain of the transport network and will be managed by the transport group. This results in two different approaches to send information to the management system

    a. Direct connection from the client to the management system, ensuring a management of the DWDM interface of the optical network (e.g. EMS, NMS)

    b. Indirect connection to the management system of the optical network using a protocol (LMP) between the client device and the directly connected WDM system node to exchange management information with the optical domain

2. Common operation and management of client device including the single channel DWDM part and the Transport network

The first option keeps the status quo in large carrier networks as mentioned above. In that case it must be ensured that the full FCAPS Management (Fault, Configuration, Accounting, Performance and Security) capabilities are supported. This means from the management staff point of view nothing changes. The transceiver/receiver optical interface will be part of the optical management domain and will be managed from the transport management staff.

The second solution addresses the case where underlying WDM transport network is mainly used to interconnect a homogeneous set of client nodes (e.g. IP routers or digital crossconnects). Since the service creation and restoration could be done by the higher layers (e.g.

IP), this may lead to an efficient network operation and a higher level of integration.

4.1. Separate Operation and Management Approaches

4.1.1. Direct connection to the management system

As depicted in Figure 3 (case 1a) one possibility to manage the optical interface within the client domain is a direct connection to the management system of the optical domain. This ensures manageability as usual.

```
                        +-----+
                        | NMS |
                        |_____|
                        /_____/
                           |
                           |
                           |
                       +---+---+
                +----->+  EMS  |
               /       |       |
              /        +-------+
             /             | MI SNMP or Yang
       SNMP / or Yang      |                DCN Network
       --------------------+--------------------------------
          /         +------+-----------------------+
         /          |     +|     WDM Domain   +    |
        /           |     |\                 /|    |
   +---+--+         |     | \     |\        / |    |          +------+
   |  CL  |-/C------+-----|OM|----|/-------|OD|----+-------/C-|  CL  |
   |      |-/C------+-----|  |----- /|-----|  |----+-------/C-|      |
   +------+         |     | /       \|      \ |    |          +------+
                    |     |/                 \|    |
                    |     +                   +    |
                    +------------------------------+

           CL = Client Device
           /C = Single Channel Optical Interface
           OM = Optical Mux
           OD = Optical Demux
           EMS = Element Management System
           MI = Management Interface
           DCN = Data Control Network
```

Figure 3: Connecting Single Channel optical interfaces to the Transport Management system

The exchange of management information between client device and the management system assumes that some form of a direct management communication link exists between the client device and the DWDM management system (e.g. EMS). This may be an Ethernet Link or a DCN connection (management communication channel MCC).

It must be ensured that the optical network interface can be managed in a standardized way to enable interoperable solutions between different optical interface vendors and vendors of the optical network management application. RFC 3591 [RFC3591] defines managed objects for the optical interface type but needs further extension to cover the optical parameters required by this framework document. Therefore an extension to this MIB for the optical interface has been drafted in [DWDM-interface-MIB]. SNMP is used to read parameters and get notifications and alarms, netconf and yang models are needed to easily provision the interface with the right parameter set as described in [YANG]

Note that a software update of the optical interface components of the client nodes must not lead obligatory to an update of the software of the EMS and vice versa.

4.1.2. Indirect connection to the DWDM management system (first optical node)

An alternative as shown in Figure 4 can be used in cases where a more integrated relationship between transport node (e.g. OM or OD or ROADM) and client device is aspired. In that case a combination of control plane features and manual management will be used.

```
                        +-----+
                        | NMS |
                        |_____|
                        /_____/
                           |
                           |
                       +---+---+
                       | EMS   |
                       |       |
                       +-------+
                           | MI  SNMP or Yang
                           |
           LMP      +------+-----------------------+
       +------------+---+ +|                  +    |
       |            |   | |\                 /|    |
   +---+--+         |   +-+ \     |\        / |    |          +------+
   |  CL  |-/C------+--- -|OM|----|/-------|OD|--- +-------/C-|  CL  |
   |      |-/C------+--- -|  |----- /|-----|  |----+-------/C-|      |
   +------+         |     | /       \|      \ |    |          +------+
                    |     |/                 \|    |
                    |     +                   +    |
                    +------------------------------+

           CL = Client Device
           /C = Single Channel optical Interface
           OM = Optical Mux
           OD = Optical Demux
           EMS= Element Management System
           MI= Management Interface
```

Figure 4: Direct connection between peer node and first optical network node

For information exchange between the client node and the direct connected node of the optical transport network LMP as specified in RFC 4209 [RFC4209] should be used. This extension of LMP may be used between a peer node and an adjacent optical network node as depicted in Figure 4.

The LMP based on RFC 4209 does not yet support the transmission of configuration data (information). This functionality must be added to the existing extensions of the protocol. The use of LMP-WDM assumes that some form of a control channel exists between the client node and the WDM equipment. This may be a dedicated lambda or an Ethernet Link.

4.2. Control Plane Considerations

The concept of integrated single channel DWDM interfaces equally applies to management and control plane mechanisms. GMPLS control plane protocols have been extended for WSON, e.g. [RFC7689] for fixed grid signal and for flexi-grid [RFC7792]. One important aspect of the [G.698.2] is the fact that it includes the wavelength that is supported by the given link. Therefore, the link can logically be considered as a fiber that is transparent only for a single wavelength. In other words, the wavelength becomes a characteristic of the link itself.

Nevertheless the procedure to light up the fiber may vary depending on the implementation. Since the implementation is unknown a priori, different sequences to light up a wavelength need to be considered:

1. Interface first, interface tuning: The transmitter is switched on and the link is immediately transparent to its wavelength. This requires the transmitter to carefully tune power and frequency not overload the line system or to create transients.

2. Interface first, OLS tuning: The transmitter is switched on first and can immediately go to the max power allowed since the OLS performs the power tuning. This leads to an intermediate state where the receiver does not receive a valid signal while the transmitter is sending out one. Alarm suppression mechanisms shall be employed to overcome that condition.

3. OLS first, interface tuning: At first the OLS is tuned to be transparent for a given wavelength, then transponders need to be tuned up. Since the OLS in general requires the presence of a wavelength to fine-tune its internal facilities there may be a period where a valid signal is transmitted but the receiver is unable to detect it. This equally need to be covered by alarm suppression mechanisms.

4. OLS first, OLS tuning: The OLS is programmed to be transparent for a given wavelength, then the interfaces need to be switched on and further power tuning takes place. The sequencing of enabling the link needs to be covered as well.

The preferred way to address these in a Control Plane enabled network is neighbour discovery including exchange of link characteristics and link property correlation. The general mechanisms are covered in RFC4209 [LMP-WDM] and RFC 4204[LMP] which provides the necessary protocol framework to exchange those characteristics between client and black link. LMP-WDM is not intended for exchanging routing or signaling information nor to provision the lambda in the transceiver but covers:

1. Control channel management

2. Link property correlation

3. Link verification

4. Fault management

Extensions to LMP/LMP-WDM covering the parameter sets (application codes) are needed. Additionally, when client and server side are managed by different operational entities, link state exchange is required to align the management systems.

4.2.1. Considerations using GMPLS signaling

The deployment of single channel optical interfaces is leading to some functional changes related to the control plane models and has therefore some impact on the existing interfaces especially in the case of a model where the edge node requests resources from the core node and the edges node do not participate in the routing protocol instance that runs among the core nodes. RFC 4208 [RFC4208] defines the GMPLS UNI that can be used between edge and core node. In case of integrated interfaces deployment additional functionalities are needed to setup a connection.

It is necessary to differentiate between topology/signalling information and configuration parameters that are needed to setup a wavelength path. RSVP-TE could be used for the signalling and the reservation of the wavelength path. But there are additional information needed before RSVP-TE can start the signalling process. There are three possibilities to proceed:

a. Using RSVP-TE only for the signalling and LMP as described above to exchange information to configure the optical interface within the edge node or

b. RSVP-TE (typically with loose ERO) to transport additional information

c. Leaking IGP information instead of exchanging this information needed from the optical network to the edge node (UNI will be transformed to a border-peer model, see RFC 5146)

Furthermore following issues should be addressed:

a) The Communication between peering edge nodes using an out of band control channel. The two nodes should exchange their optical capabilities. An extended version of LMP is needed to exchange FEC Modulation scheme, etc. that must be the same. It would be helpful to define some common profiles that will be supported. Only if the profiles match with both interface capabilities it is possible start signaling.

b) Due to the bidirectional wavelength path that must be setup, the upstream edge node must include a wavelength value into the RSVP-TE Path message. But in the case of a UNI model the client device may not have full information about which wavelength must/should be selected, whereas this information must be exchanged between the edge and the core node. The special value defined in [Network-Assigned-Upstream-Label] allows the optical network to assign the actual wavelength to be used by the upstream transponder, which is a simple and efficient solution to this issue.

5. Use cases

A Comparison with the traditional operation scenarios provides an insight of similarities and distinctions in operation and management of DWDM interfaces. The following use cases provide an overview about operation and maintenance processes.

5.1. Service Setup

It is necessary to differentiate between different operational issues for setting up a light path (a DWDM connection is specific in having defined maximum impairments) within an operational network.

The first step is to determine if transceivers located at different end-points are interoperable, i.e. support a common set of operational parameters. In this step it is required to determine transceiver capabilities in a way to be able to correlate them for interoperability purposes. Such parameters include modulation scheme, modulation parameters, FEC to name a few. If both transceivers are controlled by the same NMS or CP, such data is readily available. However in cases like Fig.4 a protocol need to be used to inform the controlling instance (NMS or CP) about transceiver parameters. It is suggested to extend LMP for that purpose.

The second step is to determine the feasibility of a lightpath between two transceivers without applying an optical signal. Understanding the limitations of the transceiver pair, a route through tho optical network has to be found, whereby each route has an individual set of impairments deteriorating a wavelength traveling along that route. Since a single transceiver can support multiple parameter sets, the selection of a route may limit the permissible parameter sets determined in step1.

The third step is then to setup the connection itself and to determine the Wavelength. This is done using the NMS of the optical transport network or by means of a control plane interaction such as signaling and includes the route information as well as the parameter set information necessary to enable communication.

In a fourth step, Optical monitoring is activated in the WDM network in order to monitor the status of the connection. The monitor functions of the optical interfaces at the terminals are also activated in order to monitor the end to end connection.

Furthermore it should be possible to automate this step. After connecting the client device towards the first control plane managed transport node a control connection may e.g. be automatically established using LMP.

5.2. Link monitoring Use Cases

The use cases described below are assuming that power monitoring functions are available in the ingress and egress network element of the DWDM network, respectively. By performing link property correlation it would be beneficial to include the current transmit power value at reference point Ss and the current received power value at reference point Rs. For example if the Client transmitter power has a value of 0dBm and the ROADM interface measured power is -6dBm the fiber patch cord connecting the two nodes may be pinched or the connectors are dirty. As discussed before, the actual route or selection of a specific wavelength within the allowed set is outside the scope of LMP. The computing entities (e.g. the first optical node originating the circuit) can rely on GMPLS IGP (OSPF) to retrieve all the information related to the network, calculate the path to reach the endpoint and signal the path implementation through the network via RSVP-TE.

G.698.2 defines a single channel optical interface for DWDM systems that allows interconnecting network-external optical transponders across a DWDM network. The optical transponders are external to the DWDM network. This so-called 'black link' approach illustrated in Figure 5-1 of G.698.2 and a copy of this figure is provided below. The single channel fiber link between the Ss/Rs reference points and the ingress/egress port of the network element on the domain boundary of the DWDM network (DWDM border NE) is called access link in this contribution. Based on the definition in G.698.2 it is part of the

DWDM network. The access link is typically realized as a passive fiber link that has a specific optical attenuation (insertion loss). As the access link is an integral part of the DWDM network, it is desirable to monitor its attenuation. Therefore, it is useful to detect an increase of the access link attenuation, for example, when the access link fiber has been disconnected and reconnected (maintenance) and a bad patch panel connection (connector) resulted in a significantly higher access link attenuation (loss of signal in the extreme case of an open connector or a fiber cut). In the following section, two use cases are presented and discussed:

1) pure access link monitoring
2) access link monitoring with a power control loop

These use cases require a power monitor as described in G.697 (see section 6.1.2), that is capable to measure the optical power of the incoming or outgoing single channel signal. The use case where a power control loop is in place could even be used to compensate an increased attenuation if the optical transmitter can still be operated within its output power range defined by its application code.

   Figure 5 Access Link Power Monitoring

```
                                       +-------------------------+
                                       |    P(in) = P(Tx) - a(Tx) |
                                       |    ___                   |
       +----------+                    |    \ /   Power Monitor   |
       |          | P(Tx)              |     V    P(in)           |
       |  +----+  | Ss    //\\         |     |    |\              |
       |  | TX |----|-----\\//------------------->| \             |
       |  +----+  | Access Link (AL-T) |       .  |  |            |
       |          | attenuation a(Tx)  |       .  |  |==============>
       |          |                    |       .  |  |            |
       | External |                    |     --->| /              |
       | Optical  |                    |          |/              |
       |Transpond.|                    |    P(out)                |
       |          |                    |    ___                   |
       |          |                    |    \ /   Power Monitor   |
       |          | P(Rx)              |     V    P(out)          |
       |  +----+  | Rs    //\\         |     |    |\              |
       |  | RX |<---|-----\\//--------------------| \             |
       |  +----+  | Access Link (AL-R) |       .  |  |            |
       |          | Attenuation a(Rx)  |       .  |  |<==============
       +----------+                    |       .  |  |            |
                                       |     <---| /              |
       P(Rx) = P(out) - a(Rx)          |          |/              |
                                       |                          |
                                       |          ROADM           |
                                       +-------------------------+
```

- For AL-T monitoring: P(Tx) and a(Tx) must be known
- For AL-R monitoring: P(RX) and a(Rx) must be known

An alarm shall be raised if P(in) or P(Rx) drops below a configured threshold (t [dB]):

- P(in) < P(Tx) - a(Tx) - t (Tx direction)
- P(Rx) < P(out) - a(Rx) - t (Rx direction)
- a(Tx) =| a(Rx)

Alarms and events can be shared between Client and Network via LMP according to RFC 4204 and RFC 4209[LMP]

Figure 5: Extended LMP Model

5.2.1. Pure Access Link (AL) Monitoring Use Case

Figure 6 illustrates the access link monitoring use case and the different physical properties involved that are defined below:

- Ss, Rs: Single Channel reference points
- P(Tx): current optical output power of transmitter Tx
- a(Tx): access link attenuation in Tx direction (external transponder point of view)
- P(in): measured current optical input power at the input port of border DWDM NE
- t: user defined threshold (tolerance)
- P(out): measured current optical output power at the output port of border DWDM NE
- a(Rx): access link attenuation in Rx direction (external transponder point of view)
- P(Rx): current optical input power of receiver Rx

Description:

- The access link attenuation in both directions (a(Tx), a(Rx)) is known or can be determined as part of the commissioning process. Typically, both values are very similar.
- A threshold value t has been configured by the operator. This should also be done during commissioning.
- A control plane protocol is in place that allows to periodically send the optical power values P(Tx) and P(Rx) to the control plane protocol instance on the DWDM border NE. This is illustrated in Figure 3.
- The DWDM border NE is capable to periodically measure the optical power Pin and Pout as defined in G.697 by power monitoring points depicted as yellow triangles in the figures below.

Access Link monitoring process:

- Tx direction: the measured optical input power Pin is compared with the expected optical input power P(Tx) - a(Tx). If the measured optical input power P(in) drops below the value (P(Tx) - a(Tx) - t) a low power alarm shall be raised indicating that the access link attenuation has exceeded a(Tx) + t.
- Rx direction: the measured optical input power P(Rx) is compared with the expected optical input power P(out) - a(Rx). If the measured optical input power P(Rx) drops below the value (P(out) - a(Rx) - t) a low power alarm shall be raised indicating that the access link attenuation has exceeded a(Rx) + t.
- to avoid toggling errors, the low power alarm threshold shall be lower than the alarm clear threshold.

Figure 6 Use case 1: Access Link monitoring

```
+----------+                    +--------------------------+
| +------+ |    P(Tx), P(Rx)    |  +-------+               |
| |      | | =================> |  |       |               |
| | LMP  | |    P(in), P(out)   |  |  LMP  |               |
| |      | | <================= |  |       |               |
| +------+ |                    |  +-------+               |
|          |                    |                          |
|          |                    |    P(in) - P(Tx) - a(Tx) |
|          |                    |    ___                   |
|          |                    |    \ /  Power Monitor    |
|          | P(Tx)              |     V                    |
|  +----+  | Ss    //\\         |     |     |\             |
|  | TX |----|-----\\//------------------->| \            |
|  +----+  | Access Link (AL-T) |       .  |  |           |
|          | attenuation a(Tx)  |       .  |  |==============>
|          |                    |       .  |  |           |
| External |                    |      --->| /            |
| Optical  |                    |          |/             |
|Transpond.|                    |    P(out)                |
|          |                    |    ___                   |
|          |                    |    \ /  Power Monitor    |
|          | P(Rx)              |     V                    |
|  +----+  | Rs    //\\         |     |     |\             |
|  | RX |<---|-----\\//--------------------| \            |
|  +----+  | Access Link (AL-R) |       .  |  |           |
|          | Attenuation a(Rx)  |       .  |  |<==============
+----------+                    |       .  |  |           |
                                |      <---| /            |
P(Rx) = P(out) - a(Rx)          |          |/             |
                                |                          |
                                |          ROADM           |
                                +--------------------------+
```

- For AL-T monitoring: P(Tx) and a(Tx) must be known
- For AL-R monitoring: P(RX) and a(Rx) must be known

An alarm shall be raised if P(in) or P(Rx) drops below a configured threshold (t [dB]):

- P(in) < P(Tx) - a(Tx) - t (Tx direction)
- P(Rx) < P(out) - a(Rx) - t (Rx direction)
- a(Tx) = a(Rx)

Alarms and events can be shared between Client and Network via LMP according to RFC 4204 and RFC 4209[LMP]

Figure 6: Extended LMP Model

5.2.2. Power Control Loop Use Case

This use case is based on the access link monitoring use case as described above. In addition, the border NE is running a power control application that is capable to control the optical output power of the single channel tributary signal at the output port of the border DWDM NE (towards the external receiver Rx) and the optical output power of the single channel tributary signal at the external transmitter Tx within their known operating range. The time scale of this control loop is typically relatively slow (e.g. some 10s or minutes) because the access link attenuation is not expected to vary much over time (the attenuation only changes when re-cabling occurs).
From a data plane perspective, this use case does not require additional data plane extensions. It does only require a protocol extension in the control plane (e.g. this LMP draft) that allows the power control application residing in the DWDM border NE to modify the optical output power of the DWDM domain-external transmitter Tx within the range of the currently used application code. Figure 5 below illustrates this use case utilizing the LMP protocol with extensions defined in this draft.

Figure 7 Use case 2: Power Control Loop

```
     +----------+                       +--------------------------+
     | +------+ | P(Tx),P(Rx),Set(Pout) |  +-------+   +--------+  |
     | |      | | ====================> |  |       |   | Power  |  |
     | | LMP  | | P(in),P(out),Set(PTx) |  |  LMP  |   |Control |  |
     | |      | | <==================== |  |       |   | Loop   |  |
     | +------+ |                       |  +-------+   +--------+  |
     |     |    |                       |                          |
     | +------+ |                       |    P(in) = P(Tx) - a(Tx) |
     | |C.Loop| |                       |    ___                   |
     | +------+ |                       |    \ /  Power Monitor    |
     |     |    | P(Tx)                 |     V                    |
     | +------+ | Ss    //\\            |     |    |\              |
     | | TX |>----|-----\\//---------------------->| \             |
     | +------+ | Access Link (AL-T)    |       .  |  |            |
     |  VOA(Tx) | attenuation a(Tx)     |       .  |  |==============>
     |          |                       |       .  |  |            |
     | External |                       |      --->| /             |
     | Optical  |                       |          |/              |
     |Transpond.|                       |    P(out)                |
     |          |                       |    ___                   |
     |          |                       |    \ /  Power Monitor    |
     |          | P(Rx)                 |     V                    |
     |  +----+  | Rs    //\\            |     |  VOA(out) |\       |
     |  | RX |<---|-----\\//---------------------<|-------| \      |
     |  +----+  | Access Link (AL-R)    |              .  |  |     |
     |          | attenuation a(Rx)     |              .  |  |<=======
     +----------+                       |         VOA(out) |  |     |
                                        |     <--<|-------| /      |
     P(Rx) = P(out) - a(Rx)             |                 |/       |
                                        |                          |
                                        |           ROADM          |
                                        +--------------------------+
```

Figure 7: Power control loop

- The Power Control Loops in Transponder and ROADM controls the Variable Optical Attenuators (VOA) to adjust the proper power in base of the ROADM and Receiver caracteristics and the Access Link attenuation

6. Requirements

Even if network architectures becomes more complex the management and operation as well as the provisioning process should have a higher degree of automation or should be fully automated. Simplifying and automating the entire management and provisioning process of the network in combination with a higher link utilization and faster restoration times will be the major requirements that has been addressed in this section.

Data Plane interoperability as defined for example in [ITU.G698.2] is a precondition to ensure plain solutions and allow the usage of standardized interfaces between network and control/management plane.

The following requirements are focusing on the usage of DWDM interfaces.

1 To ensure a lean management and provisioning process of single channel interfaces management and control plane of the client and DWDM network MUST be aware of the parameters of the interfaces and the optical network to properly setup the optical connection.

2 A standard-based northbound API (to network management system) based on Netconf SHOULD be supported, alternatively SNMP MAY be supported too.

3 A standard-based data model for single channel interfaces MUST be supported to exchange optical parameters with control/management plane.

4 Netconf SHOULD be used also for configuration of the single channel interfaces including the power setting

5 LMP SHOULD be extended and used in cases where optical parameters need to be exchanged between peer nodes to correlate link characteristics and adopt the working mode of the single channel interface.

6 LMP MAY be used to adjust the output power of the single channel DWDM interface to ensure that the interface works in the right range.

7 RSVP-TE MAY be used to exchange some relevant parameters between the client and the optical node (e.g. the label value), without preventing the network to remain in charge of the optical path computation

8 Power monitoring functions at both ends of the DWDM connection SHOULD be used to further automate the setup and shoutdown process of the optical interfaces.

9 A standardized procedure to setup an optical connection SHOULD be defined and implemented in DWDM and client devices (containing the single channel optical interface).

10 Pre-tested and configured backup paths SHOULD be stored in so called backup profiles. In fault cases this wavelength routes SHOULD be used to recover the service.

11 LMP MAY be used to monitor and observe the access link.

7. Acknowledgements

The authors would like to thank all who supported the work with fruitful discussions and contributions.

8. IANA Considerations

This memo includes no request to IANA.

9. Security Considerations

The architecture and solution space in scope of this framework imposes no additional requirements to the security models already defined in RFC5920 for packet/optical networks using GMPLS, covering also Control Plane and Management interfaces. Respective security mechanisms of the components and protocols, e.g. LMP security models, can be applied unchanged.

As this framework is focusing on the single operator use case, the security concerns can be relaxed to a subset compared to a setup where information is exchanged between external parties and over external interfaces.

Concerning the access control to Management interfaces, security issues can be generally addressed by authentication techniques providing origin verification, integrity and confidentiality. Additionally, access to Management interfaces can be physically or logically isolated, by configuring them to be only accessible out-of-band, through a system that is physically or logically separated from the rest of the network infrastructure. In case where management interfaces are accessible in-band at the client device or within the optical transport netork domain, filtering or firewalling techniques can be used to restrict unauthorized in-band traffic. Authentication techniques may be additionally used in all cases.

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A framework for Management and Control of microwave and millimeter wave interface parameters

draft-ietf-ccamp-microwave-framework-00

Abstract

To ensure an efficient data transport, meeting the requirements requested by today’s transport services, the unification of control and management of microwave and millimeter wave radio link interfaces is a precondition for seamless multilayer networking and automated network wide provisioning and operation.

This document describes the required characteristics and use cases for control and management of radio link interface parameters using a YANG Data Model. It focuses on the benefits of a standardized management model that is aligned with how other packet technology interfaces in a microwave/millimeter wave node are modeled, the need to support core parameters and at the same time allow for optional product/feature specific parameters supporting new, unique innovative features until they have become mature enough to be included in the standardized model.

The purpose is to create a framework for identification of the necessary information elements and definition of a YANG Data Model for control and management of the radio link interfaces in a microwave/millimeter wave node.

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. Terminology and Definitions

Microwave is a band of spectrum with wavelengths ranging from 1 meter to 1 millimeter and with frequencies ranging between 300 MHz and 300 GHz. Microwave radio technology is widely used for point-to-point telecommunications because of their small wavelength that allows conveniently-sized antennas to direct them in narrow beams, and their comparatively higher frequencies that allows broad bandwidth and high data transmission rates.

Millimeter wave is also known as extremely high frequency (EHF) or very high frequency (VHF) by the International Telecommunications Union (ITU), which can be used for high-speed wireless broadband communications. Millimeter wave can be used for a broad range of fixed and mobile services including high-speed, point-to-point wireless local area networks (WLANs) and broadband access. This band has short wavelengths that range from 10 millimeters to 1 millimeter, namely millimeter band or millimeter wave. The 71 - 76 GHz, 81 - 86 GHz and 92-95 GHz bands are used for point-to-point high-bandwidth communication links, which allows for higher data rates up to 10 Gbit/s but requires a license. Unlicensed short-range data links can be used on 60 GHz millimeter wave. For instance, the upcoming IEEE Wi-Fi standard 802.11ad will run on the 60 GHz spectrum with data transfer rates of up to 7 Gbit/s.

Carrier Termination is an interface for the capacity provided over the air by a single carrier. It is typically defined by its transmitting and receiving frequencies.

Radio Link Terminal is an interface providing packet capacity and/or TDM capacity to the associated Ethernet and/or TDM interfaces in a node and used for setting up a transport service over a microwave/millimeter wave link.

Figure 1 provides a graphical representation of Carrier Termination and Radio Link Terminal concepts.

```
                  /--------- Radio Link ---------\
                   Near End              Far End

            +---------------+           +---------------+
            |    Radio Link |           | Radio Link    |
            |      Terminal |           | Terminal      |
            |               |           |               |
            |           (Protected or Bonded)           |
            |               |           |               |
            | +-----------+ |           | +-----------+ |
            | |           | | Carrier A | |           | |
            | |  Carrier  | |<--------->| |  Carrier  | |
            | |Termination| |           | |Termination| |
    Packet--| |           | |           | |           | |--Packet
            | +-----------+ |           | +-----------+ |
     TDM----|               |           |               |----TDM
            | +-----------+ |           | +-----------+ |
            | |           | | Carrier B | |           | |
            | |  Carrier  | |<--------->| |  Carrier  | |
            | |Termination| |           | |Termination| |
            | |           | |           | |           | |
            | +-----------+ |           | +-----------+ |
            |               |           |               |
            +---------------+           +---------------+

      \--- Microwave Node ---/          \--- Microwave Node ---/
```

Figure 1. Radio Link Terminal and Carrier Termination

Software Defined Networking (SDN) is an emerging architecture that decouples the network control and forwarding functions enabling the network control to become directly programmable and the underlying infrastructure to be abstracted for applications and network services. This results in an extremely dynamic, manageable, cost-effective, and adaptable architecture that gives administrators unprecedented programmability, automation, and control. The SDN concept is widely applied for network management, the adoption of SDN framework to manage and control the microwave and millimeter wave interface is one of the key applications of this work.

2. Introduction

Network requirements vary between operators globally as well as within individual countries. The overall goal is however the same - to deliver the best possible network performance and quality of experience in a cost-efficient way.

Microwave/millimeter wave (hereafter referred to as microwave, but including the frequency bands represented by millimeter wave) are important technologies to fulfill this goal today, but also in the future when demands on capacity and packet features increases.

Microwave is already today able to fully support the capacity needs of a backhaul in a radio access network and will evolve to support multiple gigabits in traditional frequency bands and beyond 10 gigabits in the millimeter wave. L2 packet features are normally an integrated part of microwave nodes and more advanced L2 & L3 features will over time be introduced to support the evolution of the transport services to be provided by a backhaul/transport network. Note that the wireless access technologies such as 3/4/5G & WiFi are not within the scope of this microwave model work.

The main application for microwave is backhaul for mobile broadband. Those networks will continue to be modernized using a combination of microwave and fiber technologies. The choice of technology is a question about fiber presence and cost of ownership, not about capacity limitations in microwave.

Open and standardized interfaces are a pre-requisite for efficient management of equipment from multiple vendors, integrated in a single system/controller. This framework addresses management and control of the radio link interface(s) and the relationship to other packet interfaces, typically to Ethernet interfaces, in a microwave node. A radio link provides the transport over the air, using one or several carriers in aggregated or protected configurations. Managing and controlling a transport service over a microwave node involves both radio link and packet functionality.

Already today there are numerous IETF data models, RFCs and drafts, with technology specific extensions that cover a large part of the packet domain. Examples are IP Management [RFC7277], Routing Management [I-D.ietf-netmod-routing-cfg] and Provider Bridge [PB-YANG] They are based on RFC 7223 [RFC7223], which is the IETF YANG model for Interface Management, and is an evolution of the SNMP IF-MIB [RFC2863].

Since microwave nodes will contain more and more packet functionality which is expected to be managed using those models, there are advantages if radio link interfaces can be modeled and be managed using the same structure and the same approach, specifically for use cases in which a microwave node are managed as one common entity including both the radio link and the packet functionality, e.g. at basic configuration of node & connections, centralized trouble shooting, upgrade and maintenance. All interfaces in a node, irrespective of technology, would then be accessed from the same core model, i.e. RFC 7223, and could be extended with technology specific parameters in models augmenting that core model. The relationship/connectivity between interfaces could be given by the physical equipment configuration, e.g the slot in which the Radio Link Terminal (modem) is plugged in could be associated with a specific Ethernet port due to the wiring in the backplane of the system, or it could be flexible and therefore configured via a management system or controller.

```
+------------------------------------------------------------------+
| Interface [RFC7223]                                              |
|                +------------------+                              |
|                |Ethernet Port     |                              |
|                +------------------+                              |
|                      \                                           |
|                    +------------------------+                    |
|                    |Radio Link Terminal     |                    |
|                    +------------------------+                    |
|                               \                                  |
|                            +-------------------------+           |
|                            |Carrier Termination      |           |
|                            +-------------------------+           |
+------------------------------------------------------------------+
```

Figure 2: Relationship between interfaces in a node

There will always be certain implementations that differ among products and it is therefore practically impossible to achieve industry consensus on every design detail. It is therefore important to focus on the parameters that are required to support the use cases applicable for centralized, unified, multi-vendor management and to allow other parameters to be optional or to be covered by extensions to the standardized model. Furthermore, a standard that allows for a certain degree of freedom encourages innovation and competition which is something that benefits the entire industry. It is therefore important that a radio link management model covers all relevant functions but also leaves room for product/feature-specific extensions.

For microwave radio link functionality work has been initiated (ONF: Microwave Modeling [ONF-model], IETF: Radio Link Model [I-D.ahlbergccamp-microwave-radio-link]. The purpose of this effort is to reach consensus within the industry around one common approach, with respect to the use cases and requirements to be supported, the type and structure of the model and the resulting attributes to be included. This document describes the use cases and requirements agreed to be covered, the expected characteristics of the model and at the end includes an analysis of how the models in the two on-going initiatives fulfill these expectations and a recommendation on what can be reused and what gaps need to be filled by a new and evolved radio link model.

3. 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 RFC 2119 [RFC2119].

While [RFC2119] describes interpretations of these key words in terms of protocol specifications and implementations, they are used in this document to describe requirements for the YANG Data Model for Microwave Radio Link.

4. Approaches to manage and control radio link interfaces

This framework addresses the definition of an open and standardized interface for the radio link functionality in a microwave/millimeter wave node. The application of such an interface used for management and control of nodes and networks typically vary from one operator to another, in terms of the systems used and how they interact. A traditional solution is network management system, while an emerging one is SDN. SDN solutions can be used as part of the network management system, allowing for direct network programmability and automated configurability by means of a centralized SDN control and defining standardized interfaces to program the nodes.

4.1. Network Management Solutions

The classic network management solutions, with vendor specific domain management combined with cross domain functionality for service management and analytics, still dominates the market. These solutions are expected to evolve and benefit from an increased focus on standardization by simplifying multi-vendor management and remove the need for vendor/domain specific management.

4.2. Software Defined Networking

One of the main drivers for applying SDN from an operator perspective is simplification and automation of network provisioning as well as E2E network service management. The vision is to have a global view of the network conditions spanning across different vendors? equipment and multiple technologies.

If nodes from different vendors shall be managed by the same SDN controller via a node management interface (north bound interface, NBI), without the extra effort of introducing intermediate systems, all nodes must align their node management interfaces. Hence, an open and standardized node management interface are required in a multi-vendor environment. Such standardized interface enables a unified management and configuration of nodes from different vendors by a common set of applications.

On top of SDN applications to configure, manage and control the nodes and their associated transport interfaces including the L2 and L3 packet/Ethernet interfaces as well as the radio interfaces, there are also a large variety of other more advanced SDN applications that can be exploited and/or developed.

A potential flexible approach for the operators is to use SDN in a logical control way to manage the radio links by selecting a predefined operation mode. The operation mode is a set of logical metrics or parameters describing a complete radio link configuration, such as capacity, availability, priority and power consumption.

An example of an operation mode table is shown in Figure 3. Based on its operation policy (e.g., power consumption or traffic priority), the SDN controller selects one operation mode and translates that into the required configuration of the individual parameters for the radio link terminals and the associated carrier terminations.

ID	Description	Capacity	Availability	Priority	Power
1	High capacity	400 Mbps	99.9%	Low	High
2	High avail- ability	100 Mbps	99.999%	High	Low

Figure 3. Example of an operation mode table

An operation mode bundles together the values of a set of different parameters. How each operation mode maps into certain set of attributes is out of scope of this document. Effort on a standardizing operation mode is required to implement a smoothly operator environment.

5. Use Cases

The use cases described should be the basis for identification and definition of the parameters to be supported by a YANG Data model for management of radio links, applicable for centralized, unified, multi-vendor management.

Other product specific use cases, addressing e.g. installation, on-site trouble shooting and fault resolution, are outside the scope of this framework. If required, these use cases are expected to be supported by product specific extensions to the standardized model.

5.1. Configuration Management

Configuration of a radio link terminal, the constituent carrier terminations and when applicable the relationship to packet/Ethernet and TDM interfaces.

5.1.1. Understand the capabilities & limitations

Exchange of information between a manager and a device about the capabilities supported and specific limitations in the parameter values & enumerations that can be used.

Support for the XPIC (Cross Polarization Interference Cancellation) feature or not and the maximum modulation supported are two examples on information that could be exchanged.

5.1.2. Initial Configuration

Initial configuration of a radio link terminal, enough to establish L1 connectivity over the hop to an associated radio link terminal on a device at far end. It MAY also include configuration of the relationship between a radio link terminal and an associated traffic interface, e.g. an Ethernet interface, unless that is given by the equipment configuration.

Frequency, modulation, coding and output power are examples of parameters typically configured for a carrier termination and type of aggregation/bonding or protection configurations expected for a radio link terminal.

5.1.3. Radio link re-configuration & optimization

Re-configuration, update or optimization of an existing radio link terminal. Output power and modulation for a carrier termination and protection schemas and activation/de-activation of carriers in a radio link terminal are examples on parameters that can be re-configured and used for optimization of the performance of a network.

5.1.4. Radio link logical configuration

Radio link terminals comprising a group of carriers are widely used in microwave technology. There are several kinds of groups: aggregation/bonding, 1+1 protection/redundancy, etc. To avoid configuration on each carrier termination directly, a logical control provides flexible management by mapping a logical configuration to a set of physical attributes. This could also be applied in a hierarchical SDN environment where some domain controllers are located between the SDN controller and the radio link terminal.

5.2. Inventory

5.2.1. Retrieve logical inventory & configuration from device

Request from manager and response by device with information about radio interfaces, their constitution and configuration.

5.2.2. Retrieve physical/equipment inventory from device

Request from manager about physical and/or equipment inventory associated with the radio link terminals and carrier terminations.

5.3. Status & statistics

5.3.1. Actual status & performance of a radio link interface

Manager requests and device responds with information about actual status and statistics of configured radio link interfaces and their constituent parts.

5.4. Performance management

5.4.1. Configuration of historical measurements to be performed

Configuration of historical measurements to be performed on a radio link interface and/or its constituent parts is a subset of the configuration use case to be supported. See 5.1 above.

5.4.2. Collection of historical performance data

Collection of historical performance data in bulk by the manager is a general use case for a device and not specific to a radio link interface.

Collection of an individual counter for a specific interval is in same cases required as a complement to the retrieval in bulk as described above.

5.5. Fault Management

5.5.1. Configuration of alarm reporting

Configuration of alarm reporting associated specifically with radio interfaces, e.g. configuration of alarm severity, is a subset of the configuration use case to be supported. See 5.1 above.

5.5.2. Alarm management

Alarm synchronization, visualization & handling, and notifications & events are generic use cases for a device and not specific to a radio link interface and should be supported accordingly.

5.6. Troubleshooting and Root Cause Analysis

Information and actions required by a manager/operator to investigate and understand the underlying issue to a problem in the performance and/or functionality of a radio link terminal and the associated carrier terminations.

6. Requirements

For managing a microwave node including both the radio link and the packet functionality, a unified data model is desired to unify the modeling of the radio link interfaces and the packet interfaces using the same structure and the same modelling approach.

The purpose of the YANG Data Model is for management and control of the radio link interface(s) and the relationship/connectivity to other packet interfaces, typically to Ethernet interfaces, in a microwave node.

The capability of configuring and managing microwave nodes includes the following requirements for the modelling:

1) It MUST be possible to configure, manage and control a radio link terminal and the constituent carrier terminations.

   a) Frequency, channel bandwidth, modulation, coding and transmitter power are examples of parameters typically configured for a carrier termination.

   b) A radio link terminal MUST configure the associated carrier terminations and the type of aggregation/bonding or protection configurations expected for the radio link terminal.

   c) The capability, e.g. the maximum modulation supported, and the actual status/statistics, e.g. administrative status of the carriers, SHOULD also be supported by the data model.

2) It MUST be possible to map different traffic types (e.g. TDM, Ethernet) to the transport capacity provided by a specific radio link terminal.

3) It MUST be possible to configure and collect historical measurements (for the use case described in section 5.4) to be performed on a radio link interface, e.g. minimum, maximum and average transmit power and receive level in dBm.

4) It MUST be possible to configure and retrieve alarms reporting associated with the radio interfaces, e.g. configuration of alarm severity, supported alarms like configuration fault, signal lost, modem fault, radio fault.

7. Gap Analysis on Models

The purpose of the gap analysis is to identify and recommend what existing and established models as well as draft models under definition to support the use cases and requirements specified in the previous chapters. It shall also make a recommendation on how the gaps not supported should be filled, including the need for development of new models and evolution of existing models and drafts.

For microwave radio link functionality work has been initiated (ONF: Microwave Modeling [ONF-model], IETF: Radio Link Model [I-D.ahlbergccamp-microwave-radio-link]. The analysis is expected to take these initiatives into consideration and make a recommendation on how to make use of them and how to complement them in order to fill the gaps identified.

For generic functionality, not specific for radio link, the ambition is to refer to existing or emerging models that could be applicable for all functional areas in a microwave node.

7.1. Microwave Radio Link Functionality

[ONF CIM] defines a CoreModel of the ONF Common Information Model. An information model describes the things in a domain in terms of objects, their properties (represented as attributes), and their relationships. The ONF information model is expressed in Unified Modeling Language (UML). The ONF CoreModel is independent of specific data plane technology. Data plane technology specific properties are acquired in a runtime solution via "filled in" cases of specification (LtpSpec etc). These can be used to augment the CoreModel to provide a data plane technology specific representation.

IETF Data Model defines an implementation and NETCONF-specific details. YANG is a data modeling language used to model the configuration and state data. It is well aligned with the structure of the Yang data models proposed for the different packet interfaces which are all based on RFC 7223. Furthermore, several YANG data models have been proposed in the IETF for other transport technologies such as optical transport; e.g., RFC 7277 [RFC7277], [I.D.zhang-ccamp-l1-topo-yang], [I.D.ietf-ospf-yang]. In light of this trend, the IETF data model is becoming a popular approach for modeling most packet transport technology interfaces and it is thereby well positioned to become an industry standard.

RFC 3444 [RFC3444] explains the difference between Information Model(IM) and Data Models(DM). IM is to model managed objects at a conceptual level for designers and operators, DM is defined at a lower level and includes many details for implementers. In addition, the protocol-specific details are usually included in DM. Since conceptual models can be implemented in different ways, multiple DMs can be derived from a single IM. To ensure better interoperability, it is better to focus on DM directly.

RFC 7223 describes an interface management model, however it doesn?t include technology specific information, e.g., for radio interface. [I-D.ahlberg-ccamp-microwave-radio-link] provides a model proposal for radio interfaces, which includes support for basic configuration, status and performance but lacks full support for alarm management and interface layering, i.e. the connectivity of the transported capacity (TDM & Ethernet) with other internal technology specific interfaces in a microwave node.

The recommendation is to use the structure of the IETF: Radio Link Model [I-D.ahlberg-ccamp-microwave-radio-link] as the starting point, since it is a data model providing the wanted alignment with RFC 7223. For the definition of the detailed leafs/parameters, the recommendation is to use the IETF: Radio Link Model and the ONF: Microwave Modeling [ONF-model] as the basis and to define new ones to cover identified gaps. The parameters in those models have been defined by both operators and vendors within the industry and the implementations of the ONF Model have been tested in the Proof of Concept events in multi-vendor environments, showing the validity of the approach proposed in this framework document.

It is also recommended to add the required data nodes to describe the interface layering for the capacity provided by a radio link terminal and the associated Ethernet and TDM interfaces in a microwave node. The principles and data nodes for interface layering described in RFC 7223 should be used as a basis.

7.2. Generic Functionality

For generic functionality, not specific for radio link, the recommendation is to refer to existing RFCs or emerging drafts according to the table in figure 4 below. New Radio Link Model is used in the table for the cases where the functionality is recommended to be included in the new radio link model as described in chapter 7.1.

Generic Functionality	Recommendation
1.Fault Management	
Alarm Configuration	New Radio Link Model
Alarm notifications/ synchronization	[I-D.vallin-netmod-alarm-module]
2.Performance Management	
Performance Configuration/ Activation	New Radio Link Model
Performance Collection	New Radio Link Model & XML files
3.Physical/Equipment Inventory	[I-D.ietf-netmod-entity]

Figure 4. Recommendation on how to support generic functionality

Microwave specific alarm configurations are recommended to be included in the new radio link model and could be based on what is supported in the IETF and ONF Radio Link Models. Alarm notifications and synchronization are general and is recommended to be supported by a generic model, such as [I-D.vallin-netmod-alarm-module].

Activation of interval counters & thresholds could be a generic function but it is recommended to be supported by the new radio link specific model and can be based on both the ONF and IETF Microwave Radio Link models.

Collection of interval/historical counters is a generic function that needs to be supported in a node. File based collection via SFTP and collection via a Netconf/YANG interfaces are two possible options and the recommendation is to include support for the latter in the new radio link specific model. The ONF and IETF Microwave Radio Link models can be used as a basis also in this area.

Physical and/or equipment inventory associated with the radio link terminals and carrier terminations is recommended to be covered by a model generic for the complete node, e.g. [I-D.ietf-netmod-entity] and it is thereby outside the scope of the radio link specific model.

7.3. Summary

The conclusions and recommendations from the analysis can be summarized as follows:

1) A Microwave Radio Link YANG Data Model should be defined with a scope enough to support the use cases and requirements in chapter 5 and 6 of this document.

2) Use the structure in the IETF: Radio Link Model [I-D.ahlberg-ccamp-microwave-radio-link] as the starting point. It augments RFC 7223 and is thereby as required aligned with the structure of the models for management of the packet domain.

3) Use the IETF: Radio Link Model [I-D.ahlberg-ccamp-microwave-radio-link] and the ONF: Microwave Modeling [ONF-model] as the basis for the definition of the detailed leafs/parameters to support the specified use cases and requirements, and proposing new ones to cover identified gaps.

4) Add the required data nodes to describe the interface layering for the capacity provided by a radio link terminal and the associated Ethernet and TDM interfaces, using the principles and data nodes for interface layering described in RFC 7223 as a basis.

5) Include support for configuration of microwave specific alarms in the Microwave Radio Link model and rely on a generic model such as [I.D.vallin-netmod-alarm-module] for notifications and alarm synchronization.

6) Use a generic model such as [I-D.ietf-netmod-entity] for physical/equipment inventory.

It is furthermore recommended that the Microwave Radio Link YANG Date Model should be validated by both operators and vendors as part of the process to make it stable and mature.

8. Security Considerations

TBD

9. IANA Considerations

This memo includes no request to IANA.

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A framework for Management and Control of microwave and millimeter wave interface parameters
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Abstract

To ensure an efficient data transport, meeting the requirements requested by today’s transport services, the unification of control and management of microwave and millimeter wave radio link interfaces is a precondition for seamless multilayer networking and automated network wide provisioning and operation.

This document describes the required characteristics and use cases for control and management of radio link interface parameters using a YANG Data Model. It focuses on the benefits of a standardized management model that is aligned with how other packet technology interfaces in a microwave/millimeter wave node are modeled, the need to support core parameters and at the same time allow for optional product/feature specific parameters supporting new, unique innovative features until they have become mature enough to be included in the standardized model.

The purpose is to create a framework for identification of the necessary information elements and definition of a YANG Data Model for control and management of the radio link interfaces in a microwave/millimeter wave node. Some part of the resulting model MAY be generic which COULD also be used by other technology.

Status of This Memo

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1. Terminology and Definitions

Microwave is a band of spectrum with wavelengths ranging from 1 meter to 1 millimeter and with frequencies ranging between 300 MHz and 300 GHz. Microwave radio technology is widely used for point-to-point telecommunications because of their small wavelength that allows conveniently-sized antennas to direct them in narrow beams, and their comparatively higher frequencies that allows broad bandwidth and high data transmission rates.

Millimeter wave is also known as extremely high frequency (EHF) or very high frequency (VHF) by the International Telecommunications Union (ITU), which can be used for high-speed wireless broadband communications. Millimeter wave can be used for a broad range of fixed and mobile services including high-speed, point-to-point wireless local area networks (WLANs) and broadband access. This band has short wavelengths that range from 10 millimeters to 1 millimeter, namely millimeter band or millimeter wave. The 71 - 76 GHz, 81 - 86 GHz and 92-95 GHz bands are used for point-to-point high-bandwidth communication links, which allows for higher data rates up to 10 Gbit/s but requires a license. Unlicensed short-range data links can be used on 60 GHz millimeter wave. For instance, the upcoming IEEE Wi-Fi standard 802.11ad will run on the 60 GHz spectrum with data transfer rates of up to 7 Gbit/s.

ETSI EN 302 217 series defines the characteristics and requirements of microwave/millimeter wave equipment and antennas. Especially ETSI EN 302 217-2 specifies the essential parameters for the systems operating from 1.4GHz to 86GHz.

Carrier Termination and Radio Link Terminal are two concepts defined to support modeling of microwave radio link features and parameters in a structured and yet simple manner.

Carrier Termination is an interface for the capacity provided over the air by a single carrier. It is typically defined by its transmitting and receiving frequencies.

Radio Link Terminal is an interface providing packet capacity and/or TDM capacity to the associated Ethernet and/or TDM interfaces in a node and used for setting up a transport service over a microwave/millimeter wave link.

Figure 1 provides a graphical representation of Carrier Termination and Radio Link Terminal concepts.

```
                  /--------- Radio Link ---------\
                   Near End             Far End

             +---------------+          +---------------+
             |    Radio Link |          | Radio Link    |
             |      Terminal |          | Terminal      |
             |               |          |               |
             |          (Protected or Bonded)           |
             |               |          |               |
             | +-----------+ |          | +-----------+ |
             | |           | | Carrier A | |           | |
             | |  Carrier  | |<--------->| |  Carrier  | |
             | |Termination| |          | |Termination| |
     Packet--| |           | |          | |           | |--Packet
             | +-----------+ |          | +-----------+ |
      TDM----|               |          |               |----TDM
             | +-----------+ |          | +-----------+ |
             | |           | | Carrier B | |           | |
             | |  Carrier  | |<--------->| |  Carrier  | |
             | |Termination| |          | |Termination| |
             | |           | |          | |           | |
             | +-----------+ |          | +-----------+ |
             |               |          |               |
             +---------------+          +---------------+

       \--- Microwave Node ---/          \--- Microwave Node ---/
```

Figure 1. Radio Link Terminal and Carrier Termination

Software Defined Networking (SDN) is an emerging architecture that decouples the network control and forwarding functions enabling the network control to become directly programmable and the underlying infrastructure to be abstracted for applications and network services. This results in an extremely dynamic, manageable, cost-effective, and adaptable architecture that gives administrators unprecedented programmability, automation, and control. The SDN concept is widely applied for network management, the adoption of SDN framework to manage and control the microwave and millimeter wave interface is one of the key applications of this work.

2. Introduction

Network requirements vary between operators globally as well as within individual countries. The overall goal is however the same - to deliver the best possible network performance and quality of experience in a cost-efficient way.

Microwave/millimeter wave (hereafter referred to as microwave, but including the frequency bands represented by millimeter wave) are important technologies to fulfill this goal today, but also in the future when demands on capacity and packet features increases.

Microwave is already today able to fully support the capacity needs of a backhaul in a radio access network and will evolve to support multiple gigabits in traditional frequency bands and beyond 10 gigabits in the millimeter wave. L2 packet features are normally an integrated part of microwave nodes and more advanced L2 & L3 features will over time be introduced to support the evolution of the transport services to be provided by a backhaul/transport network. Note that the wireless access technologies such as 3/4/5G & WiFi are not within the scope of this microwave model work.

The main application for microwave is backhaul for mobile broadband. Those networks will continue to be modernized using a combination of microwave and fiber technologies. The choice of technology is a question about fiber presence and cost of ownership, not about capacity limitations in microwave.

Open and standardized interfaces are a pre-requisite for efficient management of equipment from multiple vendors, integrated in a single system/controller. This framework addresses management and control of the radio link interface(s) and the relationship to other packet interfaces, typically to Ethernet interfaces, in a microwave node. A radio link provides the transport over the air, using one or several carriers in aggregated or protected configurations. Managing and controlling a transport service over a microwave node involves both radio link and packet functionality.

Already today there are numerous IETF data models, RFCs and drafts, with technology specific extensions that cover a large part of the packet domain. Examples are IP Management [RFC7277], Routing Management [RFC8022] and Provider Bridge [PB-YANG] They are based on the IETF YANG model for Interface Management [RFC7223], which is an evolution of the SNMP IF-MIB [RFC2863].

Since microwave nodes will contain more and more packet functionality which is expected to be managed using those models, there are advantages if radio link interfaces can be modeled and be managed using the same structure and the same approach, specifically for use cases in which a microwave node are managed as one common entity including both the radio link and the packet functionality, e.g. at basic configuration of node & connections, centralized trouble shooting, upgrade and maintenance. All interfaces in a node, irrespective of technology, would then be accessed from the same core model, i.e. [RFC7223], and could be extended with technology specific parameters in models augmenting that core model. The relationship/connectivity between interfaces could be given by the physical equipment configuration, e.g the slot in which the Radio Link Terminal (modem) is plugged in could be associated with a specific Ethernet port due to the wiring in the backplane of the system, or it could be flexible and therefore configured via a management system or controller.

```
+------------------------------------------------------------------+
| Interface [RFC7223]                                              |
|                 +------------------+                             |
|                 |Ethernet Port     |                             |
|                 +------------------+                             |
|                       \                                          |
|                     +-----------------------+                    |
|                     |Radio Link Terminal    |                    |
|                     +-----------------------+                    |
|                              \                                   |
|                             +-----------------------+            |
|                             |Carrier Termination    |            |
|                             +-----------------------+            |
+------------------------------------------------------------------+
```

Figure 2: Relationship between interfaces in a node

There will always be certain implementations that differ among products and it is therefore practically impossible to achieve industry consensus on every design detail. It is therefore important to focus on the parameters that are required to support the use cases applicable for centralized, unified, multi-vendor management and to allow other parameters to be optional or to be covered by extensions to the standardized model. Furthermore, a standard that allows for a certain degree of freedom encourages innovation and competition which is something that benefits the entire industry. It is therefore important that a radio link management model covers all relevant functions but also leaves room for product/feature-specific extensions.

For microwave radio link functionality work has been initiated (ONF: Microwave Modeling [ONF-model], IETF: Radio Link Model [I-D.ahlbergccamp-microwave-radio-link]. The purpose of this effort is to reach consensus within the industry around one common approach, with respect to the use cases and requirements to be supported, the type and structure of the model and the resulting attributes to be included. This document describes the use cases and requirements agreed to be covered, the expected characteristics of the model and at the end includes an analysis of how the models in the two on-going initiatives fulfill these expectations and a recommendation on what can be reused and what gaps need to be filled by a new and evolved radio link model.

3. 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].

While [RFC2119] describes interpretations of these key words in terms of protocol specifications and implementations, they are used in this document to describe requirements for the YANG Data Model for Microwave Radio Link.

4. Approaches to manage and control radio link interfaces

This framework addresses the definition of an open and standardized interface for the radio link functionality in a microwave/millimeter wave node. The application of such an interface used for management and control of nodes and networks typically vary from one operator to another, in terms of the systems used and how they interact. A traditional solution is network management system, while an emerging one is SDN. SDN solutions can be used as part of the network management system, allowing for direct network programmability and automated configurability by means of a centralized SDN control and defining standardized interfaces to program the nodes.

4.1. Network Management Solutions

The classic network management solutions, with vendor specific domain management combined with cross domain functionality for service management and analytics, still dominates the market. These solutions are expected to evolve and benefit from an increased focus on standardization by simplifying multi-vendor management and remove the need for vendor/domain specific management.

4.2. Software Defined Networking

One of the main drivers for applying SDN from an operator perspective is simplification and automation of network provisioning as well as E2E network service management. The vision is to have a global view of the network conditions spanning across different vendors' equipment and multiple technologies.

If nodes from different vendors shall be managed by the same SDN controller via a node management interface (north bound interface, NBI), without the extra effort of introducing intermediate systems, all nodes must align their node management interfaces. Hence, an open and standardized node management interface are required in a multi-vendor environment. Such standardized interface enables a unified management and configuration of nodes from different vendors by a common set of applications.

On top of SDN applications to configure, manage and control the nodes and their associated transport interfaces including the L2 and L3 packet/Ethernet interfaces as well as the radio interfaces, there are also a large variety of other more advanced SDN applications that can be exploited and/or developed.

A potential flexible approach for the operators is to use SDN in a logical control way to manage the radio links by selecting a predefined operation mode. The operation mode is a set of logical metrics or parameters describing a complete radio link configuration, such as capacity, availability, priority and power consumption.

An example of an operation mode table is shown in Figure 3. Based on its operation policy (e.g., power consumption or traffic priority), the SDN controller selects one operation mode and translates that into the required configuration of the individual parameters for the radio link terminals and the associated carrier terminations.

ID	Description	Capacity	Availability	Priority	Power
1	High capacity	400 Mbps	99.9%	Low	High
2	High avail- ability	100 Mbps	99.999%	High	Low

Figure 3. Example of an operation mode table

An operation mode bundles together the values of a set of different parameters. How each operation mode maps into certain set of attributes is out of scope of this document. Effort on a standardizing operation mode is required to implement a smoothly operator environment.

5. Use Cases

The use cases described should be the basis for identification and definition of the parameters to be supported by a YANG Data model for management of radio links, applicable for centralized, unified, multi-vendor management.

Other product specific use cases, addressing e.g. installation, on-site trouble shooting and fault resolution, are outside the scope of this framework. If required, these use cases are expected to be supported by product specific extensions to the standardized model.

5.1. Configuration Management

Configuration of a radio link terminal, the constituent carrier terminations and when applicable the relationship to packet/Ethernet and TDM interfaces.

5.1.1. Understand the capabilities & limitations

Exchange of information between a manager and a device about the capabilities supported and specific limitations in the parameter values & enumerations that can be used.

Support for the XPIC (Cross Polarization Interference Cancellation) feature or not and the maximum modulation supported are two examples on information that could be exchanged.

5.1.2. Initial Configuration

Initial configuration of a radio link terminal, enough to establish L1 connectivity over the hop to an associated radio link terminal on a device at far end. It MAY also include configuration of the relationship between a radio link terminal and an associated traffic interface, e.g. an Ethernet interface, unless that is given by the equipment configuration.

Frequency, modulation, coding and output power are examples of parameters typically configured for a carrier termination and type of aggregation/bonding or protection configurations expected for a radio link terminal.

5.1.3. Radio link re-configuration & optimization

Re-configuration, update or optimization of an existing radio link terminal. Output power and modulation for a carrier termination and protection schemas and activation/de-activation of carriers in a radio link terminal are examples on parameters that can be re-configured and used for optimization of the performance of a network.

5.1.4. Radio link logical configuration

Radio link terminals comprising a group of carriers are widely used in microwave technology. There are several kinds of groups: aggregation/bonding, 1+1 protection/redundancy, etc. To avoid configuration on each carrier termination directly, a logical control provides flexible management by mapping a logical configuration to a set of physical attributes. This could also be applied in a hierarchical SDN environment where some domain controllers are located between the SDN controller and the radio link terminal.

5.2. Inventory

5.2.1. Retrieve logical inventory & configuration from device

Request from manager and response by device with information about radio interfaces, their constitution and configuration.

5.2.2. Retrieve physical/equipment inventory from device

Request from manager about physical and/or equipment inventory associated with the radio link terminals and carrier terminations.

5.3. Status & statistics

5.3.1. Actual status & performance of a radio link interface

Manager requests and device responds with information about actual status and statistics of configured radio link interfaces and their constituent parts.

5.4. Performance management

5.4.1. Configuration of historical measurements to be performed

Configuration of historical measurements to be performed on a radio link interface and/or its constituent parts is a subset of the configuration use case to be supported. See 5.1 above.

5.4.2. Collection of historical performance data

Collection of historical performance data in bulk by the manager is a general use case for a device and not specific to a radio link interface.

Collection of an individual counter for a specific interval is in same cases required as a complement to the retrieval in bulk as described above.

5.5. Fault Management

5.5.1. Configuration of alarm reporting

Configuration of alarm reporting associated specifically with radio interfaces, e.g. configuration of alarm severity, is a subset of the configuration use case to be supported. See 5.1 above.

5.5.2. Alarm management

Alarm synchronization, visualization & handling, and notifications & events are generic use cases for a device and not specific to a radio link interface and should be supported accordingly.

5.6. Troubleshooting and Root Cause Analysis

Information and actions required by a manager/operator to investigate and understand the underlying issue to a problem in the performance and/or functionality of a radio link terminal and the associated carrier terminations.

6. Requirements

For managing a microwave node including both the radio link and the packet functionality, a unified data model is desired to unify the modeling of the radio link interfaces and the packet interfaces using the same structure and the same modelling approach. If some part of model is generic for other technology usage, it should be clearly stated.

The purpose of the YANG Data Model is for management and control of the radio link interface(s) and the relationship/connectivity to other packet interfaces, typically to Ethernet interfaces, in a microwave node.

The capability of configuring and managing microwave nodes includes the following requirements for the modelling:

1) It MUST be possible to configure, manage and control a radio link terminal and the constituent carrier terminations.

   a) Frequency, channel bandwidth, modulation, coding and transmitter power are examples of parameters typically configured for a carrier termination.

   b) A radio link terminal MUST configure the associated carrier terminations and the type of aggregation/bonding or protection configurations expected for the radio link terminal.

   c) The capability, e.g. the maximum modulation supported, and the actual status/statistics, e.g. administrative status of the carriers, SHOULD also be supported by the data model.

   d) The definition of the features and parameters SHOULD be based on established microwave equipment and radio standards, such as ETSI EN 302 217 [EN 302 217-2] which specifies the essential parameters for microwave systems operating from 1.4GHz to 86GHz.

2) It MUST be possible to map different traffic types (e.g. TDM, Ethernet) to the transport capacity provided by a specific radio link terminal.

3) It MUST be possible to configure and collect historical measurements (for the use case described in section 5.4) to be performed on a radio link interface, e.g. minimum, maximum and average transmit power and receive level in dBm.

4) It MUST be possible to configure and retrieve alarms reporting associated with the radio interfaces, e.g. configuration of alarm severity, supported alarms like configuration fault, signal lost, modem fault, radio fault.

7. Gap Analysis on Models

The purpose of the gap analysis is to identify and recommend what existing and established models as well as draft models under definition to support the use cases and requirements specified in the previous chapters. It shall also make a recommendation on how the gaps not supported should be filled, including the need for development of new models and evolution of existing models and drafts.

For microwave radio link functionality work has been initiated (ONF: Microwave Modeling [ONF-model], IETF: Radio Link Model [I-D.ahlbergccamp-microwave-radio-link]. The analysis is expected to take these initiatives into consideration and make a recommendation on how to make use of them and how to complement them in order to fill the gaps identified.

For generic functionality, not specific for radio link, the ambition is to refer to existing or emerging models that could be applicable for all functional areas in a microwave node.

7.1. Microwave Radio Link Functionality

[ONF CIM] defines a CoreModel of the ONF Common Information Model. An information model describes the things in a domain in terms of objects, their properties (represented as attributes), and their relationships. The ONF information model is expressed in Unified Modeling Language (UML). The ONF CoreModel is independent of specific data plane technology. Data plane technology specific properties are acquired in a runtime solution via "filled in" cases of specification (LtpSpec etc). These can be used to augment the CoreModel to provide a data plane technology specific representation.

IETF Data Model defines an implementation and NETCONF-specific details. YANG is a data modeling language used to model the configuration and state data. It is well aligned with the structure of the Yang data models proposed for the different packet interfaces which are all based on [RFC7223]. Furthermore, several YANG data models have been proposed in the IETF for other transport technologies such as optical transport; e.g. [RFC7277], [I.D.zhang-ccamp-l1-topo-yang], [I.D.ietf-ospf-yang]. In light of this trend, the IETF data model is becoming a popular approach for modeling most packet transport technology interfaces and it is thereby well positioned to become an industry standard.

[RFC3444] explains the difference between Information Model(IM) and Data Models(DM). IM is to model managed objects at a conceptual level for designers and operators, DM is defined at a lower level and includes many details for implementers. In addition, the protocol-specific details are usually included in DM. Since conceptual models can be implemented in different ways, multiple DMs can be derived from a single IM. To ensure better interoperability, it is better to focus on DM directly.

[RFC7223] describes an interface management model, however it doesn't include technology specific information, e.g., for radio interface. [I-D.ahlberg-ccamp-microwave-radio-link] provides a model proposal for radio interfaces, which includes support for basic configuration, status and performance but lacks full support for alarm management and interface layering, i.e. the connectivity of the transported capacity (TDM & Ethernet) with other internal technology specific interfaces in a microwave node.

The recommendation is to use the structure of the IETF: Radio Link Model [I-D.ahlberg-ccamp-microwave-radio-link] as the starting point, since it is a data model providing the wanted alignment with [RFC7223]. For the definition of the detailed leafs/parameters, the recommendation is to use the IETF: Radio Link Model and the ONF: Microwave Modeling [ONF-model] as the basis and to define new ones to cover identified gaps. The parameters in those models have been defined by both operators and vendors within the industry and the implementations of the ONF Model have been tested in the Proof of Concept events in multi-vendor environments, showing the validity of the approach proposed in this framework document.

It is also recommended to add the required data nodes to describe the interface layering for the capacity provided by a radio link terminal and the associated Ethernet and TDM interfaces in a microwave node. The principles and data nodes for interface layering described in [RFC7223] should be used as a basis.

7.2. Generic Functionality

For generic functionality, not specific for radio link, the recommendation is to refer to existing RFCs or emerging drafts according to the table in figure 4 below. New Radio Link Model is used in the table for the cases where the functionality is recommended to be included in the new radio link model as described in chapter 7.1.

Generic Functionality	Recommendation
1.Fault Management	
Alarm Configuration	New Radio Link Model
Alarm notifications/ synchronization	[I-D.vallin-ccamp-alarm-module]
2.Performance Management	
Performance Configuration/ Activation	New Radio Link Model
Performance Collection	New Radio Link Model & XML files
3.Physical/Equipment Inventory	[I-D.ietf-netmod-entity]

Figure 4. Recommendation on how to support generic functionality

Microwave specific alarm configurations are recommended to be included in the new radio link model and could be based on what is supported in the IETF and ONF Radio Link Models. Alarm notifications and synchronization are general and is recommended to be supported by a generic model, such as [I-D.vallin-ccamp-alarm-module].

Activation of interval counters & thresholds could be a generic function but it is recommended to be supported by the new radio link specific model and can be based on both the ONF and IETF Microwave Radio Link models.

Collection of interval/historical counters is a generic function that needs to be supported in a node. File based collection via SFTP and collection via a Netconf/YANG interfaces are two possible options and the recommendation is to include support for the latter in the new radio link specific model. The ONF and IETF Microwave Radio Link models can be used as a basis also in this area.

Physical and/or equipment inventory associated with the radio link terminals and carrier terminations is recommended to be covered by a model generic for the complete node, e.g. [I-D.ietf-netmod-entity] and it is thereby outside the scope of the radio link specific model.

7.3. Summary

The conclusions and recommendations from the analysis can be summarized as follows:

1) A Microwave Radio Link YANG Data Model should be defined with a scope enough to support the use cases and requirements in chapter 5 and 6 of this document.

2) Use the structure in the IETF: Radio Link Model [I-D.ahlberg-ccamp-microwave-radio-link] as the starting point. It augments [RFC7223] and is thereby as required aligned with the structure of the models for management of the packet domain.

3) Use established microwave equipment and radio standards, such as [EN 302 217-2], and the IETF: Radio Link Model [I-D.ahlberg-ccamp-microwave-radio-link] and the ONF: Microwave Modeling [ONF-model] as the basis for the definition of the detailed leafs/parameters to support the specified use cases and requirements, and proposing new ones to cover identified gaps.

4) Add the required data nodes to describe the interface layering for the capacity provided by a radio link terminal and the associated Ethernet and TDM interfaces, using the principles and data nodes for interface layering described in [RFC7223] as a basis.

5) Include support for configuration of microwave specific alarms in the Microwave Radio Link model and rely on a generic model such as [I.D.vallin-ccamp-alarm-module] for notifications and alarm synchronization.

6) Use a generic model such as [I-D.ietf-netmod-entity] for physical/equipment inventory.

It is furthermore recommended that the Microwave Radio Link YANG Date Model should be validated by both operators and vendors as part of the process to make it stable and mature. During the Hackathon in IETF 99, a project "SDN Applications for microwave radio link via IETF YANG Data Model" successfully validated this framework and the YANG data model[I.D.ietf-ccamp-mw-yang]. The project also received the BEST OVERALL award from the Hackathon.

8. Security Considerations

Security issue concerning the access control to Management interfaces can be generally addressed by authentication techniques providing origin verification, integrity and confidentiality. In additon, management interfaces can be physically or logically isolated, by configuring them to be only accessible out-of-band, through a system that is physically or logically separated from the rest of the network infrastructure. In case where management interfaces are accessible in-band at the client device or within the microwave transport netork domain, filtering or firewalling techniques can be used to restrict unauthorized in-band traffic. Authentication techniques may be additionally used in all cases.

This framework describes the requirements and charactersitics of of a YANG Data Model for control and management of the radio link interfaces in a microwave node. It is supposed to be accessed via a management protocol with a secure transport layer, such as NETCONF [RFC6241].

9. IANA Considerations

This memo includes no request to IANA.

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A Yang Data Model for WSON Optical Networks

draft-ietf-ccamp-wson-yang-05.txt

Abstract

This document provides a YANG data model for the routing and wavelength assignment (RWA) TE topology in wavelength switched optical networks (WSONs).

Status of this Memo

Copyright Notice

Table of Contents

1. Introduction

This document provides a YANG data model for the routing and wavelength assignment (RWA) Traffic Engineering (TE) topology in wavelength switched optical networks (WSONs). The YANG model described in this document is a WSON technology-specific Yang model based on the information model developed in [RFC7446] and the two encoding documents [RFC7581] and [RFC7579] that developed protocol independent encodings based on [RFC7446]. This document augments the the generic TE topology draft [TE-TOPO].

What is not in scope of this document is both impairment-aware WSON and flex-grid.

2. YANG Model (Tree Structure)

```
module: ietf-wson-topology
  augment /nd:networks/nd:network/nd:network-types:
    +--rw wson-topology!
  augment /nd:networks/nd:network/nd:node/tet:te/tet:config/tet:te-node-
attributes/tet:connectivity-matrix:
    +--rw matrix-interface* [in-port-id]
       +--rw in-port-id     wson-interface-ref
       +--rw out-port-id?   wson-interface-ref
  augment /nd:networks/nd:network/nd:node/tet:te/tet:state/tet:te-node-
attributes/tet:connectivity-matrix:
    +--ro matrix-interface* [in-port-id]
       +--ro in-port-id     wson-interface-ref
       +--ro out-port-id?   wson-interface-ref
  augment /nd:networks/nd:network/lnk:link/tet:te/tet:config/tet:te-link-attribu
tes:
    +--rw channel-max?                    int32
    +--rw default-frequency?              decimal64
    +--rw channel-spacing?                decimal64
    +--rw wavelength-available-bitmap*   binary
  augment /nd:networks/nd:network/lnk:link/tet:te/tet:state/tet:te-link-attribut
es:
    +--ro channel-max?                    int32
    +--ro default-frequency?              decimal64
    +--ro channel-spacing?                decimal64
    +--ro wavelength-available-bitmap*   binary
  augment /nd:networks/nd:network/nd:node/tet:te/tet:config/tet:te-node-attribut
es:
    +--rw wson-node
    |  +--rw device-type?   devicetype
    |  +--rw dir?           directionality
    |  +--rw interfaces* [name]
    |     +--rw name           string
    |     +--rw port-number?   uint32
    |     +--rw input-port?    boolean
    |     +--rw output-port?   boolean
    |     +--rw description?   string
    +--rw resource-pool* [resource-pool-id]
       +--rw resource-pool-id    uint32
       +--rw pool-state?         boolean
       +--rw matrix-interface* [in-port-id]
          +--rw in-port-id     wson-interface-ref
          +--rw out-port-id?   wson-interface-ref
  augment /nd:networks/nd:network/nd:node/tet:te/tet:state/tet:te-node-attribute
s:
    +--ro wson-node
    |  +--ro device-type?   devicetype
    |  +--ro dir?           directionality
    |  +--ro interfaces* [name]
    |     +--ro name           string
```

```
    |     +--ro port-number?   uint32
    |     +--ro input-port?    boolean
    |     +--ro output-port?   boolean
    |     +--ro description?   string
    +--ro resource-pool* [resource-pool-id]
       +--ro resource-pool-id    uint32
       +--ro pool-state?         boolean
       +--ro matrix-interface* [in-port-id]
          +--ro in-port-id     wson-interface-ref
          +--ro out-port-id?   wson-interface-ref
```

3. WSON-RWA YANG Model

<CODE BEGINS> file "ietf-wson-topology@2017-02-21.yang"

```
module   ietf-wson-topology {
      yang-version 1.1;

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

      prefix "wson";

       import ietf-network {
          prefix "nd";
       }

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

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

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

   organization
         "IETF CCAMP Working Group";

   contact
         "Editor:   Young Lee  <leeyoung@huawei.com>";

   description
         "This module contains a collection of YANG definitions for
         RWA WSON.

         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 2017-02-21 {
         description
               "version 5.";

         reference
               "RFC XXX: A Yang Data Model for WSON Optical Networks ";
   }

   typedef wson-topology-id {
         type inet:uri;
         description
               "The WSON Topology ID";
   }

   typedef wson-node-id {
         type inet:ip-address;
         description
               "The WSON Node ID";
   }

   typedef devicetype {
         type enumeration {
               enum adm {
                     value 1;
```

```
                        description
                              "Device is ADM";
                  }

                  enum roadm {
                        value 2;
                        description
                              "Device is ROAMD/OXC";
                  }
            }
            description
                  "device type: fixed (ADM) or switched (ROADM/OXC)";
      }

      typedef directionality {
            type enumeration {
                  enum bidir {
                        value 0;
                        description
                              "bi-directional";
                  }
                  enum input {
                        value 1;
                        description
                              "input direction";
                  }
                  enum output {
                        value 2;
                        description
                              "output direction";
                  }
            }
            description
                  "The directionality of link set";
      }



      typedef wson-interface-ref {
            type leafref {
                path "/nd:networks/nd:network/nd:node/tet:te/tet:config"
                  + "/tet:te-node-attributes/wson:wson-node/"
                  + "wson:interfaces/wson:name";
            }
            description
                  "This type is used by data models that need to
                  reference WSON interface.";
      }
```

```
      grouping wson-topology-type {
            description "wson-topology type";
            container wson-topology {
                  presence "indicates a topology of wson";
                  description
                        "Container to identify wson topology type";
                  }
      }

      grouping wson-node-attributes {
            description "wson node attributes";
            container wson-node {
                  description "WSON node attrtibutes.";
                  leaf device-type {
                        type devicetype;
                        description
                              "device type: fixed (ADM) or switched
                              (ROADM/OXC)";
                  }
                  leaf dir {
                        type directionality;
                        description
                              "bi-directionality or input or output
                              of link set";
                  }
                  list interfaces {
                 key "name";
                unique "port-number"; // TODO Puerto y TP ID
                description "List of interfaces contained in the node";
                uses node-interface;
                  }
            }
      }

      grouping node-interface {
          description "node interface definition";
        leaf name {
           type string;
           description "Interface name";
        }
        leaf port-number {
           type uint32;
           description "Number of the port used by the interface";
        }
        leaf input-port {
           type boolean;
           description "Determines if the port is an input port";
        }
        leaf output-port {
```

```
           type boolean;
           description
           "Determines if the port is an output port";
        }
        leaf description {
           type string;
           description "Description of the interface";
        }
      }

      grouping available-wavelength {
            description "describe available wavelengths";
            leaf-list wavelength-available-bitmap {
                  type binary;
                  description
                        "array of bits (i.e., bitmap) that indicates
                        if a wavelength is available or not on each
                        channel.";
            }
      }

      grouping wson-link-attributes {
            description "Set of WSON link attributes";
                  leaf channel-max {
                        type int32;
                        description "Maximum Number of OCh channels available
by the node";
                  }
                  leaf default-frequency {
                        type decimal64 {
                              fraction-digits 5;
                        }
                        units THz;
                        default 193.1;
                        description "Default Central Frequency";
                  }
                  leaf channel-spacing {
                        type decimal64 {
                              fraction-digits 5;
                        }
                        units GHz;
                        description "This is fixed channel spacing for WSON,
e.g, 12.5, 25, 50, 100, ..";
                  }
      }

      grouping wson-connectivity-matrix {
            description "wson connectivity matrix";
            list matrix-interface {
```

```
                        key "in-port-id";

                        description
                              "matrix-interface describes input-ports
                              and out-ports around a connectivity
                              matrix";

                        leaf in-port-id {
                              type wson-interface-ref;
                              description
                                    "The reference to in-port";
                        }

                        leaf out-port-id {
                              type wson-interface-ref;
                              description
                                    "The reference to out-port";
                        }
            }
      }

      grouping resource-pool-attributes {
            description "resource pool describes regeneration or wave converter"
;
            list resource-pool {
                  key "resource-pool-id";
                  description
                        "The resource pool list";

                  leaf resource-pool-id {
                        type uint32;
                        description
                              "The resource pool ID";
                  }

                  leaf pool-state {
                        type boolean;
                        description
                              "TRUE is state UP; FALSE is state down";
                  }

                  uses wson-connectivity-matrix;
            }
      }

      augment "/nd:networks/nd:network/nd:network-types" {
            description "wson-topology augmented";
            uses wson-topology-type;
      }
```

```
      augment "/nd:networks/nd:network/nd:node/tet:te/tet:config"
                  +"/tet:te-node-attributes/tet:connectivity-matrix" {
            when "/nd:networks/nd:network/nd:network-types"
                  +"/wson-topology" {
                  description
                        "This augment is only valid for WSON connectivity
matrix.";
            }
          description "WSON connectivity matrix config augmentation";
            uses wson-connectivity-matrix;
      }

      augment "/nd:networks/nd:network/nd:node/tet:te/tet:state"
                  +"/tet:te-node-attributes/tet:connectivity-matrix" {
            when "/nd:networks/nd:network/nd:network-types"
                  +"/wson-topology" {
                  description
                        "This augment is only valid for WSON connectivity
matrix.";
          }
          description "WSON connectivity matrix state augmentation";
            uses wson-connectivity-matrix;
      }

      augment "/nd:networks/nd:network/lnk:link/tet:te/tet:config"
                  + "/tet:te-link-attributes"   {
        when "/nd:networks/nd:network/nd:network-types"
                  +"/wson-topology" {
                  description
                        "This augment is only valid for WSON.";
            }
            description "WSON Link augmentation.";

            uses wson-link-attributes;
            uses available-wavelength;
      }

      augment "/nd:networks/nd:network/lnk:link/tet:te/tet:state"
                  + "/tet:te-link-attributes"   {
        when "/nd:networks/nd:network/nd:network-types"
                  +"/wson-topology" {
                  description
                        "This augment is only valid for WSON.";
                  }
            description "WSON Link augmentation.";

            uses wson-link-attributes;
            uses available-wavelength;
```

```
      }

      augment "/nd:networks/nd:network/nd:node/tet:te/tet:config"
             + "/tet:te-node-attributes" {
            when "/nd:networks/nd:network/nd:network-types"
                  +"/wson-topology" {
                  description
                        "This augment is only valid for WSON.";
            }
            description "WSON Node augmentation.";

            uses wson-node-attributes;
            uses resource-pool-attributes;
      }

      augment "/nd:networks/nd:network/nd:node/tet:te/tet:state"
             + "/tet:te-node-attributes" {
        when "/nd:networks/nd:network/nd:network-types"
                  +"/wson-topology" {
                  description
                        "This augment is only valid for WSON.";
            }
            description "WSON Node augmentation.";

            uses wson-node-attributes;
            uses resource-pool-attributes;
      }

}
```

<CODE ENDS>

4. Security Considerations

TDB

5. IANA Considerations

TDB

6. Acknowledgments

This document was prepared using 2-Word-v2.0.template.dot.

7. References

7.1. Normative References

[TE-TOPO] X. Liu, et al., "YANG Data Model for TE Topologies", work in progress: draft-ietf-teas-yang-te-topo.

7.2. Informative References

[RFC7446] Y. Lee, G. Bernstein, D. Li, W. Imajuku, "Routing and Wavelength Assignment Information Model for Wavelength Switched Optical Networks", RFC 7446, Feburary 2015.

[RFC7579] G. Bernstein, Y. Lee, D. Li, W. Imajuku, "General Network Element Constraint Encoding for GMPLS Controlled Networks", RFC 7579, June 2015.

[RFC7581] G. Bernstein, Y. Lee, D. Li, W. Imajuku, "Routing and Wavelength Assignment Information Encoding for Wavelength Switched Optical Networks", RFC 7581, June 2015.

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Expires: May 12, 2018 November 12, 2017

A Yang Data Model for WSON Optical Networks

draft-ietf-ccamp-wson-yang-09.txt

Abstract

This document provides a YANG data model for the routing and wavelength assignment (RWA) TE topology in wavelength switched optical networks (WSONs).

Status of this Memo

The list of Internet-Draft Shadow Directories can be accessed at http://www.ietf.org/shadow.html

This Internet-Draft will expire on May 12, 2018.

Table of Contents

1. Introduction

This document provides a YANG data model for the routing and wavelength assignment (RWA) Traffic Engineering (TE) topology in wavelength switched optical networks (WSONs). The YANG model described in this document is a WSON technology-specific Yang model based on the information model developed in [RFC7446] and the two encoding documents [RFC7581] and [RFC7579] that developed protocol independent encodings based on [RFC7446]. This document augments the the generic TE topology draft [TE-TOPO].

What is not in scope of this document is both impairment-aware WSON and flex-grid.

This document defines two YANG models: ietf-wson-topology (Section 3) and ietf-te-wson-types (Section 4).

2. YANG Model (Tree Structure)

```
module: ietf-wson-topology
  augment /nd:networks/nd:network/nd:network-types/tet:te-topology:
    +--rw wson-topology!
  augment /nd:networks/nd:network/nd:node/tet:te/tet:te-node-
attributes/tet:connectivity-matrices/tet:connectivity-matrix:
    +--rw wavelength-availability-range?   te-wson-types:wavelength-range-type
  augment /nd:networks/nd:network/lnk:link/tet:te/tet:te-link-attributes:
    +--rw channel-num?                 int32
    +--rw first-channel-frequency?     decimal64
    +--rw channel-spacing?             decimal64
    +--rw available-wavelength-info* [priority]
       +--rw priority                         uint8
       +--rw wavelength-availability-range?   te-wson-types:wavelength-range-
type
  augment /nd:networks/nd:network/nd:node/tet:te/tet:te-node-attributes:
    +--rw wson-node
       +--rw node-type?   identityref
  augment /nd:networks/nd:network/nd:node/tet:te/tet:tunnel-termination-point:
    +--rw available-operational-mode*   te-wson-types:operational-mode
    +--rw operational-mode?             te-wson-types:operational-mode
```

3. IETF-WSON-Topology YANG Model

```
<CODE BEGINS> file "ietf-wson-topology@2017-10-09.yang"

module   ietf-wson-topology {
//TODO: FIXME
      //yang-version 1.1;

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

      prefix "wson";

       import ietf-network {
          prefix "nd";
       }

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

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

      import ietf-te-topology {
      prefix "tet";
      }
      import ietf-te-wson-types { //Modified
      prefix "te-wson-types";
      }

      //NOT NEEDED
      /*import ietf-transport-types {
      prefix "tran-types";
      } */

      organization
            "IETF CCAMP Working Group";

      contact
            "Editor:   Young Lee  <leeyoung@huawei.com>";

      description
            "This module contains a collection of YANG definitions
```

```
for
            RWA WSON.

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as
            authors of the code.  All rights reserved.

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or
            without modification, is permitted pursuant to, and
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            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 2017-10-09 {
            description
                  "version 8.";

            reference
                  "RFC XXX: A Yang Data Model for WSON Optical
Networks ";
      }

      typedef wson-topology-id {
            type inet:uri;
            description
                  "The WSON Topology ID";
      }

      grouping wson-topology-type {
            description "wson-topology type";
            container wson-topology {
                  presence "indicates a topology of wson";
                  description
                        "Container to identify wson topology type";
                  }
      }

      grouping wson-node-attributes {
            description "WSON node attributes";
            container wson-node {
                  description "WSON node attrtibutes.";
```

```
                  leaf node-type {
                        type identityref {
                        base te-wson-types:wson-node-type;
                        }
                        description "WSON node type.";
                  }
            }
      }

      grouping wson-wavelength-availability-range{
            description "wavelength availability range";

            leaf wavelength-availability-range{
                  type te-wson-types:wavelength-range-type;
                  description
                        "range that indicates if a wavelength is
                         available or not on each channel at
                         specified priority level.";
            }
      }
      grouping wson-link-attributes {
            description "WSON link attributes";
            leaf channel-num {
                 type int32;
                 description "Number of OCh channels available";
            }
            leaf first-channel-frequency {
                 type decimal64 {
                       fraction-digits 5;
                 }
                 units THz;
                 description "First channel frequency in the grid";
            }
            leaf channel-spacing {
                 type decimal64 {
                       fraction-digits 5;
                 }
                 units GHz;
                 description "This is fixed channel spacing for
WSON,
                 e.g, 12.5, 25, 50, 100, ..";
            }

            list available-wavelength-info{
                  key "priority";
```

```
                  max-elements "8";

                  description
                        "List of available wavelength channels on
this link";
                  leaf priority {
                        type uint8 {
                               range "0..7";
                        }
                        description "priority";
                  }
                  uses wson-wavelength-availability-range;
            }
      }
      grouping wson-tp-attributes {
            description "wson-tp-attributes";

            leaf client-facing {
                  type empty;
                  description
                        "if present, it means this tp is a client-
facing tp.
                         adding/dropping client signal flow.";
            }

/*
//can it be fully covered by interface-switching-capability of base
TE model?
            leaf-list supported-client-signals {
                  type identityref {
                        base tran-types:client-signal;
                  }
                  description
                        "Supported client signals at this TP";
            }
*/
      }

      grouping wson-ttp-attributes {
            description "WSON tunnel termination point (e.g.
tranponder)
            attributes";
            leaf-list available-operational-mode {
               type te-wson-types:operational-mode;
               description "List of all vendor-specific supported
```

```
              mode identifiers";
           }

           leaf operational-mode {
              type te-wson-types:operational-mode;
              description "Vendor-specific mode identifier";
           }
     }

   /* AUGMENTS */

      augment "/nd:networks/nd:network/nd:network-types"
           + "/tet:te-topology" {
              description "wson-topology augmented";
              uses wson-topology-type;
         }

         //FIXING NMDA
         augment "/nd:networks/nd:network/nd:node/tet:te"
                 +"/tet:te-node-attributes/tet:connectivity-matrices"
                 + "/tet:connectivity-matrix" {
              when "/nd:networks/nd:network/nd:network-types"
                    +"/tet:te-topology/wson:wson-topology" {
                    description
                          "This augment is only valid for WSON
   connectivity
   matrix.";
              }
            description "WSON connectivity matrix config
   augmentation";
              uses wson-wavelength-availability-range;
         }

         //REMOVING
         /*
         augment "/nd:networks/nd:network/nd:node/tet:te/tet:state"
                 +"/tet:te-node-attributes/tet:connectivity-matrices"
                 + "/tet:connectivity-matrix" {
              when "/nd:networks/nd:network/nd:network-types"
                    +"/tet:te-topology/wson-topology" {
                    description
                          "This augment is only valid for WSON
   connectivity
   matrix.";
             }
```

```
            description "WSON connectivity matrix state augmentation";
              uses wson-wavelength-availability-range;
        }*/

        //FIXING NMDA
        augment "/nd:networks/nd:network/lnk:link/tet:te"
                    + "/tet:te-link-attributes"   {
          when "/nd:networks/nd:network/nd:network-types"
                    +"/tet:te-topology/wson:wson-topology" {
                    description
                          "This augment is only valid for WSON.";
              }
              description "WSON Link augmentation.";

              uses wson-link-attributes;
        }

        //REMOVING
        /*
        augment "/nd:networks/nd:network/lnk:link/tet:te/tet:state"
                    + "/tet:te-link-attributes"   {
          when "/nd:networks/nd:network/nd:network-types"
                    +"/tet:te-topology/wson:wson-topology" {
                    description
                          "This augment is only valid for WSON.";
                    }
              description "WSON Link augmentation.";

              uses wson-link-attributes;
        }*/

        //FIXING NMDA
        augment "/nd:networks/nd:network/nd:node/tet:te"
                + "/tet:te-node-attributes" {
              when "/nd:networks/nd:network/nd:network-types"
                    +"/tet:te-topology/wson:wson-topology" {
                    description
                          "This augment is only valid for WSON.";
              }
              description "WSON Node augmentation.";

              uses wson-node-attributes;
        }

        //REMOVING
```

```
         /*
         augment "/nd:networks/nd:network/nd:node/tet:te/tet:state"
                 + "/tet:te-node-attributes" {
           when "/nd:networks/nd:network/nd:network-types"
                     +"/tet:te-topology/wson:wson-topology" {
                     description
                           "This augment is only valid for WSON.";
               }
               description "WSON Node augmentation.";

               uses wson-node-attributes;
         }*/

         //FIXING NMDA
         augment "/nd:networks/nd:network/nd:node/tet:te"
                 + "/tet:tunnel-termination-point" {
           when "/nd:networks/nd:network/nd:network-types"
                     +"/tet:te-topology/wson:wson-topology" {
                     description
                           "This augment is only valid for WSON.";
               }
               description "WSON tunnel termination point
   augmentation.";

               uses wson-ttp-attributes;
         }

         //removing
         /*augment "/nd:networks/nd:network/nd:node/tet:te"
                 + "/tet:tunnel-termination-point/tet:state" {
           when "/nd:networks/nd:network/nd:network-types"
                     +"/tet:te-topology/wson:wson-topology" {
                     description
                           "This augment is only valid for WSON.";
               }
               description "WSON tunnel termination point
   augmentation.";

               uses wson-ttp-attributes;
         }*/
   }
```

<CODE ENDS>

4. IETF-TE-WSON-Types YANG Model

```
<CODE BEGINS> file "ietf-te-wson-types@2017-10-09.yang"
   module ietf-te-wson-types {
        namespace "urn:ietf:params:xml:ns:yang:ietf-te-wson-types";
        prefix "te-wson-types";

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

            Editor: Aihua Guo
                    <mailto:aihuaguo@huawei.com>

            Editor: Young Lee
                    <mailto:leeyoung@huawei.com>";

        description
            "This module defines WSON types.";

        revision "2017-10-09" {
            description
                "Revision 0.1";
            reference "TBD";
        }

        typedef operational-mode {
           type string;
           description
             "Vendor-specific mode that guarantees interoperability.
              It must be an string with the following format:
              B-DScW-ytz(v) where all these attributes are conformant
              to the ITU-T recomendation";
             reference "ITU-T G.698.2 (11/2009) Section 5.3";
        }

        identity wson-node-type {
            description
```

```
                "WSON node type.";
        reference
                "";
    }

    identity wson-node-foadm {
        base wson-node-type;
        description
                "Fixed OADM node.";
    }

    identity wson-node-roadm {
        base wson-node-type;
        description
                "ROADM or OXC node.";
    }

    identity wson-node-ila {
        base wson-node-type;
        description
                "ILA (In-Line Amplifier) node.";
    }

   //ADDED
    typedef wavelength-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 WDM channel numbers (starting at 1)
             in ascending order. For example: 1,12-20,40,50-80";
    }

   identity wavelength-assignment {
       description "Wavelength selection base";
   }

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

```
       }

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

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

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


    }


<CODE ENDS>
```

5. Security Considerations

TDB

6. IANA Considerations

TDB

7. Acknowledgments

This document was prepared using 2-Word-v2.0.template.dot.

8. References

8.1. Normative References

[TE-TOPO] X. Liu, et al., "YANG Data Model for TE Topologies", work in progress: draft-ietf-teas-yang-te-topo.

8.2. Informative References

[RFC7446] Y. Lee, G. Bernstein, D. Li, W. Imajuku, "Routing and Wavelength Assignment Information Model for Wavelength Switched Optical Networks", RFC 7446, Feburary 2015.

[RFC7579] G. Bernstein, Y. Lee, D. Li, W. Imajuku, "General Network Element Constraint Encoding for GMPLS Controlled Networks", RFC 7579, June 2015.

[RFC7581] G. Bernstein, Y. Lee, D. Li, W. Imajuku, "Routing and Wavelength Assignment Information Encoding for Wavelength Switched Optical Networks", RFC 7581, June 2015.

9. Contributors

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Traffic Engineering Extensions to OSPF for GMPLS Control of Beyond-100G G.709 Optical Transport Networks

draft-izh-ccamp-b100g-routing-00

Abstract

This document describes Open Shortest Path First - Traffic Engineering (OSPF-TE) routing protocol extensions to support GMPLS control of Optical Transport Networks (OTNs) specified in ITU-T Recommendation G.709 published in 2016. The 2016 version of G.709 [ITU-T_G709_2016] introduces support for higher rate OTU signals, termed OTUCn (which have a nominal rate of 100n Gbps). The newly introduced OTUCn represent a very powerful extension to the OTN capabilities, and one which naturally scales to transport any newer clients with bit rates in excess of 100G, as they are introduced. This document extends the mechanisms defined in [RFC7138].

Status of This Memo

Table of Contents

1. Introduction

The current GMPLS routing extensions RFC [RFC7138] includes coverage for all the OTN capabilities that were defined in the 2012 version of G.709 [ITU-T_G709_2012]. The 2016 version of G.709 [ITU-T_G709_2016] introduces the following key extensions:

a. OTUCn signals with bandwidth larger than 100G (n*100G)

b. ODUCn signals with bandwidth larger than 100G.

c. ODUflex signals with bandwidth larger than 100G

d. mapping client signals with bandwidth larger than 100G into the corresponding ODUflex containers.

e. Tributary Slot Granularity of 5G

This document provides extensions required in GMPLS OSPF-TE for B100G OTN technology. For a short overview of OTN evolution and implications of B100G on GMPLS routing, please refer to [I-D.zih-ccamp-otn-b100g-fwk].

1.1. Terminology

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].

2. OSPF-TE Extensions

As discussed in [I-D.zih-ccamp-otn-b100g-fwk], OSPF-TE must be extended to advertise the termination, Switching and multiplexing Capabilities for ODUCn and OTUCn (Optical Transport Unit) links. These capabilities are carried in the Switching Capability specific information field of the Interface Switching Capability Descriptor (ISCD) using formats defined in this document.

3. TE-Link Representation

G.709 ODUCn/OTUCn links are represented as TE-Links in GMPLS Traffic Engineering Topology for supporting ODUj layer switching. These TE-Links can be modeled in multiple ways. Figure 1 below provides an illustration of one-hop OTUCn TE-Links.

```
+-------+                +-------+                +-------+
|  OTN  |                |  OTN  |                |  OTN  |
|Switch |<- OTUCn Link ->|Switch |<- OTUCn Link ->|Switch |
|   A   |                |   B   |                |   C   |
+-------+                +-------+                +-------+

        |<-- TE-Link -->|       |<-- TE-Link -->|
```

Figure 1: OTUCn TE-Links

4. ISCD Format Extensions

The ISCD describes the Switching Capability of an interface and is defined in [RFC4203]. This document resues the switching capability defined in [RFC7138] but introduces a new encoding type (to be assigned) as follows:

- o G.709-2106 ODUCn (Digital Section): One codepoint (applicable to all values of n) needs to be defined in the signaling extensions [TBD]. The same value is used for advertising fixed rate ODUs, as well as ODUflex signals supported by an ODUCn link. When the Switching Capability and Encoding fields are set to values as stated above, the Interface Switching Capability Descriptor MUST be interpreted as defined in [RFC7138].

The MAX LSP Bandwidth field is used according to [RFC4203], i.e., 0 <= MAX LSP Bandwidth <= rate (ODUCn). The bandwidth is expressed in bytes/second and the encoding MUST be in IEEE floating point format. The discrete rates for new ODUs introduced in G709-2016 are shown in Table 1.

ODU Type	ODU Bit Rate	IEEE encoding of bw (bytes/sec)
ODUflex for IMP mapped packet traffic	s x 239/238 x 5 156 250 kbit/s: s=2,8,5*n, n >= 1	TBD
ODUflex for FlexE aware transport	103 125 000 x 240/238 x n/20 kbit/s, where n is total number of available tributary slots among all PHYs which have been crunched and combined.	TBD

Note that this table doesn’t include ODUCn -- since it cannot be generated by mapping a non-OTN signal. An ODUCn is always formed by multiplexing multiple LO-ODUs.

Table 1: Types and rates of ODUs usable for client mappings

ISCD advertisement and processing rules are exactly as specified in [RFC7138].

4.1. Switching Capability Specific Information

The technology-specific part of the OTN-TDM ISCD may include a variable number of sub-TLVs called Bandwidth sub-TLVs. Each sub-TLV is encoded with the sub-TLV header as defined in [RFC7138]. The muxing hierarchy tree MUST be encoded as an order-independent list. In addition to the sub-TLVs of types 1 and 2 defined in [RFC7138], Section 4.1.1 introduces a new sub-TLV type 3 to advertise ODUCn Information.

The Switching Capability specific information (SCSI) for OTUCn links MUST include a Type 3 TLV at the beginning, followed by Type 1 and/or Type 2 sub-TLVs as defined in [RFC7138].

With respect to ODUflex, new Signal Types need to be defined for the new ODUflex signals introduced in Table 1:

- o 23 - ODUflex (IMP)
- o 24 - ODUflex (FlexE)

Each ODUflex signal MUST always be advertised in a separate Type 2 sub-TLV as per [RFC7138].

4.1.1. Switching Capability Specific Information for ODUCn containers

The format of the Bandwidth sub-TLV for ODUCn signals is depicted in the following figure:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       Type = 3 (Unres-ODUC, TBA) |            Length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Sig Type=ODUCn | N Value       |T|S| TSG | Res |    Priority   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2: Bandwidth Sub-TLV -- Type 3

The values of the fields in the Bandwidth sub-TLV shown in Figure 2 are explained below.

o Signal Type (8 bits): Indicates the ODU type being advertised. For this sub-TLV type, a new signal type needs to be defined for ODUCn signals. Rather than define a unique signal type for each value of the parameter ’n’, this draft proposes that we allocate a single signal type for the ODUCn signal family, and encode the value of 'n' as a separate field. The first row after Type and Lengh MUST be followed by ODUCn information as shown.

- N-Value (8 bits): Indicates the value of 'n' in ODUCn field. The value of this field is an integer in the range 1...256 as per [ITU-T_G709_2016].

- Flags (8 bits):

  * T Flag (bit 17): Indicates whether the advertised bandwidth can be terminated per [RFC7138]. Since an ODUCn MUST be advertised as non-switchable and terminated, the T field MUST be set to 1.

  * S Flag (bit 18): Indicates whether the advertised bandwidth can be switched. Since an ODUCn MUST be advertised as non-switchable and terminated, the S field MUST be set to 0.

- TSG (3 bits): Tributary Slot Granularity. Used for the advertisement of the supported tributary slot granularity. This document defines a new value for 5 Gbps time slots - which MUST be used when advertising OTUCn links. The values in the range 0-3 MUST be interpreted as defined in [RFC7138].

  * 0 - Ignored

  * 1 - 1.25 Gbps / 2.5 Gbps

  * 2 - 2.5 Gbps only

  * 3 - 1.25 Gbps only

  * 4 - 5.0 Gbps only [TBA by IANA]

  * 5-7 - Reserved

- Priority (8 bits): The meaning and usage of priority field MUST same as in [RFC7138].

5. Examples

The examples in the following pages are not normative and are not intended to imply or mandate any specific implementation.

5.1. MAX LSP Bandwidth Fields in the ISCD

This example shows how the MAX LSP Bandwidth fields of the ISCD are filled according to TE-Link bandwidth occupancy. In this example, an OTUC4 link is considered, with (a) supported priorities 0,2,4,7 (b) 300G of bandwidth already consumed (c) 100G bandwidth available, and able to support an ODU4 LSP.

At time T0, the advertisement would be as shown in Figure 3:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| SwCap=OTN_TDM | Encoding = TBA|    Reserved (all zeros)       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           MAX LSP Bandwidth at priority 0 = 100 Gpbs          +
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           MAX LSP Bandwidth at priority 1 = 0                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           MAX LSP Bandwidth at priority 2 = 100 Gpbs          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 3 = 0               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 4 = 100 Gbps        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 5 = 0               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 6 = 0               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 7 = 100 Gbps        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             Switching Capability Specific Information         |
|                        (variable length)                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3: MAX LSP Bandwidth Fields in the ISCD at T0

At time T1, an ODU3 at priority 2 is set up. Once the ODU3 is carried over the ODUC4, the unreserved bandwidth reduces to 60G and consequently MAX LSP Bandwidth is advertised as ODU3, since no more ODU4s are available and the next supported ODUj in the hierarchy is ODU3. The updated advertisement is as shown in Figure 4:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| SwCap=OTN_TDM | Encoding = TBA|    Reserved (all zeros)       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 0 = 100 Gbps        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 1 = 0               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 2 = 40 Gbps         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 3 = 0               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 4 = 40 Gbps         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 5 = 0               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 6 = 0               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 7 = 40 Gbps         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             Switching Capability Specific Information         |
|                        (variable length)                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4: MAX LSP Bandwidth Fields in the ISCD at T1

At time T2, an ODU2 at priority 4 is set up. The Max LSP bandwidth is still advertised as ODU3 as in Figure 4 since the remaining bandwidth is 50G. When the available BW drops below 40G, the max LSP BW is advertised as 10G. The advertisement is updated as shown in Figure 5:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| SwCap=OTN_TDM | Encoding =TBA |    Reserved (all zeros)       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 0 = 100 Gbps        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 1 = 0               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 2 = 40 Gbps         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 3 = 0               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 4 = 10 Gbps         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 5 = 0               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 6 = 0               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 7 = 10 Gbps         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             Switching Capability Specific Information         |
|                        (variable length)                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5: MAX LSP Bandwidth Fields in the ISCD at T2

5.2. Example of T, S, and TS Granularity Utilization

To be added later.

5.3. Example of ODUflex Advertisement

To be added later.

5.4. Example of Single-Stage Muxing

Suppose there is 1 OTUC4 link supporting single-stage muxing of ODU1, ODU2, ODU3, and ODUflex, the supported hierarchy can be summarized in a tree as in the following figure. For the sake of simplicity, we also assume that only priorities 0 and 3 are supported.

```
      ODU1 ODU2  ODU3 ODU4 ODUflex
         \   \    /   /    /
          \   \  /   /    /
           \   \/   /    /
               ODUC4
```

The related SCSIs are as follows:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|        Type = 3 (Unres-fix)   |           Length = 8          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Sig type=ODUCn | N-value=4    |1|0|  4  |0 0 0|0|0|0|0|0|0|0|0|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|        Type = 1 (Unres-fix)   |           Length = 12         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Sig type=ODU1  | #stages= 1   |X|X|X X X|0 0 0|1|0|0|1|0|0|0|0|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Stage#1=ODUCn |            Padding (all zeros)                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Unres ODU1 at Prio 0 =160   |    Unres ODU1 at Prio 3 =160  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|        Type = 1 (Unres-fix)   |           Length = 12         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Sig type=ODU2  | #stages= 1   |X|X|X X X|0 0 0|1|0|0|1|0|0|0|0|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Stage#1=ODUCn |            Padding (all zeros)                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Unres ODU2 at Prio 0 =40    |    Unres ODU2 at Prio 3 =40   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|        Type = 1 (Unres-fix)   |           Length = 12         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Sig type=ODU3  | #stages= 1   |X|X|X X X|0 0 0|1|0|0|1|0|0|0|0|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Stage#1=ODUCn |            Padding (all zeros)                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Unres ODU3 at Prio 0 =10     |    Unres ODU3 at Prio 3 =10  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type = 2 (Unres/MAX-var)   |           Length = 24         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Sig type=ODUCn | N-value=4    |1|0|  4  |0 0 0|0|0|0|0|0|0|0|0|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|S. type=ODUflex| #stages= 1   |X|X|X X X|0 0 0|1|0|0|1|0|0|0|0|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Stage#1=ODUCn|            Padding (all zeros)                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Unreserved Bandwidth at priority 0 =400 Gbps       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Unreserved Bandwidth at priority 3 =400 Gbps       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              MAX LSP Bandwidth at priority 0 =400 Gbps        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
   |              MAX LSP Bandwidth at priority 3 =400 Gbps        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 6: Single-Stage Muxing

5.5. Example of Multi-Stage Muxing -- Unbundled Link

Suppose there is 1 OTUC4 link with muxing capabilities as shown in the following figure:

```
          ODU2 ODU0    ODUflex ODU0
             \ /           \ /
              |             |
            ODU3          ODU2
               \           /
                \         /
                 \       /
                  \     /
                   ODUC4
```

The ODUC4 is not a switchable entity. It is advertised with zero counts to show TSG information. Considering only supported priorities 0 and 3, the advertisement is composed by the followingBandwidth sub-TLVs:

```
    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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |        Type = 3 (Unres-fix)   |           Length = 8          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Sig type=ODUCn | N-value=4    |1|0|4    |0 0 0|0|0|0|0|0|0|0|0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |        Type = 1 (Unres-fix)   |           Length = 12         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Sig type=ODU3  | #stages= 1   |X|X|  1  |0 0 0|1|0|0|1|0|0|0|0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Stage#1=ODUCn|         Padding (all zeros)                   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |   Unres ODU3 at Prio 0 =10    |    Unres ODU3 at Prio 3 =10   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |        Type = 1 (Unres-fix)   |           Length = 12         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Sig type=ODU2  | #stages= 1   |X|X|  1  |0 0 0|1|0|0|1|0|0|0|0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Stage#1=ODUCn |         Padding (all zeros)                   |
```

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Unres ODU2 at Prio 0 =40    |    Unres ODU2 at Prio 3 =40   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|        Type = 1 (Unres-fix)   |           Length = 12         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Sig type=ODU2  | #stages= 2   |X|X|  0  |0 0 0|1|0|0|1|0|0|0|0|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Stage#1=ODU3  | Stage#2=ODUCn |    Padding (all zeros)        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Unres ODU2 at Prio 0 =40    |    Unres ODU2 at Prio 3 =40   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|        Type = 1 (Unres-fix)   |           Length = 12         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Sig type=ODU0  | #stages= 2   |X|X|  0  |0 0 0|1|0|0|1|0|0|0|0|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Stage#1=ODU3  | Stage#2=ODUCn |    Padding (all zeros)        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Unres ODU0 at Prio 0 =320   |    Unres ODU0 at Prio 3 =320  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|        Type = 1 (Unres-fix)   |           Length = 12         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Sig type=ODU0  | #stages= 2   |X|X|  0  |0 0 0|1|0|0|1|0|0|0|0|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Stage#1=ODU2  | Stage#2=ODUCn |    Padding (all zeros)        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Unres ODU0 at Prio 0 =320   |    Unres ODU0 at Prio 3 =320  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type = 2 (Unres/MAX-var)   |           Length = 24         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|S.type=ODUflex | #stages= 2    |X|X|  0  |0 0 0|1|0|0|1|0|0|0|0|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Stage#1=ODU2  | Stage#2=ODUCn |    Padding (all zeros)        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Unreserved Bandwidth at priority 0 =400 Gbps       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Unreserved Bandwidth at priority 3 =400 Gbps       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            MAX LSP Bandwidth at priority 0 =10 Gbps           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            MAX LSP Bandwidth at priority 3 =10 Gbps           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 7: Multi-Stage Muxing -- Unbundled Link

6. Security Considerations

Please refer to [RFC5920] for details on security threats; defensive techniques; monitoring, detection, and reporting of security attacks; and requirements.

7. IANA Considerations

TBD

8. Contributors

9. Acknowledgements

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August 29, 2017

Traffic Engineering Extensions to OSPF for GMPLS Control of Beyond-100G G.709 Optical Transport Networks

draft-izh-ccamp-b100g-routing-01

Abstract

This document describes Open Shortest Path First - Traffic Engineering (OSPF-TE) routing protocol extensions to support GMPLS control of Optical Transport Networks (OTNs) specified in ITU-T Recommendation G.709 published in 2016. The 2016 version of G.709 [ITU-T_G709_2016] introduces support for higher rate OTU signals, termed OTUCn (which have a nominal rate of 100n Gbps). The newly introduced OTUCn represent a very powerful extension to the OTN capabilities, and one which naturally scales to transport any newer clients with bit rates in excess of 100G, as they are introduced. This document extends the mechanisms defined in [RFC7138].

Status of This Memo

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Table of Contents

1. Introduction

The current GMPLS routing extensions RFC [RFC7138] includes coverage for all the OTN capabilities that were defined in the 2012 version of G.709 [ITU-T_G709_2012]. The 2016 version of G.709 [ITU-T_G709_2016] introduces the following key extensions:

a. OTUCn signals with bandwidth larger than 100G (n*100G)

b. ODUCn signals with bandwidth larger than 100G.

c. ODUflex signals with bandwidth larger than 100G

d. mapping client signals with bandwidth larger than 100G into the corresponding ODUflex containers.

e. Tributary Slot Granularity of 5G

This document provides extensions required in GMPLS OSPF-TE for B100G OTN technology. For a short overview of OTN evolution and implications of B100G on GMPLS routing, please refer to [I-D.zih-ccamp-otn-b100g-fwk].

1.1. Terminology

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].

2. OSPF-TE Extensions

As discussed in [I-D.zih-ccamp-otn-b100g-fwk], OSPF-TE must be extended to advertise the termination, Switching and multiplexing Capabilities for ODUCn and OTUCn (Optical Transport Unit) links. These capabilities are carried in the Switching Capability specific information field of the Interface Switching Capability Descriptor (ISCD) using formats defined in this document.

3. TE-Link Representation

G.709 ODUCn/OTUCn links are represented as TE-Links in GMPLS Traffic Engineering Topology for supporting ODUj layer switching. These TE-Links can be modeled in multiple ways. Figure 1 below provides an illustration of one-hop OTUCn TE-Links.

```
        +-------+                +-------+                +-------+
        |  OTN  |                |  OTN  |                |  OTN  |
        |Switch |<- OTUCn Link ->|Switch |<- OTUCn Link ->|Switch |
        |   A   |                |   B   |                |   C   |
        +-------+                +-------+                +-------+

                |<-- TE-Link -->|       |<-- TE-Link -->|
```

Figure 1: OTUCn TE-Links

4. ISCD Format Extensions

The ISCD describes the Switching Capability of an interface and is defined in [RFC4203]. This document resues the switching capability defined in [RFC7138] but introduces a new encoding type (to be assigned) as follows:

- o G.709-2106 ODUCn (Digital Section): One codepoint (applicable to all values of n) needs to be defined in the signaling extensions [TBD]. The same value is used for advertising fixed rate ODUs, as well as ODUflex signals supported by an ODUCn link. When the Switching Capability and Encoding fields are set to values as stated above, the Interface Switching Capability Descriptor MUST be interpreted as defined in [RFC7138].

The MAX LSP Bandwidth field is used according to [RFC4203], i.e., 0 <= MAX LSP Bandwidth <= rate (ODUCn). The bandwidth is expressed in bytes/second and the encoding MUST be in IEEE floating point format. The discrete rates for new ODUs introduced in G709-2016 are shown in Table 1.

ODU Type	ODU Bit Rate	IEEE encoding of bw (bytes/sec)
ODUflex for IMP mapped packet traffic	s x 239/238 x 5 156 250 kbit/s: s=2,8,5*n, n >= 1	TBD
ODUflex for FlexE aware transport	103 125 000 x 240/238 x n/20 kbit/s, where n is total number of available tributary slots among all PHYs which have been crunched and combined.	TBD

Note that this table doesn’t include ODUCn -- since it cannot be generated by mapping a non-OTN signal. An ODUCn is always formed by multiplexing multiple LO-ODUs.

Table 1: Types and rates of ODUs usable for client mappings

ISCD advertisement and processing rules are exactly as specified in [RFC7138].

4.1. Switching Capability Specific Information

The technology-specific part of the OTN-TDM ISCD may include a variable number of sub-TLVs called Bandwidth sub-TLVs. Each sub-TLV is encoded with the sub-TLV header as defined in [RFC7138]. The muxing hierarchy tree MUST be encoded as an order-independent list. In addition to the sub-TLVs of types 1 and 2 defined in [RFC7138], Section 4.1.1 introduces a new sub-TLV type 3 to advertise ODUCn Information.

The Switching Capability specific information (SCSI) for OTUCn links MUST include a Type 3 TLV at the beginning, followed by Type 1 and/or Type 2 sub-TLVs as defined in [RFC7138].

With respect to ODUflex, new Signal Types need to be defined for the new ODUflex signals introduced in Table 1:

o 23 - ODUflex (IMP)

o 24 - ODUflex (FlexE)

Each ODUflex signal MUST always be advertised in a separate Type 2 sub-TLV as per [RFC7138].

4.1.1. Switching Capability Specific Information for ODUCn containers

The format of the Bandwidth sub-TLV for ODUCn signals is depicted in the following figure:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       Type = 3 (Unres-ODUC, TBA) |            Length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Sig Type=ODUCn | N Value       |T|S| TSG | Res |    Priority   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2: Bandwidth Sub-TLV -- Type 3

The values of the fields in the Bandwidth sub-TLV shown in Figure 2 are explained below.

o Signal Type (8 bits): Indicates the ODU type being advertised. For this sub-TLV type, a new signal type needs to be defined for ODUCn signals. Rather than define a unique signal type for each value of the parameter ’n’, this draft proposes that we allocate a single signal type for the ODUCn signal family, and encode the value of 'n' as a separate field. The first row after Type and Lengh MUST be followed by ODUCn information as shown.

- N-Value (8 bits): Indicates the value of 'n' in ODUCn field. The value of this field is an integer in the range 1...256 as per [ITU-T_G709_2016].

- Flags (8 bits):

  * T Flag (bit 17): Indicates whether the advertised bandwidth can be terminated per [RFC7138]. Since an ODUCn MUST be advertised as non-switchable and terminated, the T field MUST be set to 1.

  * S Flag (bit 18): Indicates whether the advertised bandwidth can be switched. Since an ODUCn MUST be advertised as non-switchable and terminated, the S field MUST be set to 0.

- TSG (3 bits): Tributary Slot Granularity. Used for the advertisement of the supported tributary slot granularity. This document defines a new value for 5 Gbps time slots - which MUST be used when advertising OTUCn links. The values in the range 0-3 MUST be interpreted as defined in [RFC7138].

  * 0 - Ignored

  * 1 - 1.25 Gbps / 2.5 Gbps

  * 2 - 2.5 Gbps only

  * 3 - 1.25 Gbps only

  * 4 - 5.0 Gbps only [TBA by IANA]

  * 5-7 - Reserved

- Priority (8 bits): The meaning and usage of priority field MUST same as in [RFC7138].

5. Examples

The examples in the following pages are not normative and are not intended to imply or mandate any specific implementation.

5.1. MAX LSP Bandwidth Fields in the ISCD

This example shows how the MAX LSP Bandwidth fields of the ISCD are filled according to TE-Link bandwidth occupancy. In this example, an OTUC4 link is considered, with (a) supported priorities 0,2,4,7 (b) 300G of bandwidth already consumed (c) 100G bandwidth available, and able to support an ODU4 LSP.

At time T0, the advertisement would be as shown in Figure 3:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| SwCap=OTN_TDM | Encoding = TBA|    Reserved (all zeros)       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           MAX LSP Bandwidth at priority 0 = 100 Gpbs          +
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           MAX LSP Bandwidth at priority 1 = 0                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           MAX LSP Bandwidth at priority 2 = 100 Gpbs          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 3 = 0               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 4 = 100 Gbps        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 5 = 0               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 6 = 0               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 7 = 100 Gbps        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             Switching Capability Specific Information         |
|                        (variable length)                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3: MAX LSP Bandwidth Fields in the ISCD at T0

At time T1, an ODU3 at priority 2 is set up. Once the ODU3 is carried over the ODUC4, the unreserved bandwidth reduces to 60G and consequently MAX LSP Bandwidth is advertised as ODU3, since no more ODU4s are available and the next supported ODUj in the hierarchy is ODU3. The updated advertisement is as shown in Figure 4:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| SwCap=OTN_TDM | Encoding = TBA|    Reserved (all zeros)       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 0 = 100 Gbps        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 1 = 0               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 2 = 40 Gbps         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 3 = 0               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 4 = 40 Gbps         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 5 = 0               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 6 = 0               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             MAX LSP Bandwidth at priority 7 = 40 Gbps         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             Switching Capability Specific Information         |
|                        (variable length)                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4: MAX LSP Bandwidth Fields in the ISCD at T1

At time T2, an ODU2 at priority 4 is set up. The Max LSP bandwidth is still advertised as ODU3 as in Figure 4 since the remaining bandwidth is 50G. When the available BW drops below 40G, the max LSP BW is advertised as 10G. The advertisement is updated as shown in Figure 5:

```
    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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | SwCap=OTN_TDM | Encoding =TBA |    Reserved (all zeros)       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |             MAX LSP Bandwidth at priority 0 = 100 Gbps        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |             MAX LSP Bandwidth at priority 1 = 0               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |             MAX LSP Bandwidth at priority 2 = 40 Gbps         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |             MAX LSP Bandwidth at priority 3 = 0               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |             MAX LSP Bandwidth at priority 4 = 10 Gbps         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |             MAX LSP Bandwidth at priority 5 = 0               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |             MAX LSP Bandwidth at priority 6 = 0               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |             MAX LSP Bandwidth at priority 7 = 10 Gbps         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |             Switching Capability Specific Information         |
   |                        (variable length)                      |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5: MAX LSP Bandwidth Fields in the ISCD at T2

5.2. Example of T, S, and TS Granularity Utilization

To be added later.

5.3. Example of ODUflex Advertisement

To be added later.

5.4. Example of Single-Stage Muxing

Suppose there is 1 OTUC4 link supporting single-stage muxing of ODU1, ODU2, ODU3, and ODUflex, the supported hierarchy can be summarized in a tree as in the following figure. For the sake of simplicity, we also assume that only priorities 0 and 3 are supported.

```
          ODU1 ODU2  ODU3 ODU4 ODUflex
             \   \    /   /    /
              \   \  /   /    /
               \   \/   /    /
                   ODUC4
```

The related SCSIs are as follows:

```
    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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |        Type = 3 (Unres-fix)   |          Length = 8           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Sig type=ODUCn | N-value=4    |1|0|  4  |0 0 0|0|0|0|0|0|0|0|0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |        Type = 1 (Unres-fix)   |          Length = 12          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Sig type=ODU1  | #stages= 1   |X|X|X X X|0 0 0|1|0|0|1|0|0|0|0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Stage#1=ODUCn |            Padding (all zeros)                |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |   Unres ODU1 at Prio 0 =160   |    Unres ODU1 at Prio 3 =160  |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |        Type = 1 (Unres-fix)   |          Length = 12          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Sig type=ODU2  | #stages= 1   |X|X|X X X|0 0 0|1|0|0|1|0|0|0|0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Stage#1=ODUCn |            Padding (all zeros)                |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |   Unres ODU2 at Prio 0 =40    |    Unres ODU2 at Prio 3 =40   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |        Type = 1 (Unres-fix)   |          Length = 12          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Sig type=ODU3  | #stages= 1   |X|X|X X X|0 0 0|1|0|0|1|0|0|0|0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Stage#1=ODUCn |            Padding (all zeros)                |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |   Unres ODU3 at Prio 0 =10     |    Unres ODU3 at Prio 3 =10  |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |    Type = 2 (Unres/MAX-var)   |          Length = 24          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Sig type=ODUCn | N-value=4    |1|0|  4  |0 0 0|0|0|0|0|0|0|0|0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |S. type=ODUflex| #stages= 1   |X|X|X X X|0 0 0|1|0|0|1|0|0|0|0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Stage#1=ODUCn|            Padding (all zeros)                |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |            Unreserved Bandwidth at priority 0 =400 Gbps       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |            Unreserved Bandwidth at priority 3 =400 Gbps       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |              MAX LSP Bandwidth at priority 0 =400 Gbps        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
   |              MAX LSP Bandwidth at priority 3 =400 Gbps        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 6: Single-Stage Muxing

5.5. Example of Multi-Stage Muxing -- Unbundled Link

Suppose there is 1 OTUC4 link with muxing capabilities as shown in the following figure:

```
          ODU2 ODU0    ODUflex ODU0
             \ /           \ /
              |             |
            ODU3          ODU2
               \          /
                \        /
                 \      /
                  \    /
                  ODUC4
```

The ODUC4 is not a switchable entity. It is advertised with zero counts to show TSG information. Considering only supported priorities 0 and 3, the advertisement is composed by the followingBandwidth sub-TLVs:

```
    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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |        Type = 3 (Unres-fix)   |           Length = 8          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Sig type=ODUCn | N-value=4    |1|0|4    |0 0 0|0|0|0|0|0|0|0|0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |        Type = 1 (Unres-fix)   |           Length = 12         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Sig type=ODU3  | #stages= 1   |X|X|  1  |0 0 0|1|0|0|1|0|0|0|0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Stage#1=ODUCn|         Padding (all zeros)                   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |   Unres ODU3 at Prio 0 =10    |    Unres ODU3 at Prio 3 =10   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |        Type = 1 (Unres-fix)   |           Length = 12         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Sig type=ODU2  | #stages= 1   |X|X|  1  |0 0 0|1|0|0|1|0|0|0|0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Stage#1=ODUCn |         Padding (all zeros)                   |
```

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Unres ODU2 at Prio 0 =40    |    Unres ODU2 at Prio 3 =40   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|        Type = 1 (Unres-fix)   |           Length = 12         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Sig type=ODU2  | #stages= 2   |X|X|  0  |0 0 0|1|0|0|1|0|0|0|0|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Stage#1=ODU3  | Stage#2=ODUCn |    Padding (all zeros)        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Unres ODU2 at Prio 0 =40    |    Unres ODU2 at Prio 3 =40   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|        Type = 1 (Unres-fix)   |           Length = 12         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Sig type=ODU0  | #stages= 2   |X|X|  0  |0 0 0|1|0|0|1|0|0|0|0|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Stage#1=ODU3  | Stage#2=ODUCn |    Padding (all zeros)        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Unres ODU0 at Prio 0 =320   |    Unres ODU0 at Prio 3 =320  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|        Type = 1 (Unres-fix)   |           Length = 12         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Sig type=ODU0  | #stages= 2   |X|X|  0  |0 0 0|1|0|0|1|0|0|0|0|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Stage#1=ODU2  | Stage#2=ODUCn |    Padding (all zeros)        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Unres ODU0 at Prio 0 =320   |    Unres ODU0 at Prio 3 =320  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type = 2 (Unres/MAX-var)   |           Length = 24         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|S.type=ODUflex | #stages= 2    |X|X|  0  |0 0 0|1|0|0|1|0|0|0|0|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Stage#1=ODU2  | Stage#2=ODUCn |    Padding (all zeros)        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Unreserved Bandwidth at priority 0 =400 Gbps       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Unreserved Bandwidth at priority 3 =400 Gbps       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            MAX LSP Bandwidth at priority 0 =10 Gbps           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            MAX LSP Bandwidth at priority 3 =10 Gbps           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 7: Multi-Stage Muxing -- Unbundled Link

6. Security Considerations

Please refer to [RFC5920] for details on security threats; defensive techniques; monitoring, detection, and reporting of security attacks; and requirements.

7. IANA Considerations

TBD

8. Contributors

9. Acknowledgements

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GMPLS Routing and Signaling Framework for Flexible Ethernet (FlexE)

draft-izh-ccamp-flexe-fwk-02

Abstract

This document specifies GMPLS Control Plane Signalling and Routing protocol extensions for Flexible Ethernet (FlexE). The FlexE data plane were specified by Optical Internetworking Forum (OIF) in two implementation agreements in 2016.

As different from earlier Ethernet data planes FlexE allows for decoupling of the Ethernet Physical layer (PHY) and Media Access Control layer (MAC) rates.

This document also specifies the use cases of FlexE technology, GMPLS control plane requirements, framework and architecture.

Status of This Memo

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Table of Contents

1. Introduction

Traditionally, Ethernet MAC rates were constrained to match the rates of the Ethernet PHY(s). OIF's implementation agreement [OIFMLG3] was the first step in allowing MAC rates to be different than the PHY rates standardized by IEEE. A recently approved implementation agreement [OIFFLEXE1] allows for complete decoupling of the MAC data rates and the Ethernet PHY(s).

This includes support for

a. MAC rates which are greater than the rate of a single PHY (multiple PHYs) are bonded to achive this

b. MAC rates which are less than the rate of a PHY (sub-rate)

c. support of multiple FlexE CLients carried over a single PHY, or over a collection of bonded PHY).

The capabilities supported by the FlexE implementation agreement version 1.0 are:

a. Support a large rate Ethernet MAC over bonded Ethernet PHYs, e.g. supporting a 200G MAC over 2 bonded 100GBASE-R PHY(s)

b. Support a sub-rate Ethernet MAC over a single Ethernet PHY, e.g. supportnig a 50G MAC over a 100GBASE-R PHY

c. Support a collection of flexible Ethernet clients over a single Ethernet PHY, e.g. supporting two MACs with the rates 25G, 50G over a single 100GBASE-R PHY

d. Support a sub-rate Ethernet MAC over bonded PHYs, e.g. supporting a 150G Ethernet client over 2 bonded 100GBASE-R PHY(s)

e. Support a collection of Ethernet MAC clients over bonded Ethernet PHYs, e.g. supporting a 50G, and 150G MAC over 2 bonded Ethernet PHY(s)

All networks which support the bonding of Ehernet interfaces (as per [OIFFLEXE1]) include a basic building block -- which consists of two FlexE Shim functions (located at opposite ends of a link) and the (logical) point to point links that carry the Ethernet PHY signals between the two FlexE Shim Functions. These logical point-to-point PHY links can be realized in a variety of ways:

a. These are direct point-to-point links with no intervening transport network.

b. The Ethernet PHY(s) are transparently transported via an Optical Transport Network. Optical Transport Networks (defined by [G.709] and [G798]) have recently expanded the traditional bit (or codeword) transparent transport of Ethernet client signals, and included support for the usecases identified in the OIF FlexE implementation agreement.

c. Realized by tunneling the Ethernet PHY(s) over some other type of network (e.g. IP/MPLS). Thus, for example, the Ethernet PHY(s) signals could be carried over a pseudowire (or a LSP)in the IP/MPLS network. Note that the OIF implementation agreement [OIFFLEXE1] only includes support for 100G Ethernet PHY(s). As a result of this encapsulation into a PW, the bandwidth of the PW will be much larger than the bit rate of the Ethernet PHY (i.e. 100G), and such a pseudowire cannot be transported in networks that only include 100G Ethernet links. This scenario is realizable when (a) higher rate Ethernet PHY(s), e.g. 200G/40G are supported) or (b) OIF extends the FlexE groups to include lower rate Ethernet PHY(s), e.g. at the 25G/50G rate. Further study is needed to ensure that these scenarios are realizable, practical, and beneficial to operators. With this in mind, the current draft doesn’t include any coverage for this scenario.

This Internet-draft examines the usescases that arise when the logical links between FlexE capable devices are (a) point-to-point links without any intervening network (b) realized via Optical transport networks. This draft considers the variants in which fhe two peer FlexE devices are both customer-edge devices, or customer-edge/provider edge devices. This list of usecases will help identify the Control Plane (i.e. Routing and Signaling) extensions that may be required.

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. Terminology

a. CE (Customer Edge) - the group of functions that support the termination/orignation of data received from or sent to the network,

b. Crunching: (Editors note: text to be submitted>)

c. Ethernet PHY: an entity representing 100G-R Physical Coding Sublayer (PCS), Physical Media Attachment (PMA), and Physical Media Dependent (PMD) layers.

d. FlexE Calendar: The total capacity of a FlexE group is represented as a collection of slots which have a granularty of 5G. The calendar for a FlexE group composed of n 100G PHYs is represented as an array of 20n slots (each representing 5G of bandwidth). This calendar is partitioned into sub-calendars, with 20 slots per 100G PHY. Each FlexE client is mapped into one or more calendar slots (based on the bandwidth of the FlexE client).

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

f. FlexE Group: A FlexE Group is composed of from 1 to n Ethernet PHYs. In the first version of FlexE each PHY is identified by a number in the range [1-254].

g. FlexE Interface: A logic interface that is composed of from 1 to n Ethernet interfaces.

h. FlexE Link: A logic link that connects two FexE interfaces residing in two adjacent nodes.

i. FlexE Shim: the layer that maps or demaps the FlexE clients carried over a FlexE group.

j. FlexE Sub-Interface: A channelized logic sub-interface that is allocated specific slots from a FlexE interface, the number of slots depends on the rate of the FlexE Client that will be transmitted through this sub-interface.

k. FlexE Sub-Link: A logic link that connects two FlexE sub-interfaces that residing in two adjacent nodes.

3. Usecases

3.1. FlexE Unware transport

The FlexE Shim layer in a router maps the FlexE client(s) over the FlexE group. The transport network is unware of the FlexE. Each of the FlexE group PHY is carried independently across the transport network over the same fiber route. The FlexE Shim in the router tolerates end-to-end skew across the network. In this usecase, the router makes flexible use of the full capacity of the FlexE group, and depends on legacy transport equipment to realize PCS-codeword-transparent transport of 100GbE. It allows striping of PHYs in the FlexE group over multiple line cards in the transport equipment. It is worth mentioning that in this case, the FlexE Shim layer is terminated at the routers, and the coordination of operations related to FlexE clients, e.g. creating new FlexE clients, deleting existing FlexE clients, and resizing the bandwidth of existing FlexE clients (if desired) happens between the two routers. Note that the transport network is completely transparent to the FlexE signals, and doesn’t participate in any FlexE protocols.

```
    ===================================================================

       +                           FlexE Ethernet Client(s)        +
       +-----------------------------------------------------------+
       +                                                           +
                        +  FlexE skew tolerance                  +
                        +----------------------------------------+
                        +  for end-to-distance                   +

   +-----------+ 2x100GE +---------+   +----------+     +------------+
   |           |         |         |   |          |     |            |
   | Router1   |         |         |   |          |     |            |
   |FlexE Shim +---------+ A-end   |   |  Z-end   +-----+Router 2    |
   |           |         | (FlexE  |   |  (FlexE  |     |(FlexE Shim)|
   |           +---^-----+ unaware)|   |  unaware)+-----+            |
   |           |   |     |         |   |          |     |            |
   |           |   |     |         |   |          |     |            |
   +-----------+   +     +---------+   +----------+     +------------+
                    FlexE Group

                        \----------Transport----------/
                                   network
   +--------------+                                  +----------------+
   | FlexE Clients|                                  | FlexE Client(s)|
   +--------------+                                  +----------------+
   | FlexE Shim   |                                  |  FlexE Shim    |
   +----+----+----+                                  +----+------+----+
   |PHY |  |  PHY |                                  |  PHY |   | PHY |
   +---+---+--+---+                                  +---+--+   +--+--+
       |      |          +-----+           +-----+       |         |
       |      +----------+ PHY |           | PHY |-------+         |
       |                 +-----+           +-----+                 |
       |                 | ODU4+-----------+ ODU4|                 |
       |                 +-----+           +-----+                 |
       |                                                           |
       |                 +-----+           +-----+                 |
       +-----------------+ PHY |           | PHY +-----------------+
                         +-----+           +-----+
                         | ODU4+-----------+ ODU4|
                         +-----+           +-----+

    ===================================================================
```

Figure 1: FlexE unaware transport

3.2. FlexE Aware transport

This scenario represents an optimization of the FlexE unaware transport presented in Section 3.1, and illustrated in Figure 1. In this application (see Figure 2), the devices at the edge of the transport network do not terminate the FlexE shim layer, but are aware of the (a) composition of the FlexE group (i.e. set of all contained Ethernet PHYs) and (b) format of the FlexE overhead. At the ingress to the transport network, the transport network edge removes the unavailable calendar slots, and retains all available calendar slots (whether they are allocated or not). At the egress point of the transport network, the edge device adds the unavailable calendar slots back. The result is that the FlexE Shim layers at both routers see exactly the same input that they saw in the FlexE unware scenario -- with the added benefit that the line (or DWDM) side bandwidth has been optimized to be sufficient to carry only the available calendar slots in all of the Ethernet PHY(s) in the FlexE group.

The transport network edge device could learn of the set of unavailable calendar slots in a variety of ways; a few examples are listed below:

a. In this scenario, the transport network edge does not expect the number of unavailable calendar slots to change dynamically. The set of unavailable calendar slots is configured against each Ethernet PHY in the FlexE group. The FlexE demux function in the transport network edge device (A) compares the information about calendar slots which are expected to be unavailable (as per user supplied configuration), with the corresponding information encoded by the customer edge device in the FlexE overhead (as specified in [OIFFLEXE1]). If there is a mismatch between the unavailable calendar slots in any of the PHYs within a FlexE group, the transport edge node software could raise an alarm to report the inconsistency between the provisioning information at the transport network edge, and the customer edge device.

b. The Transport network edge is configured to act in a "slave" mode. In this mode, the FlexE demux function at the Transport network edge (A) receives the information about the available/ unavailable calendar slots by observing the FlexE overhead (as specified in [OIFFLEXE1]) and uses this information to calculate the bandwidth of the ODUflex (or fixed rate ODUs) connection that could carry the FlexE PCS end-to-end. This scenario allows for the set of available/unavailable calendar slots to change (slowly) with time -- but comes with the complexity of resizing the ODUflex connection in response to changes in the number of available calendar slots.

Note that the process of removing unavailable calendar slots from a FlexE PHY is called "crunching" (see [OIFFLEXE1]). The following additional notes apply to Figure 2:

a. As in the FlexE unaware case, all PHYs of the FlexE group MUST be terminated between the same two FlexE shims.

b. The crunched FlexE PHYs are independently transported through the transport network. The number of used (and unused) calendar slots can be different across the FlexE group. In particular, if all the calendar slots in a FlexE PHY are in use, the crunching operation leaves the original signal intact.

c. In this illustration, the different FlexE PHY(s) are transported using ODUflex containers in the transport network. These ODUflex connections can be of different rates.

d. In the most general form, G.709 Section 17.12 [G.709] allows for a FlexE group consisting of m Ethernet PHY(s) to be crunched, combined, and transported using n ODUFlex containers (where n can range between 1 and m). In other words, the ITU G.709 recommendation allows for (but not require the support for) the degenerate cases in which (a) each Ethernet PHY within the group is transported using its own ODUflex, and (b) all the PHY(s) are crunched, combined and transported over a single ODUflex container. If all the sub-calendar slots in a given PHY are available, it is possible to transport the content of the PHY in one of two ways: (a) as shown in Figure 2, or (b) using a FlexE unware (i.e. PCS-codeword transparent transport) mode. The latter approach (of using FlexE unaware transport) for a few select (fully-utilized) PHYs is not attractive from the perspective of skew between the PHYs that comprise the FlexE group. For simplicity, the preferred mode of operation will be one in which the same mapping procedure is used for member PHYs of a FlexE group.

e. When the crunched FlexE PHY(s) have a rate that is identical to that of a standard Ethernet PHY, it is possible that the transport network may utilize standard ODU containers such as ODU2e, ODU4 etc. As currently defined by ITU G.709 Section 17.12 [G.709], the crunched signal is always mapped to an ODUflex, and the mapping to a fixed rate ODU signal is not required. This option could be dropped if it results in any significant simplification.

f. The bandwidth of the ODUFlex connections shall be computed based on the total number of available 5G calendar slots which in the subset of PHY(s) which are transported over this ODUflex entity (see Section 3.2, G.709:Table 7-2 [G.709]).

g. As in the FlexE unaware case, the FlexE Shim layer is terminated at the routers, and the coordination of operations related to FlexE clients, e.g. creating new FlexE clients, deleting existing FlexE clients, and resizing the bandwidth of existing FlexE clients (if desired) happens between the two routers. Note that the transport network is completely transparent to the FlexE signals, and doesn’t participate in any FlexE protocols. As long as the set of available (and unavailable) calendar slots on the PHY(s) does not change after the initial setup, the transport network is not required to make any changes to the number/rates of ODUflex connections which were created at service setup time.

h. In the FlexE aware case, the OTN pipes are sized to match the currently configured set of available/unavailable calendar slots across the FlexE group. If this set of available/unavailable calendar slots on the PHY(s) is allowed to dynamically change, the ODUflex connections would also require resizing to match the new usage of available slots. However, the ODUflex hitless resizing mechanism defined in G.7044 [G7044] has the following restrictions: (a) ODUflex connection being resized must have bandwidth of 100G or less (b) the ODUflex connection cannot traverse OTUCn links which were introduced in the latest revision of G.709. With the present limitations in the ODUflex resizing mechanism, the dynamic adjustent of ODUflex bandwidth (for the FlexE aware case) is possible only if (a) the transport network edge maps each crunched PHY to its own ODUflex connection (b) the Ethernet PHY rates are 100G or less (c) the ODUflex connection does not traverse any OTUCn links along the end-to-end path. As a result, this scenario is not considered in this document.

[[N1: The figure may need further editing to accurately depict the signal hierarchy. --RV]]

==

```
                     FlexE Ethernet Client(s)
     +------------------------------------------------------+
                 FlexE skew tolerance
         +----------------------------------------------+
                  for end+to+distance

   +--------+ 2 x 100GE +---------+      +---------+    +------+
   |  R1    |           |         |      |         +----+  R2  |
   |  (FlexE+-----------+  NE A   |      |  NE Z   |    |(FlexE|
   |  Shim) |           | (FlexE  |      | (FlexE  +----+ Shim |
   |        +-----^-----+ aware)  |      | aware)  |    |      |
   |        |     |     |         |      |         |    |      |
   +--------+     +     +---------+      +---------+    +------+
                        FlexE Group
                        \+------+Transport+-------+/
                                  network
   +-------------+                               +-------------+
   |FlexE clients|                               |FlexE clients|
   +-------------+                               +-------------+
   | FlexE Shim  |                               | FlexE Shim  |
   +-------------+                               +-------------+
   |  PHY |  PHY |                               |  PHY |  PHY |
   +-------------+                               +-------------+
    |      |                                          |      |
    |      |  +-------------+       +------------+  |      |
    |      |  |  FlexE-psg  |       | FlexE-psg  |  |      |
    |      |  +-------------+       +------------+  |      |
    |      +--+ PHY|ODUflex +--------|ODUFlex|PHY +--+      |
    |         +-------------+       +------------+         |
    |                                                      |
    |         +-------------+       +------------+         |
    |         |  FlexE-psg  |       | FlexE-psg  |         |
    |         +-------------+       +------------+         |
    +---------+ PHY|ODUflex +--------|ODUFlex|PHY +---------+
              +-------------+       +------------+

        + Legend:
        | R1, R2 + Routers (supporting the FlexE clients)
        | NE A, Z  + Transport Network Edge nodes
        + FlexE-psg: FlexE partial rate (sub) group signal
                        (per G.709:17.12)

   ===============================================================
```

Figure 2: FlexE Aware Transport

3.3. FlexE Termination in Transport

These usecases build upon the basic router-transport equipment connectivity illustrated in Figure 1. The FlexE shim layer at the router maps to the set of FlexE clients over the FlexE group, as usual. This section considers various usecases in which the equipment located at the edge of the transport network instantiates the FlexE Shim function which peers with the FlexE shim on the customer device. In the router to network direction, the transport edge node terminates the FlexE shim layer, and extracts one or more FlexE client signals, and transports them through the network. That is, these usecases are distinguished from the FlexE unaware cases in that the FlexE group, and the FlexE shim layer end at the transport network edge, and only the extracted FlexE client signals transit the optical network. In the network to router direction, the transport edge node maps a set of FlexE clients to the FlexE group (i.e. performing the same functions as the router which connects to the transport network).The various usecases differ in the combination of service endpoints in the transport network. In the FlexE termination scenarios, the distance between the FlexE Shims is limited the normal Ethernet link distance. The FlexE shims in the router, and the equipment need to support a small amount skew.

3.3.1. FlexE Client at Both endpoints

In this scenario, service consists of transporting a FlexE client through the transport network, and possibly combining this FlexE client with other FlexE clients into a FlexE group at the endpoints. The FlexE client signal BMP mapped into an ODUflex (of the appropriate rate) and then switched across the OTN. Figure 3 illustrates the scenario involving the mapping of a FlexE client to an ODUflex envelope; this figure only shows the signal "stack" at the service endpoints, and doesn’t illustrate the switching of the ODUflex entity through the OTN. The ODUflex signal then carried over a sequence of OTUk links (with a maximum rate of 100G), and/or OTUCn (with rates of n X 100G). Although Figure 3 illustrates the scenario in which one FlexE client is transported within the OTN, the following points should be noted:

a. When the FlexE Shim termination function recovers multiple FlexE client signals (at node A), the FlexE signals can be transported independently. In other words, it is not a requirement that all the FlexE client signals be co-routed.

b. Conversely, at the egress node, FlexE clients from different endpoints can be combined via the FlexE shim, eventually exiting the transport edge node over an Ethernet group.

c. The description presented above(implicitly) assumes that the FlexE Client signals have a constant bit rate which does not change after the service setup. In the scenarios in which the FlexE Client Signal rates are permitted to be dynamically adjusted (i.e. resized), the resizing process would require coordination across three resizing domains: (a) between Router1, Node A (b) Resizing the ODUflex connection between the transport edge nodes A, Z (c) between the Node Z, Router2. This usecase is not considered in this document since G.709 [G.709] has dropped support for the the hitless resizing of ODUflex connections with bandwidths larger than 100G. In the absence of a hitless B100G ODUflex resizing mechanism, this will have to be realized by treating it like a request for new service with a new (increased or decreased) rate. The FlexE client bandwidth resize applicability for various use cases is summarized in Table 1.

```
==================================================================


+--------+ 2 x 100GE +---------+       +----------+      +--------+
|        |           |         |       |          |      |        |
| Router1|           |         |       |          |      |        |
| FlexE  +-----------+ A-end   |       |  Z-end   +------+Router2 |
| Shim   |           | (FlexE  |       |  (FlexE  |      |FlexE   |
|        +-----^-----+  term)          |  term)   +------+ Shim   |
|        |     |     |         |       |          |      |        |
|        |     |     |         |       |          |      |        |
+--------+     +     +---------+       +----------+      +--------+
          FlexE Group
                     \+--------+Transport+--------+/
                                network

+-----------+   +--------------+    +-------------+   +-----------+
| Client(s) |   | Client       |    | Client      |   | Client(s) |
+-----------+   +--------+-----+    +------+------+   +-----------+
| FlexE Shim|   | Shim   |     |    |      | Shim |   | FlexE Shim|
+-----------+   +--------+ ODU |    | ODU  +------+   +-----------+
| PHY(s)    |   | PHY(s) | flex|    | flex |PHY(s)|   | PHY(s)    |
+---+-------+   +---+----+--+--+    +---+--+---+--+   +---+-------+
|               |           |           |      |          |
+---------------+           +-----------+------+----------+


 =================================================================
```

Figure 3: FlexE termination: FlexE clients at both endpoints

3.3.2. Interworking of FlexE Client w/ Native Client at the other endpoint

The OIF implementation agreement [OIFFLEXE1] currently supports FlexE client signals carried over one or more 100GBASE-R PHY(s). There is a calendar of 5G timeslots associated with each PHY, and each FlexE client can make use of a number of timeslots (possibly distributed across the members of the FlexE group). This implies that the FlexE client rates are multiples of 5Gbps. When the rates of the FlexE client signals matches the MAC rates corresponding to existing Ethernet PHYs, i.e. 10GBASE-R/40GBASE-R/100GBASE-R, there is a need for the FlexE client signal to interwork with the native Ethernet client received from a single (non-FlexE capable) Ethernet PHY. This capability is expected to be extended to any future Ethernet PHY rates that the IEEE may define in future (e.g. 25G, 50G, 200G etc.). In these cases, although the bit rate of the FlexE client matches the MAC rate of other endpoint, the 64B66B PCS codewords for the FlexE client need to be transformed (via ordered set translation) to match the specification for the specific Ethernt PHY. These details are described in Section 7.2.2 of [OIFFLEXE1] and are not eloborated any further in this document.

Figure 4 illustrates a scenario involving the interworking of a 10G FlexE client with a 10GBASE-R native Ethernet signal. In this example, the network wrapper is ODU2e.

```
    ==================================================================


    +--------+ 2 x 100GE +-------+          +-------+      +---------+
    |        |           |       |          |       |      |         |
    | Router1|           |       |          |       |      |         |
    |(FlexE  +-----------+ A-end |          | Z-end | 10GE |Router 2|
    | Shim)  |           |(FlexE |          |       +------+         |
    |        +-----^-----+ term) |          |       |      |         |
    |        |     |     |       |          |       |      |         |
    |        |     |     |       |          |       |      |         |
    +--------+     +     +-------+          +-------+      +---------+
             FlexE Group
                       \+---------Transport---------+/
                                   network

    +-----------+   +---------------+
    | Client(s) |   | Client        |     +-------------+    +----------+
    +-----------+   +-------+-------+     |   10GE PCS |    | 10GE PCS|
    | FlexE Shim|   | Shim  |       |     +-------+----+    +----------+
    +-----------+   +-------+  ODU  |     | ODU2e | PHY|    | PHY      |
    | PHY(s)    |   | PHY(s)|  2e   |     +---+---+--+-+    +-----+---+
    +---+-------+   +---+-------+---+         |      |            |
        |               |       |             |      |            |
        |               |       |             |      |            |
        +---------------+       +-------------+      +------------+


     =================================================================
```

Figure 4: FlexE client interop with Native Ethernet Client

3.3.3. Interworking of FlexE client w/ Client from OIF_MLG

As explained in the Introduction section (Section 1 OIFMLG3 [OIFMLG3] introduced support for carrying 10GE and 40GE client signals over a group of 100GBASE-R Ethernet PHY(s). While the most recent implementation agreement doesn’t call it out explicitly, it is expected that the FlexE clients (as defined in [OIFFLEXE1]), and 10GBASE-R/40GBASE-R clients supported by OIFMLG3 [OIFMLG3]) will interoperate.

Figure 5 illustrates a scenario involving the interworking of a 10G FlexE client with a 10GBASE-R client supported by an OIFMLG3 interface. In this example, the network wrapper is ODU2e.

```
    ==================================================================


    +--------+ 2 x 100GE +---------+       +---------+      +---------+
    |        |           |         |       |         |      |         |
    | Router1|           |         |       |         |      |         |
    | FlexE  +-----------+ A-end   |       |  Z-end  +------+Router 2 |
    | Shim   |           | (FlexE  |       |         |      |(MLG-3.0)|
    |        +-----^-----+ term)   |       |         +------+         |
    |        |     |     |         |       |         |      |         |
    |        |     |     |         |       |         |      |         |
    +--------+     +     +---------+       +---------+      +---------+
              FlexE Group

                         \+--------+Transport+--------+/
                                    network

   +-----------+   +-------------+      +--------------+   +----------+
   | Client(s) |   | Client      |      | 10GE PCS     |   | 10GE Cl. |
   +-----------+   +--------+----+      +------+-------+   +----------+
   | FlexE Shim|   | Shim   |    |      |      | MLG3  |   | MLG3     |
   +-----------+   +--------+ ODU|      | ODU  +-------+   +----------+
   | PHY(s)    |   | PHY(s) | 2e |      | 2e   | PHY(s)|   | PHY(s)   |
   +---+-------+   +---+----+--+-+      +---+--+---+---+   +---+------+
       |               |       |            |      |           |
       +---------------+       +------------+      +-----------+


     =================================================================
```

Figure 5: FlexE client interop with Ethernet Client supported by MLG3

3.4. Back-to-Back FlexE

This section covers a degenerate FlexE termination scenario in which Router1, Router2, and Router3 are interconnected through back-to-back FlexE groups without an intermediate transport network (see Figure 6). Even in scenarios where there is a transport network providing FlexE unaware/aware transport services for this pair of FlexE groups, the FlexE layer network can be viewed as an overlay on top of the underlying transport network. As such, all of the FlexE Shim operations (e.g. adding/deleting FlexE clients, resizing existing clients) proceed in the same manner -- regardless of whether the routers are directly connected or not.

In this example, the FlexE Shim at Router2 extracts one or more FlexE client signals from the FlexE group connected to Router1, and mutliplexes these extracted FlexE signals into the FlexE group towards the appropriate router (e.g. Router3). Note that each of the extracted FlexE client signals can be independently routed towards its respective FlexE group.

```
 ==================================================================


        +--------+ 2 x 100GE +---------+ 3 x 100GE +---------+
        |        |           |         |           |         |
        | Router1|           |         |           |         |
        | FlexE  +-----------+ Router2 +-----------+ Router3 |
        | Shim   |           | FlexE   +-----------+ FlexE   |
        |        +-----^-----+ Shim    +-----^-----+ Shim    |
        |        |     |     |         |     |     |         |
        |        |     |     |         |     |     |         |
        +--------+     +     +---------+     +     +---------+
                  FlexE Group           FlexE Group


  =================================================================
```

Figure 6: Back-to-Back FlexE

3.5. FlexE Client BW Resizing

The hop-by-hop (a hop is delimited by two FlexE Shim functions) resizing of a FlexE client signal operates by maintaining two sets of calendar slots for each client: the present and the future. Once the configuration of both calendar slots for a specific client is complete, the node signals to its peer to switch to from the present set to the new set of calendar slots. Note that the switch to the new set of calendar slots is unidirectional, and the process is executed independently for both directions of transfer. This process makes use of the following FlexE overhead (as per [OIFFLEXE1]

a. Currently active FlexE calendar (containing a list of mapping between the 5G tributary slots and the FlexE client signals

b. Future calendar to which the sender wants to transition to.

c. Calendar switch request bit (CR)

d. Calendar switch acknowldege bit (CA)

FlexE client resizing operations are supported and can be achieved via the configuration of Calendar A and Calendar B. It is worth noting that there is no guarantee that such resizing will be hitless.

Table 1 provides a summary of client bandwidth resize applicability in various use cases presented in this document.

FlexE Shim endpoint 1	FlexE Shim endpoint 2	Usecase	Transport Network Function	Resizing supported?
CE (e.g. router)	CE	Section 3.1	FlexE unaware transport	Yes. Done at endpoints. The OTN pipes are configured for the maximum number of calendar slots across each PHY in the FlexE group. Therefore, no resizing is required in the OTN layer.
CE (e.g. router)	CE	Section 3.2	FlexE aware transport	Supported at the endpoints only if the set of available/unavailable calendar slots is constant. Not supported otherwise (see notes at the end of Section 3.2).
CE (e.g. router)	Transport Network Edge	Section 3.3.1	FlexE Termination in Transport	Not supported due to lack to lack of a general (i.e. one that works regardless of the ODUflex bandwidth) hitless ODUflex resizing in G.709.
CE (e.g. router)	CE	Section 3.4	No transport network	Yes. Done at endpoints by CE(s). Thus, for example, in Figure 6, the resizing of the end-to-end FlexE client circuit with a scope of Router1-Router2-Router3 is

				accomplished by correctly coordinating the resizing operations across these two segments: Router1-Router2, Router2-Router3. It is expected that the exact sequence of hop-by-hop resize operations is different between bandwidth increase/decrease scenarios.

Table 1: FlexE Client Resizing

4. Requirements

This section summarizes the requirements for FlexE Group and FlexE Client signaling and routing. The requirements are derived from the usecases described in Section 3 of this document. Data plane requirements (and/or solutions) (e.g. crunching of tributary slots, adding unavailable tributary slots etc.) are not explicitly mentioned in the following text. Given that the control plane sets up circuits that transport client streams, there are no implications for the control plane in matters of delay, jitter tolerance etc. The requirements listed in this section will be used to identify the Control Plane (i.e. Routing and Signaling) extensions that will be required to support FlexE services in an OTN.

A Control Plane solution will be compliant to the specification in Section 7 if it meets all the mandatory (MUST, SHALL) requirments, the solution may also meet the optional (SHOULD, MAY) requirments.

Req-1 The solution SHALL support the creation of a FlexE group, consisting of one or more (i.e., in the 1 to 254 range) 100GE Ethernet PHY(s).

There are several alternatives that can meet this requirement, e.g. routing and signaling protocols, or a centrailized controller/management system with network access to the FlexE mux/demux at each FlexE group termination point.

Req-2 The solution SHOULD be able to verify that the collection of Ethernet PHY(s) included in a FlexE group have the same characteristics (e.g. number of PHYs, rate of PHYs, etc.) at the peer FlexE shims.

Req-3 The solution SHALL support the ability to delete a FlexE group.

Req-4 It SHALL support the ability to administratively lock/unlock a FlexE group.

Req-5 It SHALL be possible to add/remove PHY(s) to/from an operational FlexE group while the group has been administratively locked.

[Note: Since the addition/removal of Ethernet PHY(s) is done only when the group has been locked, this dataplane operation of the FlexE group ceases until it is placed in an unlocked state.]

Req-6 The solution SHALL support the ability to advertise (and discover) the information about FlexE capable nodes, and the FlexE group instances they are supporting.

Req-7 It SHALL be possible to assign the transport network treatment for a FlexE group to one the following choices: (a) FlexE unaware transport (b) FlexE aware transport (c) FlexE termination in Transport.

Req-8 For the FlexE unaware case, each of the Ethernet PHY(s) in the FlexE group SHALL be mapped independently to the appropriately sized ODU container (as per [G.709], and switched across the transport network [OIFFLEXE1]. The control plane SHALL be capable of co-routing the ODU signals that are transporting the member PHY(s) between the two FlexE Shim functions.

[Note: Insert applicable references to ITU, OIF spec for hard skew tolerances]

Req-9 In the FlexE aware mode, the OTN SHALL crunch the PHY(s), and map them to one or more ODUflex connections as per [G.709].

When two or more ODUflex connections are used to transport the collection of FlexE PHY(s) in a FlexE group, the system SHALL support the ability to constrain the routes for these ODUflex connections (e.g. co-route them) so that the end-to-end skew is kept to a minimum (and within the range supported by the FlexE Shims).

Req-10 The system SHALL allow the addition (or removal) of one or more FlexE clients against the FlexE group which is being terminated. The addition (or removal) of FlexE client SHALL not affect the services for the other FlexE client signals.

Req-11 The system SHALL allow the FlexE client signals to flexibly span the set of Ethernet PHY(s) which comprise the FlexE group. In other words, it SHALL be possible to distribute any FlexE client over an arbitrary combination of calendar slots (whose total capacity matches the client bitrate) chosen from a subset of the PHY(s).

Req-12 When the FlexE group is terminated on the Transport edge node, this node SHOULD be capable of resizing one or more FlexE client (using the "A/B" calendar signaling defined by OIF) (see Section 3.5). It is acceptable that this resizing is not hitless, and the client signal incurs a glitch during the resizing operation.

There is no requirement for the OTN network to support the hitless resizing of the ODUFlex connection which is transporting the FlexE client signal.

Req-13 The solution SHALL support FlexE client resizing without affecting any existing FlexE clients within the same FlexE group.

5. Framework

This section discusses the environment where FlexE operates, this should include both what FlexE runs over and what applications run on top of FlexE.

5.1. FlexE Layer Model

Based on the cases addressed in Section 3, FlexE has different kinds of mapping hierarchy accordingly. This section gives some description of FlexE layer model in different cases.

5.1.1. Layer Model in FlexE Unaware Case

This case is depicted in Section 3.1. The FlexE Ethernet client represents an end-to-end connection, which is from the Router 1 to destination Router 2. The FlexE Ethernet client signal is first mapped into the slots of FlexE at Router 1, then the FlexE signal is carried by Ethernet PHYs towards the destination Router 2. When the Ethernet PHYs arrive at Transport network edge node A-end, each PHY will be mapped into a separate ODU4 connection and then forwarded across the OTN network towards the ODU layer connection destination Z-end.

Note: in this case, more than one FlexE clients can be carried by FlexE layer.

Four different layers exist in this case, and the mapping hierarchy can be seen in Figure 1.

5.1.2. Layer Model in FlexE Terminating Case

This case is depicted in Section 3.3. Take Section 3.3.1 for example. The FlexE Ethernet signal is first mapped into the slots of FlexE at Router 1, then the FlexE signal is carried by Ethernet PHYs towards the Transport Network edge node A-end. When the FlexE signal arrives at node A-end, node A-end first terminate Ethernet PHY signal and FlexE signal, extracts the FlexE Ethernet client signal, then maps the Ethernet client signal into ODU signal and forwards across the OTN network towards destination node Z-end. Node Z-end first terminate the ODU signal, extract the FlexE client signal from the ODU signal, then map the Ethernet client signal into FlexE signal, which will then be carried by Ethernet PHYs towards destination node Router 2.

Two segments of FlexE connection exist in this case. one is from Router 1 to node A-end, and the other is from node Z-end to Router 2. The mapping hierarchy can be seen in Figure 3

5.1.3. Layer Model in FlexE Aware Case

This case is depicted in Section 3.2. The FlexE Ethernet client is transferred from the R1 to destination R2, while the internal node NE A and NE Z are capable of "crunching" and "combining" operation. The FlexE Ethernet client signal is first mapped into the slots of FlexE at R1, then the FlexE signal is carried by Ethernet PHYs towards the destination R2. When the Ethernet PHY signal arrives at node NE A, node NE A first discards unavailable slots, then map the remaining FlexE slots onto ODU Connection. According to the description in [G.709], these FlexE slots can be carried across the OTN network via a couple of ODUflex signals which are carried in ODUCn/OTUCn/OTSiA signals.

Two kinds of mapping hierarchy exist in this case, one is the FlexE connection is carried by Ethernet PHYs, the other is FlexE connection (e.g., FlexE-psg) is carried by ODUflex, which can be seen in Figure 2.

5.2. GMPLS Considerations

The goal of this section is to provide an insight into the application of GMPLS as a control mechanism in FlexE networks. Specific control-plane requirements for the support of FlexE networks are covered in Section 5.3. This section aims to describe the modelling of controlling the FlexE shim layer specific attributes in different network scenarios based on the capability of FlexE described in OIF Flex Ethernet (FlexE) Implementation Agreement [OIFFLEXE1].

5.2.1. General Considerations

The GMPLS control of the FlexE layer deals with the establishment of FlexE connections that are transferred in FlexE capable nodes. GMPLS labels are used to locally represent the FlexE connections and its associated slots assignment information for client.

5.2.2. Consideration of FlexE LSPs

The FlexE LSP is a control-plane representation of a FlexE Connection and MUST be carried by Ethernet PHYs LSP or ODU LSP in the network.

Figure 1 depicts a scenario that the FlexE LSP is carried over Ethernet PHYs LSP from Router 1 to Router 2. When there is a need to set up FlexE end-to-end connection to carry FlexE Ethernet client signal at R1, R1 will first check if there are enough resources for setting up FlexE LSP. If yes, R1 will first set up Ethernet PHYs LSP from R1 to R2, and then set up the FlexE LSP over the Ethernet PHYs LSP. This process actually includes three signalling procedures, the first one is to set up multiple ODU4 LSPs to carry Ethernet PHYs, the second one is to set up multiple Ethernet PHYs connection to carry FlexE LSP, and the third one is to set up FlexE connection to carry FlexE Ethernet client signal. The signalling of FlexE LSP SHOULD be able to reserve resource for Ethernet client.

Figure 2 depicts the case that the FlexE LSP is carried over ODU LSP between NE A and NE Z. This case is different from that one in Figure 1, and is used to support cases such as the Ethernet PHY rate is be greater than the wavelength rate, the wavelength rate is not an integral multiple of the PHY rate. Both NE A and NE Z support the partial-rate ability ,which means when the FlexE LSP over Ethernet PHYs arrives at NE A, NE A should first discard the unavailable slots and then map the remaining FlexE slots into the ODU signal.

5.2.3. Control-Plane Modelling of FlexE Network Elements

FlexE is a new kinds of transport technology, which has many new constraints. These constraints are listed as follows:

Unavailable slots: this is different from "unused" slot, in that it is known, due to transport network constraints, that not all of the calendar slots generated from the FlexE mux will reach the FlexE demux and therefore no FlexE client should be assigned to those slots. As defined in the Flex Ethernet Implementation Agreement, unavailable slots are always at the end of the sub-calendar configuration for the respective PHY.

Unused slots: unused slots can be allocated to Ethernet client as available resource.

Partial-rate capability: the partial-rate capability is usually supported by the OTN edge equipments. If an equipment supports partial-rate, it means this equipment has the capability of discarding unavailable slots and transfers the remaining slots across OTN transport network.

Slot granularity: currently, only one kinds of 5G slot granularity is defined in OIF Flex Ethernet (FlexE) Implementation Agreement.

5.2.4. FlexE Layer Resource Allocation Considerations

FlexE LSP is used to provide resource service for its client, which is mainly reflected through the provision of the unused slot resource information towards the client layer. Besides the slot information, there are also some other attributes that need to be specified when allocating resource during connection setup process.

FlexE group number: a bunch of Ethernet PHYs can be bounded together and used as a whole as one FlexE LSP. FlexE LSPs between the same source and destination equipment SHOULD NOT have the same FlexE group number. Source equipment and destination equipment SHOULD be aware of the existing of different FlexE groups and which Ethernet PHYs are in which FlexE group.

PHY Number: it’s a dynamic and logical number that is assigned through control plane or management plane, which is unique within the context of (source, destination), and has a one-to-one correlation with physical port. This information will also be carried in the FlexE overhead. Source equipment and destination equipment SHOULD negotiate a value for every Ethernet PHYs within one FlexE group.

Slot Assignment information: the FlexE LSP transfers based on the slot positions, so the equipment SHOULD be able to tell which slot is assigned to which client.

Partial-rate: during the process of resource allocation, where the partial-rate would happen should be indicated.

Granularity: currently, only one kinds of 5G slot granularity is defined in OIF Flex Ethernet (FlexE) Implementation Agreement [FlexE-IA].

5.2.5. Neighbour Discovery and Link Property Correlation

There are potential interworking problems between different FlexE capable equipment. Devices or equipments might not be able to support the interworking of every slot due to the constraints of transport network equipment or other constraints. In this case, two directly connected FlexE capable equipments SHOULD run the neighbour discovery process and correlate the link property to make sure which slots are unavailable, which slots can be used by the client. Neighbour discovery protocol can be communicated in in-band FlexE section management channel, and also can be communicated through out-of-band management channel.

5.2.6. Routing and Topology Dissemination

The topology and routing information is used by the path computation entity to compute an end-to-end path. Besides the basic interconnected information, there are also some FlexE specific attributes that should be taken into consideration.

Partial-rate: partial-rate capability is a special feature which allows an equipment to discard unavailable slots and transfers the left slots across OTN transport network. Path computation entity is more likely to compute a feasible path if this capability is taken into consideration when computing path.

Unavailable slot information: this information is used to indicate certain slots SHOULD not be considered when computing an end-to-end path. The unavailable slots can not be used to forward signal because of the transport constraints.

Unused slot information: unused slot can be allocated to the path as available resource.

5.3. Control-Plane Protocol Requirements

The control of FlexE networks brings some new additional requirements to the GMPLS protocols. This section summarizes those requirements for signalling,routing and Link management protocol.

5.3.1. Support for Signalling of FlexE

Aim of the signaling is to set up an end-to-end LSP for FlexE signal.

The signalling procedures shall be able to assign FlexE releated attributes for an LSP, which include FlexE group number for a FlexE LSP. This FlexE group number is unique and can be used to indicate a group of Ethernet PHYs bonded together.

The signalling procedures shall be able to assign an unique PHY number for each bonded Ethernet PHY, and a correlation relationship SHOULD also be indicated between the assigned PHY number and real physical port number when signalling.

The signalling procedures shall be able to configure the slots information allocated for a FlexE LSP.

The Signalling procedures shall be able to indicate the palace where partial-rate mapping happens.

The Signalling procedures shall be able to support the non-hitless resizing of FlexE client.

5.3.2. Support for Routing of FlexE

The routing protocol extensions are mainly based on the functionality that is described in [RFC4202] and these extensions are made to fit into FlexE network.

The routing protocol SHALL distribute sufficient information to compute paths to enable the signalling procedure to establish LSPs as described in the previous sections.

The routing protocol SHALL update its advertisements of available resources and capabilities to include the partial-rate support information and unused slot information on each Ethernet PHY port.

5.3.3. Support for Neighbour Discovery and Link Property and Link Correlation

The control plane MAY include support for neighbour discovery such that a FlexE network can be constructed in a "plug-and-play" manner.

The control plane SHOULD allow the nodes at opposite ends of a link to correlate the properties that they will apply to the link. Such a correlation SHOULD include at least the identities of the nodes and the identities that they apply to the link. Other FlexE specific properties, such as the link characteristics of unavailable slot information, SHOULD also be correlated. Such neighbour discovery and link property correlation, if provided, MUST be able to operate in both in-band and out-of-band manner.

6. Architecture

This section discusses the different parts of FlexE signaling and routing and how these parts interoperte.

FlexE control plane technology SHOULD be able to set up end-to-end connection in different cases, which may include the management of FlexE group, assignment of the resource to the FlexE client and so on.

The FlexE routing mechanism is used to provide resource available information for set up FlexE connections, like Ethernet PHYs' information, partial-rate support information. Based on the resource available information advertised by routing protocol, an end-to-end FlexE connection is computed, and then the signalling protocol is used to set up an end-to-end connection.

7. Solution

8. Acknowledgements

9. IANA Considerations

This memo includes no request to IANA.

Note to the RFC Editor: This section should be removed before publishing.

10. Security Considerations

None.

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Appendix A. Additional Stuff

This becomes an Appendix.

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GMPLS Routing and Signaling Framework for Flexible Ethernet (FlexE)
draft-izh-ccamp-flexe-fwk-04

Abstract

This document specifies GMPLS control plane requirements, framework, and architecture for FlexE technology.

As different from earlier Ethernet data planes FlexE allows for decoupling of the Ethernet Physical layer (PHY) and Media Access Control layer (MAC) rates.

Study Group 15 (SG15) of the ITU-T has endorsed the FlexE Implementation Agreement from Optical Internetworking Forum (OIF) and included it, by reference, in some of their Recommendations.

Table of Contents

1. Introduction

Ethernet MAC rates were until recently constrained to match the rates of the Ethernet PHY(s). Work within the OIF allows MAC rates to be different from PHY rates. An OIF implementation agreement [OIFFLEXE1] allows for complete decoupling of the MAC and PHY rates.

SG15 in ITU-T has endorsed the OIF FlexE data plane and parts of [G.872], [G.709], [G.798] and [G.8021] depends on or are based on the FlexE data plane.

This includes support for:

a. MAC rates which are greater than the rate of a single PHY; multiple PHYs are bonded to achieve this

b. MAC rates which are less than the rate of a PHY (sub-rate)

c. support for channelization within a single PHY, or over a group of bonded PHYs.

The capabilities supported by the first version of the FlexE data plane are:

a. Support a large rate Ethernet MAC over bonded Ethernet PHYs, e.g. supporting a 200G MAC over 2 bonded 100GBASE-R PHY(s)

b. Support a sub-rate Ethernet MAC over a single Ethernet PHY, e.g. supporting a 50G MAC over a 100GBASE-R PHY

c. Support a collection of flexible Ethernet clients over a single Ethernet PHY, e.g. supporting two MACs with the rates 25G, and one with rate 50G over a single 100GBASE-R PHY

d. Support a sub-rate Ethernet MAC over bonded PHYs, e.g. supporting a 150G Ethernet client over 2 bonded 100GBASE-R PHY(s)

e. Support a collection of Ethernet MAC clients over bonded Ethernet PHYs, e.g. supporting a 50G, and 150G MAC over 2 bonded Ethernet PHY(s)

Networks which support FlexE Ethernet interfaces include a basic building block, this is true also when the interfaces are bonded. This building block consists of two FlexE Shim functions, located at opposite ends of a link, and the logical point to point links that carry the Ethernet PHY signals between the two FlexE Shim Functions.

These logical point-to-point links may be realized in a variety of ways:

a. direct point-to-point links with no intervening transport network.

b. Ethernet PHY(s) may be transparently transported via an Optical Transport Network (OTN), as defined by ITU-T in [G.709] and [G.798]. The OTN set of client mappings has been extended to support the use cases identified in the OIF FlexE implementation agreement.

This draft considers the variants in which the two peer FlexE devices are both customer-edge devices, or when one is a customer-edge and the other is provider edge devices. This list of use cases will help identify the Control Plane (i.e. Routing and Signaling) extensions that may be required.

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. Terminology

a. CE (Customer Edge) - the group of functions that support the termination/origination of data received from or sent to the network

b. Ethernet PHY: an entity representing Physical Coding Sublayer (PCS), Physical Media Attachment (PMA), and Physical Media Dependent (PMD) layers.

c. FlexE Calendar: The total capacity of a FlexE Group is represented as a collection of slots which have a granularity of 5G. The calendar for a FlexE Group composed of n 100G PHYs is represented as an array of 20n slots (each representing 5G of bandwidth). This calendar is partitioned into sub-calendars, with 20 slots per 100G PHY. Each FlexE client is mapped into one or more calendar slots (based on the bandwidth the FlexE client flow will need).

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

e. FlexE Group: A FlexE Group is composed of from 1 to n Ethernet PHYs. In the first version of FlexE each PHY is identified by a number in the range {1-254}.

f. FlexE Shim: the layer that maps or demaps the FlexE client flows carried over a FlexE Group.

g. LMP: Link Management Protocol

h. LSP: Label Switched Path

i. OTN: Optical Transport Network

j. SG15: ITU-T Study Group 15 (Transport, Access and Home).

k. TE: Traffic Engineering

l. TED: Traffic Engineering Database

3. FlexE Reference Model

The figure below gives a simplified FlexE reference model.

```
                           ....................................
                  n x PHY  .         n x crunched PHYs         .
                           .                                   .
         +----+            . +-----+    +-----+    +-----+     .   +----+
         | CE +--------------+ PE1 +----+  P  +----+ PE2 +---------+ CE |
         +----+            . +-----+    +-----+    +-----+     .   +----+
                           .                                   .
         +----+   m x PHY  .                                   .   +----+
         | CE +----------------------------------------------------+ CE |
         +----+            .                                   .   +----+
                           .         OTN Network               .
                           .                                   .
                           .....................................

         +----+   p x PHY                                          +----+
         | CE +----------------------------------------------------+ CE |
         +----+                                                    +----+
```

Figure 1: FlexE Reference Model

The services offered by Flexible Ethernet are essentially the same as for traditional Ethernet, connection less Ethernet transport. However, when the relationship between the PHY and MAC layer are setup by a GMPLS control plane there is a strong connection oriented aspect.

4. Requirements

This section summarizes the control plane requirements for FlexE Group and FlexE Client signaling and routing.

Req-1 The solution SHALL support the creation of a FlexE Group, consisting of one or more (i.e., in the 1 to 254 range) 100GE Ethernet PHY(s).

There are several alternatives that can meet this requirement, e.g. routing and signaling protocols, or a centralized controller/management system with network access to the FlexE mux/demux at each FlexE Group termination point.

Req-2 The solution SHOULD be able to verify that the collection of Ethernet PHY(s) included in a FlexE Group have the same characteristics (e.g. number of PHYs, rate of PHYs, etc.) at the peer FlexE shims.

Req-3 The solution SHALL support the ability to delete a FlexE Group.

Req-4 The solution SHALL support the ability to administratively lock/unlock a FlexE Group.

Req-5 It SHALL be possible to add/remove PHY(s) to/from an operational FlexE group while the group has been administratively locked.

Req-6 The solution SHALL support the ability to advertise and discover information about FlexE capable nodes, and the FlexE Groups and FlexE Clients they support.

Req-7 The system SHALL allow the addition (or removal) of one or more FlexE clients on aFlexE Group. The addition (or removal) of a FlexE client flow SHALL NOT affect the services for the other FlexE client signals.

Req-8 The system SHALL allow the FlexE client signals to flexibly span the set of Ethernet PHY(s) which comprise the FlexE Group.

Req-9 The solution SHALL support FlexE client flow resizing without affecting any existing FlexE clients within the same FlexE Group.

Req-10 The solution SHALL support establishment of MPLS LSPs that requires the support of a FlexE infrastructure.

5. GMPLS Controlled FlexE

The high level goals for using a GMPLS control plane for FlexE can be summarized as:

- o Set up a FlexE Group
- o Set up a FlexE Client
- o Advertise FlexE Groups and FlexE Clients
- o Set up of a higher layer LSP that requires to be run over a FlexE infrastructure.

5.1. Types of LSPs in a FlexE capable network

The FlexE infrastructure may be established in three different ways

- o The FlexE Groups and FlexE Client may be pre-configured
- o Only the FlexE groups may be pre-configured, while the setup of the FlexE client is triggered by the request to setup a MPLS LSP
- o The setup of both FlexE Group and FlexE Client may be triggered by the request to setup an MPLS LSP.

5.2. Signaling Channel

In the type of equipment for which FlexE was first specified an out of band signaling channel is not commonly available. If that is the case, and the GMPLS FlexE control plane will be used, the FlexE Group will have to setup by e.g. a management system and a FlexE Client on that FlexE Group (also configured) will have to allocated as a signaling channel.

Further details of the setup of the FlexE Groups, FlexE Clients and MPLS LSPs over a FlexE infrastructure will be found in Section 7.2.

5.3. MPLS LSP in the FlexE Data Plane

FlexE is a true link layer technology, i.e. it is not switched, this means that the FlexE Groups and FlexE Clients are terminated on the next-hop node, and that the switching needs to take place on a higher layer.

The FlexE technology can be used to establish link layer connectivity with high and deterministic bandwidth. However, there is no way to, in a deterministic way, allocate certain traffic to a specific FlexE Client. A GMPLS control plane can do this.

A GMPLS controlled FlexE capable node may be thought of using the traditional model of a node with a separation between control and data plane.

```
                         +------------------+
                         |  +------------+  |
                         |  |   GMPLS    |  |
                         |  |  Control   |  |
                         |  |   Plane    |  |
                         |  +------------+  |
                         |         ^        |
                         |         |        |
                         |         v        |
                         |  +------------+  |
                         |  |   FlexE    |  |
                         |  |    Data    |  |   ^
                         |  |   Plane    |  |
                         |  +------------+  |
                         +------------------+
```

Figure 2: GMPLS controlled FlexE Node

The GMPLS control plane will speak extended standard GMPLS protocols with its neighbours and peers.

```
               Node A                  Node B                  Node Z
             +--CP
           +-|-----------+        |------------------+  ~   +---------+
           | |           |        |                  |      |         |
           | |  +------+ |        | +--------------+ |      | +-----+ |
     LSP   | +->|  v   | |        | |  ....x.....  | |      | |  ^  | |
           | |  |  .   | |        | |  .        .  | |      | |  .  | |
           | |  +--.---+ |        | +--.--------.--+ |      | +--.--+ |
    FlexE  | +->|  o   | |        | |  o  |  |  o  | |      | |  o  | |
    Client | |  |  o   | |        | |  o  |  |  o  | |      | |  o  | |
           | |  +--o---| |        | +--o--+  +--o--+ |      | +--o--| |
    FlexE  | +->|  U   | |        | |  U  |  |  U  | |      | |  U  | |
    Group  |    |  U   | |        | |  U  |  |  U  | |      | |  U  | |
           |    +--U---| |        | +--U--+  +--U--+ |      | +--U--+ |
           |-------U-----+        +----U--------U----+      +----U----+
                   U                   U        U                U
                   UUUUUUUUUUUUUUUUUUUUU        UUUUUUU ~ UUUUUUUU

                   Legend ... = LSP
                          ooo = FlexE Client
                          UUU = FlexE Group
```

Figure 3: GMPLS controlled network with FlexE infrastructure

Figure 3 describes how an MPLS LSP is mapped over a FlexE Client and FlexE Group.

5.4. Configuring the data plane in FlexE capable nodes

In Figure 3 we show an LSP, a FlexE Client and a FlexE Group, the LSP is there because while the FlexE Channel and Group are not switched, switching in our example takes place on the LSP level. This section will discuss establishment of FlexE Clients and Groups, and mapping of the LSP onto a FlexE Client.

The establishment of a LSP over a FlexE system is very similar to how this is done in any other system. Building on information gathered through the routing system and using the GMPLS signaling to establish the LSP.

5.4.1. Configure/Establish a FlexE Group/Link

Consider the setup of a FlexE Group between node A and B, corresponding to the row of U’s from node A to B in Figure 3. The FlexE group is considered to consist of n PHYs, but does not have any FlexE Clients defined from start.

When this is done by the GMPLS control plane, two conditions need to be fulfilled (1) there need to be a data channel defined between node A and B; and (2) a FlexE capable IGP-TE protocol needs to be running in the network.

Node A will send an RSVP-TE message to node be with the information describing the FlexE Group to be setup. This information might be thought of as the "FlexE Group Label" (or part of the FlexE label). It will contain at least the following information:

o A FlexE Group Identifier (FGid).

o The number of active FlexE Channels (numFC), where 0 indicates that zero clients are active.

o Number of PHYs that the FlexE Group is composed of, for each PHY

   * PHY identifier

   * PHY bandwidth

   * slot granularity/number of slots

   * available and unavailable slots

When node B receives the RSVP-TE message it checks that it can setup the requested FlexE Group. If the check turns positive, node send an acknowledgment to node A and the FlexE Group is setup.

A more detailed description of how to setup a FlexE Group, will be included in the draft dealing with signaling in detail.

5.4.2. Configure/Establish a FlexE Client

Consider the situation where a FlexE Group is already established (as described in Section 5.4.1) and an m G FlexE Client is needed. Similar to the establishment of the FlexE Group, node A will send a RSV-TE message to node B.

This RSVP-TE message include at least the following information:

- o FlexE Group Identifier
- o FlexE Client Identifier
- o from which PHYs the slots will allocated, i.e. slots might come from more than one PHY.
- o Information per PHY
  - * PHY bandwidth
  - * slot granularity
  - * available/unavailable slots
  - * allocated slots

A more detailed description of how to setup a FlexE Channel, will be included in the draft dealing with signaling in detail.

5.4.3. Advertise FlexE Groups and FlexE lts

Once the FlexE Group and FlexE CLielts are configured they can be advertised into the routing system as normal routing adjacencies, including the FlexE specific TE information.

6. Framework and Architecture

This section discusses FlexE framework and architecture. Framework is taken to mean how FlexE interoperates with other parts of the data communication system. Architecture is taken to mean how functional groups and elements within FlexE work together to deliver the expected FlexE services. Framework is taken to mean how FlexE interacts with it environment.

6.1. FlexE Framework

The service offered by Flexible Ethernet is a transport service very similar (or even identical) to the service offered by Ethernet.

There are two major additions supported by FlexE:

- FlexE is intended to support high bandwidth and FlexE can offer granular bandwidth from 5Gbits/s and a bandwidth as high as the FlexE Group allows.

- As FlexE groups and clients are setup as a configuration activity, by a centralized controller or by a GMPLS control plane the service is connection oriented.

6.2. FlexE Architecture

6.2.1. Architecture Components

This section discusses the different parts of FlexE signaling and routing and how these parts interoperate.

The FlexE routing mechanism is used to provide resource available information for setup of higher layer LSPs, like Ethernet PHYs' information, partial-rate support information. Based on the resource available information advertised by routing protocol, an end-to-end FlexE connection is computed, and then the signaling protocol is used to set up the end-to-end connection.

FlexE signaling mechanism is used to setup LSPs.

MPLS forwarding over a FlexE infrastructure is different from forwarding over other infrastructures. When MPLS runs over a FlexE infrastructure it is possible that there are more than FlexE Client that meet the next-hop requirements, often it is possible to use any suitable FlexE Clientfor a hop between two nodes. If the mapping between a MPLS encapsulated packet and the FlexE Client, this mapping need to be explicit when the LSP is set up, and the MPLS label will be used to find the correct FlexE Client.

6.2.2. FlexE Layer Model

The FLexE layer model is similar Ethernet model, the Ethernet PHY layer corresponds to the "FlexE Group", and the MAC layer corresponds to the "FlexE Client".

As different from earlier Ethernet the combination of Flexe Group and Client allows for a huge freedom when it comes to define the bandwidth of an Ethernet connectivity.

6.2.2.1. FlexE Group structure

The FlexE Group might be supported by virtually any transport network, including the Ethernet PHY. While the Ethernet PHY offers a fixed bandwidth the FlexE Group has been structured into 5 Gbit/s slots. This means that the FlexE Group can support FlexE clients of a variety of bandwidths.

The first version is defined for 20 slots of 5 Git/s over a 100 Gbit/s PHY. The 100 Gbit/s PHYs can be bonded to give higher bandwidth.

6.2.2.2. FlexE Client mapping

A FlexE client is an Ethernet flow based on a MAC data rate that may or may not correspond to any Ethernet PHY rate. The FlexE Shim is the layer that maps or demaps the FlexE client flows carried over a FlexE group. As defined in [OIFFLEXE1], MAC rates of 10, 40, and any multiple of 25 Gbit/s are supported. This means that if there is a 100 Gbit/s FlexE Group between A and B, a FlexE client of 10, 25, 40, 50, 75 and 100 Gbit/s can be created.

However, by bonding, for example 5 PHYs of 100 Git/s to a single FlexE group, FlexE clients of 500 Gbit/s can be supported.

7. Control Plane

This section discusses the procedures and extensions needed to the GMPLS Control Plane to establish FlexE LSPs.

There are several ways to establish FlexE groups, allocate slots for FlexE clients, and setup higher layer LSPs. A configuration tool, a centralized controller or the GMPLS control plane can all be used.

To create the FlexE GMPLS control plane Groups, FlexE Clients and higher layer LSPs, extensions to the following protocols may be needed:

- o "RSVP-TE: Extensions to RSVP for LSP Tunnels" (RSVP-TE) [RFC3209]

- o "Link Management Protocol" (LMP) [RFC4204]

- o "Path Computation Element (PCE) Communication Protocol" (PCEP) [RFC5440]

- o IS-IS Extensions for Traffic Engineering (ISIS-TE) [RFC5305]
- o "OSPF Extensions in Support of Generalized Multi-Protocol Label Switching (GMPLS)" (OSPF-TE) [RFC4203]
- o "North-Bound Distribution of Link-State and Traffic Engineering (TE) Information Using BGP" (BGP-LS) [RFC7752]

A FlexE control plane YANG model will also be needed.

Section 7.2 and Section 7.1 discusses the role of the GMPLS control plane when primarily setting up LSPs.

When discussing the signaling and routing procedures we assume that the FlexE group has been established prior to executing the procedures needed to establish an LSP. Technically it is possible to establish FlexE group, allocate FlexE client slots and LSP with a single exchange of GMPLS signaling messages.

7.1. GMPLS Routing

To establish an LSP the Traffic Engineering (TE) information is the most critical information, e.g. resource utilization on interfaces and link, including the availability of slots on the FlexE groups. The GPMPLS routing protocols needs to be extended to handle this information. The Traffic Engineering Database (TED) will keep an updated version of this information.

The FlexE capable nodes will be identified by IP-addresses, and the routing and traffic engineering information will be flooded to all nodes within the routing domain using TCP/IP.

When an LSP over the FlexE infrastructure is about to be setup, e.g. R1 - R4 - R5 in Figure 4 the information in the TED is used verify that resources are available. When it is conformed that the LSP is established the TED is updated, marking the resources used for the new LSP as used. Similarly when a LSP is taken down the resources are marked as free.

7.2. GMPLS Signaling

As described in Section 5 the state of the FlexE infrastructure may effect the actions needed to setup an LSPin a FlexE capable network. The FlexE infrastructure maybe be:

1. fully pre-configured

2. partially pre-configured, i.e. the FlexE Group may be pre-configured, but not the FlexE Clients

3. not pre-configured, i.e. the setup of FlexE Group and FlexE Client will be triggered because of the request to setup an LSP.

Figure 4 will be used to illustrate the different cases.

```
+----+
| R1 +---------------------+
+----+                     |
                           |
+----+                  +--+--+                         +----+
| R2 +------------------+  R4 +-------------------------+ R5 |
+----+                  +--+--+                         +----+
                           |
+----+                     |
| R3 +---------------------+   PHY R1 to R4 100 Gbit(s
+----+                         PHY R2 to R4 100 Gbit(s
                               PHY R3 to R4 100 Gbit(s
                               PHY R4 to R5 200 Gbit(s
```

Figure 4: FlexE LSP Example

The text in Section 7.2 is not a specification of the GMPLS signaling extensions for FlexE capable network, it is a description to illustrate the expected features of such a protocol. Nor do we discuss failure scenarios.

7.2.1. LSP setu with pre-configured FlexE infrastructure

In this first example, referencing Figure 4, one 100 Gbit/s FlexE group is configured between R1 and R4, between R2 and R4, and between R3 and R4. Between R4 and R5 there is a 200 Gbit/s FlexE Group.

Over each 100 Gbit/s FlexE Group there are four 5 Gbit/s, two 20 Gbit/s and one 40 Gbit/s FlrxE Clients configured. Over the 200 Git/s FlexE Group there are eoght 5 Gbit/s, four 20 Gbit/s and tow 40 Gbit/s FlrxE Clients configured.

One of the 5 Gbit/s FlexE Clients on each FlexE Groups are used as signaling channel.

To establish the for example a 200 Mbit/s MPLS LSP the normal GMPLS request/response procedures are followed. R1 sends the request to R4, R4 allocate resources on one of the FlexE Ckients, forward the request to R5. R5 responds to R4 indicating the label and the FlexE Client the traffic should be sent over, R4 does the same for R1.

The only difference between the standard signaling and what happens here is that there the assigned label will be used to find the right FlexE Client.

7.2.2. LSP setup with partially configured FlexE infrastructure

In the second example, also referencing Figure 4, the FlexE Groups are set up in the same way as in the first example, however only one 5 Gbit/s FlexE Client per FlexE Group are established by configuration. This FlexE Client will be used for signaling.

When preparing to send the request that a 5 Gbit/s MPLS LSP shall be set up R1 discovers that there are no feasible FlexE Client between R1 aand R4. R1 therefore sends the request to establish such a FlexE Client, when receiving the request R4 allocates resources for the FlexE Client on the FlexE Group. There may be different strategies for allocating the bandwidth for this FlexE client. Such strategies are out of scope for this document. R1 then sends the information about the FlexE Client to R1, and both ends establish the FlexE Client.

When the FlexE Client between R1 and R4 is established, R1 proceeds to send the request for an MPLS LSP to R4. R4 will discover that a feasible FlexE Client is missing between R4 and R5. The same procedure s for setting up the FlexE Client between R1 and R4 is repeated for R4 and R5. When there is a feasible FlexE Client available the signaling to set up the MPLS LSP continues as normal.

The label allocated for the MPLS LSP will be used to find the correct FlexE Client.

When a FlexE Clients is set up in this way they can be announced into the routing system in two different ways. First, they can be made generally available, i.e. it will be free to use for anyone that want to set up LSPs over the FlexE Group between R1 and R4 and between R4 and R5. Second, the use of the FlexE Clients may be restricted to the application that initially did set up the FlexE Client.

7.2.3. LSP setup with non-configured FlexE infrastructure

This example also refers to Figure 4 as different from the earlier example no FlexE Group or FlexE Client configuration is done prior to the first request for an MPLS LSP over the FlexE infrastructure.

To make the set up of LSPs in a FlexE network where no FlexE Groups or FlexE Clients have been configured two conditions need to be fulfilled. First an out of band signaling channel must be available. Second the FlexE Capabilities must be announced in to the IGP and/or centralized controller.

If these two conditions are fulfilled, the set up of an MPLS LSP progress pretty much as in the partially configured network. The difference is that the set up of both the FlexE Group and FlexE Client are triggered by the request to set up an MPLS LSP.

As in the partially configured case FlexE Clients can be announced into the routing system in two different modes, either they are generally availble. It or they are reserved for the applications that first established them.

7.2.4. Packet Label Switching Data Plane

This section discusses how the FlexE LSP data plane works. In general it can be said that the interface offered by the FlexE Shim and the FlexE client is equivalent to the interface offered by the Ethernet MAC.

Figure 5 below illustrates the FlexE packet switching data plane procedures.

```
        R1                          R3                          R4
     .............        ......................         ...........
     . +-------+ .        . +-----------------+ .        . +-----+ .
     . |  LSP  | .        . | LSP  \  / LSP   | .        . | LSP | .
     . |   a   | .        . |  a    \/   b    | .        . |  b  | .
     . +-------+ .        . +-----------------+ .        . +-----+ .
     . |  ETH  | .        . | ETH |     | ETH | .        . | ETH | .
     . |  i/f  | .        . | i/f |     | i/f | .        . | i/f | .
     . +-------+ .        . +-----+     +-----+ .        . +-----+ .
     . | FlexE | .        . |FlexE|     |FlexE| .        . |FlexE| .
     . | trsp  | .        . |trsp |     |trsp | .        . |trsp | .
     . +---+---+ .        . +--+--+     +--+--+ .        . +--+--+ .
     ......|......        .....^..........|.....         .....^.....
           |                   |          |                   |
           +-------------------+          +-------------------+
```

Figure 5: LSP over FlexE Data Plane

The data plane processes packets like this:

o The LSP encapsulating and forawrding function in node R1 receives a packet that needs to be encapsulated as an MPLS packet with the label "a". The label "a" is used to figure out which FlexE emulated Ethernet interfaces the label encapsulated packet need to be forwarded over.

o The Ethernet interfaces, by means of FlexE transport, forwards the packet to node R3. Node R3 swaps the label "a" to label "b" and uses "b" to decide over which interface to send the packet.

o Node R3 forwards the packet to node R, which terminates the LSP.

Sending MPLS encapsulated packets over a FlexE Client is similar to send them over an Ethernet 802.1 interface. The critical differences are:

o FlexE channelized sub-interfaces guarantee a deterministic bandwidth for an LSP.

o When a application that originally establish a FlexE Client reserve it for use by that application only, it is possible to create uninfringeable bandwidth end-to-end for an MPLS LSP.

o FlexE infrastructure allows for creating very large end to end bandwidth

8. Operations, Administration, and Maintenance (OAM)

To be added in a later version.

9. Acknowledgements

10. IANA Considerations

This memo includes no request to IANA.

Note to the RFC Editor: This section should be removed before publishing.

11. Security Considerations

To be added in a later version.

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A YANG Data Model for Microwave Radio Link

draft-mwdt-ccamp-mw-yang-01

Abstract

This document defines a YANG data model in order to control and manage the radio link interfaces, and the connectivity to packet (typically Ethernet) interfaces in a microwave/millimeter wave node.

Status of this Memo

Copyright Notice

Table of Contents

1. Terminology and Definitions

The following terms are used in this document:

Carrier Termination (CT) is an interface for the capacity provided over the air by a single carrier. It is typically defined by its transmitting and receiving frequencies.

Radio Link Terminal (RLT) is an interface providing packet capacity and/or TDM capacity to the associated Ethernet and/or TDM interfaces in a node and used for setting up a transport service over a microwave/millimeter wave link.

The following acronyms are used in this document:

ACM Adaptive Coding Modulation
ATPC Automatic Transmit Power Control
CM   Coding Modulation
CT   Carrier Termination
RLT Radio Link Terminal
RTPC Remote Transmit Power Control
XPIC Cross Polarization Interference Cancellation

MIMO Multiple-Input Multiple-Output

2. Introduction

This document defines a YANG data model for management and control of the radio link interface(s) and the relationship to packet (typically Ethernet) and/or TDM interfaces in a microwave/millimeter wave node. The date model includes configuration and state data.

The design of the data model follows the framework for management and control of microwave and millimeter wave interface parameters defined in [mw-fmwk]. This framework identifies the need and the scope of the YANG data model, the use cases and requirements that the model needs to support. Moreover, it provides a detailed gap analysis to identify the missing parameters and functionalities of the existing and established models to support the specified use cases and requirements, and based on that recommends how the gaps should be filled with the development of the new model.

According to the conclusion of the gap analysis, the structure of the data model is based on the structure defined in [I-D.ahlberg-ccamp-microwave-radio-link] and it augments RFC 7223 to align with the same structure for management of the packet interfaces. More specifically, the model will include interface layering to manage the capacity provided by a radio link terminal for the associated Ethernet and TDM interfaces, using the principles for interface layering described in RFC 7223 as a basis.

The designed YANG data model uses the IETF: Radio Link Model [I-D.ahlberg-ccamp-microwave-radio-link] and the ONF: Microwave Modeling [ONF-model] as the basis for the definition of the detailed leafs/parameters, and proposes new ones to cover identified gaps which are analyzed in [mw-fmwk].

3. YANG Data Model (Tree Structure)

```
module: ietf-microwave-radio-link
    +--rw radio-link-protection-groups
    |  +--rw radio-link-protection-group* [name]
    |     +--rw name                               string
    |     +--rw protection-architecture-type?    identityref
    |     +--rw protection-operation-type?       enumeration
    |     +--rw working-entity*                  if:interface-ref
    |     +--rw revertive-wait-to-restore?       uint16
    |     +--rw radio-link-protection-members*   if:interface-ref
    |     +---x protection-external-commands
    |        +---w input
    |           +---w protection-external-command?  identityref
    +--ro radio-link-protection-groups-state
    |  +--ro radio-link-protection-group* [name]
    |     +--ro name                 string
    |     +--ro protection-status?   identityref
    +--rw xpic-pairs {xpic}?
    |  +--rw xpic-pair* [name]
    |     +--rw name            string
    |     +--rw enabled?        boolean
    |     +--rw xpic-members*   if:interface-ref
    +--rw mimo-groups {mimo}?
       +--rw mimo-group* [name]
          +--rw name            string
          +--rw enabled?        boolean
          +--rw mimo-members*   if:interface-ref
  augment /if:interfaces/if:interface:
    +--rw id?                     string
    +--rw mode                    identityref
    +--rw carrier-terminations*   if:interface-ref
    +--rw rlp-groups*             -> /radio-link-protection-groups
                                     /radio-link-protection-group/name
    +--rw xpic-pairs*            -> /xpic-pairs/xpic-pair/name {xpic}?
    +--rw mimo-group?            -> /mimo-groups/mimo-group/name {mimo}?
    +--rw tdm-connections* [tdm-type] {tdm}?
       +--rw tdm-type           identityref
       +--rw tdm-connections    unit16
  augment /if:interfaces/if:interface:
    +--rw carrier-id?                  string
    +--rw tx-enabled?                  boolean
    +--rw tx-frequency                 uint32
    +--rw rx-frequency?                uint32
```

```
    +--rw rx-frequency-config?         boolean
    +--rw duplex-distance              uint32
    +--rw channel-separation           decimal64
    +--rw polarization?                enumeration
    +--rw power-mode                   enumeration
    +--rw selected-output-power        power
    +--rw atpc-lower-threshold         power
    +--rw atpc-upper-threshold         power
    +--rw coding-modulation-mode       enumeration
    +--rw selected-cm                  identityref
    +--rw selected-min-acm             identityref
    +--rw selected-max-acm             identityref
    +--rw if-loop?                     enumeration
    +--rw rf-loop?                     enumeration
    +--rw ct-performance-thresholds
       +--rw received-level-alarm-threshold?      power
       +--rw transmitted-level-alarm-threshold?   power
       +--rw ber-alarm-threshold?                 enumeration
  augment /if:interfaces-state/if:interface:
    +--ro tx-oper-status?             enumeration
    +--ro actual-transmitted-level?   power
    +--ro actual-received-level?      power
    +--ro actual-tx-cm?               identityref
    +--ro actual-snir?                decimal64
    +--ro actual-xpi?                 decimal64 {xpic}?
    +--ro capabilities
       +--ro min-tx-frequency?            uint32
       +--ro max-tx-frequency?            uint32
       +--ro min-rx-frequency?            uint32
       +--ro max-rx-frequency?            uint32
       +--ro available-min-output-power?   power
       +--ro available-max-output-power?   power
       +--ro available-min-acm?           identityref
       +--ro available-max-acm?           identityref
  augment /if:interfaces-state/if:interface/if:statistics:
    +--ro bbe?         yang:counter32
    +--ro es?          yang:counter32
    +--ro ses?         yang:counter32
    +--ro uas?         yang:counter32
    +--ro min-rltm?    power
    +--ro max-rltm?    power
    +--ro min-tltm?    power
    +--ro max-tltm?    power
```

4. YANG Module

   <CODE BEGINS> file "ietf-microwave-radio-link.yang"

```
module ietf-microwave-radio-link {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-microwave-radio-link";
  prefix mrl;

  import ietf-yang-types {
    prefix yang;
  }

  import ietf-interfaces {
    prefix if;
  }

  import iana-if-type {
    prefix ianaift;
  }

  organization
    "IETF CCAMP Working Group";
  contact
    "jonas.ahlberg@ericsson.com
     amy.yemin@huawei.com
     Xi.Li@neclab.eu
     cjbc@it.uc3m.es
     k-kawada@ah.jp.nec.com";

  description
    "This is a module for the entities in a generic
     microwave system.";

  revision 2016-12-22 {
    description
      "Draft revision covering a complete scope for
      configuration and state data for radio link
      interfaces.";

      reference "";
  }
```

```
  revision 2016-10-29 {
    description
      "Draft revision.";
    reference "";
  }

  /*
  * Features
  */

  feature xpic {
    description
      "Indicates that the device supports XPIC.";
  }


  feature mimo {
    description
      "Indicates that the device supports MIMO.";
  }

  feature tdm {
    description
      "Indicates that the device supports TDM.";
  }

  /*
  * Interface identities
  */

  identity radio-link-terminal {
    base ianaift:iana-interface-type;
    description
      "Interface identity for a radio link terminal.";
  }

  identity carrier-termination {
    base ianaift:iana-interface-type;
    description
      "Interface identity for a carrier termination.";
  }

 /*
  * Radio-link-terminal mode identities
  */
```

```
  identity rlt-mode {
    description
      "A description of the mode in which the radio
      link terminal is configured. The format is X
      plus Y. X represent the number of bonded
      carrier terminations. Y represent the number
      of protecting carrier terminations.";
  }

  identity one-plus-zero {
    base rlt-mode;
    description
      "1 carrier termination only.";
  }

  identity one-plus-one {
    base rlt-mode;
    description
      "1 carrier termination
       and 1 protecting carrier termination.";
  }

  identity two-plus-zero {
    base rlt-mode;
    description
      "2 bonded carrier terminations.";
  }

  /*
  * Coding and modulation identities
  */

  identity coding-modulation {
    description
      "The coding and modulation schemes.";
  }

  identity half-bpsk-strong {
    base coding-modulation;
    description
    "Half BPSK strong coding and modulation scheme.";
  }
```

```
  identity half-bpsk {
    base coding-modulation;
    description
      "Half BPSK coding and modulation scheme.";
  }

  identity half-bpsk-light {
    base coding-modulation;
    description
      "Half BPSK light coding and modulation scheme.";
  }

  identity bpsk-strong {
    base coding-modulation;
    description
      "BPSK strong coding and modulation scheme.";
  }

  identity bpsk {
    base coding-modulation;
    description
      "BPSK coding and modulation scheme.";
  }

    identity bpsk-light {
    base coding-modulation;
    description
      "BPSK light coding and modulation scheme.";
  }

  identity qpsk {
    base coding-modulation;
    description
      "QPSK coding and modulation scheme.";
  }

  identity qam-4-strong {
    base coding-modulation;
    description
      "4 QAM strong coding and modulation scheme.";
  }

  identity qam-4 {
    base coding-modulation;
    description
      "4 QAM coding and modulation scheme.";
  }
```

```
  identity qam-4-light {
    base coding-modulation;
    description
      "4 QAM light coding and modulation scheme.";
  }

  identity qam-16-strong {
    base coding-modulation;
    description
      "16 QAM strong coding and modulation scheme.";
  }

  identity qam-16 {
    base coding-modulation;
    description
      "16 QAM coding and modulation scheme.";
  }

  identity qam-16-light {
    base coding-modulation;
    description
      "16 QAM light coding and modulation scheme.";
  }

  identity qam-32-strong {
    base coding-modulation;
    description
      "32 QAM strong coding and modulation scheme.";
  }

  identity qam-32 {
    base coding-modulation;
    description
      "32 QAM coding and modulation scheme.";
  }

  identity qam-32-light {
    base coding-modulation;
    description
      "32 QAM light coding and modulation scheme.";
  }

  identity qam-64-strong {
    base coding-modulation;
    description
      "64 QAM strong coding and modulation scheme.";
  }
```

```
  identity qam-64 {
    base coding-modulation;
    description
      "64 QAM coding and modulation scheme.";
  }

  identity qam-64-light {
    base coding-modulation;
    description
      "64 QAM light coding and modulation scheme.";
  }

  identity qam-128-strong {
    base coding-modulation;
    description
      "128 QAM strong coding and modulation scheme.";
  }

  identity qam-128 {
    base coding-modulation;
    description
      "128 QAM coding and modulation scheme.";
  }

  identity qam-128-light {
    base coding-modulation;
    description
      "128 QAM light coding and modulation scheme.";
  }

  identity qam-256-strong {
    base coding-modulation;
    description
      "256 QAM strong coding and modulation scheme.";
  }

  identity qam-256 {
    base coding-modulation;
    description
      "256 QAM coding and modulation scheme.";
  }

  identity qam-256-light {
    base coding-modulation;
    description
      "256 QAM light coding and modulation scheme.";
  }
```

```
  identity qam-512-strong {
    base coding-modulation;
    description
      "512 QAM strong coding and modulation scheme.";
  }

  identity qam-512 {
    base coding-modulation;
    description
      "512 QAM coding and modulation scheme.";
  }

  identity qam-512-light {
    base coding-modulation;
    description
      "512 QAM light coding and modulation scheme.";
  }

  identity qam-1024-strong {
    base coding-modulation;
    description
      "1024 QAM strong coding and modulation scheme.";
  }

  identity qam-1024 {
    base coding-modulation;
    description
      "1024 QAM coding and modulation scheme.";
  }

  identity qam-1024-light {
    base coding-modulation;
    description
      "1024 QAM light coding and modulation scheme.";
  }

  identity qam-2048-strong {
    base coding-modulation;
    description
      "2048 QAM strong coding and modulation scheme.";
  }

  identity qam-2048 {
    base coding-modulation;
    description
      "2048 QAM coding and modulation scheme.";
  }
```

```
  identity qam-2048-light {
    base coding-modulation;
    description
      "2048 QAM light coding and modulation scheme.";
  }

  identity qam-4096-strong {
    base coding-modulation;
    description
      "4096 QAM strong coding and modulation scheme.";
  }

  identity qam-4096 {
    base coding-modulation;
    description
      "4096 QAM coding and modulation scheme.";
  }

  identity qam-4096-light {
    base coding-modulation;
    description
      "4096 QAM light coding and modulation scheme.";
  }


  /*
   * Protection architecture type identities
  */
  identity protection-architecture-type {
    description
      "protection architecture type";
  }

  identity one-plus-one-type {
    base protection-architecture-type;
    description
      "One carrier termination and
      one protecting carrier termination.";
  }

  identity one-to-n-type {
    base protection-architecture-type;
    description
      "One carrier termination protecting
       n other carrier terminations.";
  }
```

```
  /*
   * Protection states identities
   */

  identity protection-states {
    description
     "Identities describing the status of the protection,
     in a group of carrier terminations configured in
     a radio link protection mode.";
  }

  identity unprotected {
    base protection-states;
    description "Not protected";
  }

  identity protected {
    base protection-states;
    description "Protected";
  }

  identity unable-to-protect {
    base protection-states;
    description "Unable to protect";
  }


  /*
   * protection-external-commands identities
   */

  identity protection-external-commands{
    description
      "Protection external commands for trouble shooting
      purpose.";
  }

  identity manual-switch{
    base protection-external-commands;
    description
      "A switch action initiated by an operator command.
      It switches normal traffic signal to the protection
      transport entity.";
  }
```

```
  /*
  * TDM-type identities
  */
  identity tdm-type {
    description
      "A description of the type of TDM connection,
      also indicating the supported capacity of the
      connection.";
  }

  identity E1 {
    base tdm-type;
    description
      "E1 connection, 2,048 Mbit/s.";
  }

  identity STM-1 {
    base tdm-type;
    description
      "STM-1 connection, 155,52 Mbit/s.";
  }

  /*
   * Typedefs
   */
  typedef power {
    type decimal64 {
      fraction-digits 1;
    }
    description
      "Type used for power values, selected and measured.";
  }

  /*
  * Radio Link Terminal (RLT) - Configuration data nodes
  */
  augment "/if:interfaces/if:interface" {
    when "if:type = 'mrl:radio-link-terminal'";
    description
      "Addition of data nodes for radio link terminal to
       the standard Interface data model, for interfaces of
       the type 'radio-link-terminal'.";
```

```
    leaf id {
      type string;
      default "";
      description
        "ID of the radio link terminal. Used by far-end when
         checking that it's connected to the correct RLT.";
    }

    leaf mode {
      type identityref {
        base rlt-mode;
      }
      mandatory true;
      description
        "A description of the mode in which the radio link
         terminal is configured. The format is X plus Y.
         X represent the number of bonded carrier terminations.
         Y represent the number of protecting carrier
         terminations.";
    }

    leaf-list carrier-terminations {
      type if:interface-ref;
      must "/if:interfaces/if:interface[if:name = current()]"
         + "/if:type = 'mrl:carrier-termination'" {
        description
          "The type of interface must be
           'carrier-termination'.";
      }
      min-elements 1;
      description
        "A list of references to carrier terminations
         included in the radio link terminal.";
    }

    leaf-list rlp-groups {
      type leafref {
        path "/mrl:radio-link-protection-groups/"
           + "mrl:radio-link-protection-group/mrl:name";
      }
      description
        "A list of references to the carrier termination
         groups configured for radio link protection in this
         radio link terminal.";
    }
```

```
    leaf-list xpic-pairs {
      if-feature xpic;
      type leafref {
        path "/mrl:xpic-pairs/mrl:xpic-pair/mrl:name";
      }
      description
        "A list of references to the XPIC pairs used in this
         radio link terminal. One pair can be used by two
         terminals.";
    }

    leaf mimo-group {
      if-feature mimo;
      type leafref {
        path "/mrl:mimo-groups/mrl:mimo-group/mrl:name";
      }
      description
        "A reference to the MIMO group used in this
         radio link terminal. One group can be used by more
         than one terminal.";
    }

    list tdm-connections {
      if-feature tdm;
      key "tdm-type";
      description
       "A list stating the number of TDM connections of a
       specified tdm-type that is supported by the RLT.";
      leaf tdm-type {
        type identityref {
          base tdm-type;
        }
        description
          "The type of TDM connection, which also indicates
          the supported capacity.";
      }

      leaf tdm-connections {
        type uint16;
        mandatory true;
        description "Number of connections of the specified type.";
      }
    }
  }
```

```
  /*
   * Carrier Termination - Configuration data nodes
   */

  augment "/if:interfaces/if:interface" {
    when "if:type = 'mrl:carrier-termination'";
    description
      "Addition of data nodes for carrier termination to
      the standard Interface data model, for interfaces
      of the type 'carrier-termination'.";
    leaf carrier-id {
      type string;
      default "A";
      description
        "ID of the carrier. (e.g. A, B, C or D)
         Used in XPIC & MIMO configurations to check that
         the carrier termination is connected to the correct
         far-end carrier termination. Should be the same
         carrier ID on both sides of the hop.
         Defaulted when not MIMO or XPIC.";
    }

    leaf tx-enabled {
      type boolean;
      default "false";
      description
        " Disables (false) or enables (true) the
        transmitter.Only applicable when the interface
        is enabled (interface:enabled = true) otherwise
        it's always disabled.";
    }

    leaf tx-frequency {
      type uint32;
      units "kHz";
      mandatory true;
      description
        "Selected transmitter frequency.";
    }
```

```
    leaf rx-frequency {
      type uint32;
      units "kHz";
      description
        "Selected receiver frequency.
         Mandatory and writeable when rx-frequency-config=true.
         Otherwise read-only and calculated from tx-frequency
         and duplex-distance.";
    }

    leaf rx-frequency-config {
      type boolean;
      default "true";
      description
        "Enable (true) or disable (false) direct
         configuration of rx-frequency and instead
         using a defined duplex distance.";
    }

    leaf duplex-distance {
      when "../rx-frequency-config = 'false'";
      type uint32;
      units "kHz";
      mandatory true;
      description
        "Distance between Tx & Rx frequencies.
         Used to calaculate rx-frequency when
         rx-frequency-config=false.";
    }

    leaf channel-separation {
      type decimal64 {
        fraction-digits 1;
      }
      units "MHz";
      mandatory true;
      description
        "The amount of bandwidth allocated to a carrier.";
    }

    leaf polarization {
      type enumeration {
        enum "horizontal" {
          description "Horizontal polarization.";
        }
```

```
        enum "vertical" {
          description "Vertical polarization.";
        }
        enum "not-specified" {
          description "Polarization not specified.";
        }
      }
      default "not-specified";
      description
        "Polarization - A textual description for info only.";
    }

    leaf power-mode {
      type enumeration {
        enum rtpc {
          description "Remote Transmit Power Control (RTPC).";
        }
        enum atpc {
          description "Automatic Transmit Power Contro
                       (ATPC).";
        }
      }
      mandatory true;
      description
        "A choice of Remote Transmit Power Control (RTPC)
         or Automatic Transmit Power Control (ATPC).";
    }

    leaf selected-output-power {
      type power {
        range "-99..40";
      }
      units "dBm";
      mandatory true;
      description
        "Selected output power in RTPC mode and selected
        maximum selected maximum output power in ATPC mode.
        Minimum ouput power in ATPC mode is the same as the
        system capability, available-min-output-power.";
    }

    leaf atpc-lower-threshold {
      when "../power-mode = 'atpc'";
      type power {
        range "-99..-30";
      }
      units "dBm";
```

```
      mandatory true;
      description
        "The lower threshold for the input power at far-end used in
        the ATPC mode.";
    }

    leaf atpc-upper-threshold {
      when "../power-mode = 'atpc'";
      type power {
        range "-99..-30";
      }
      units "dBm";
      mandatory true;
      description
        "The upper threshold for the input power
         at far-end used in the ATPC mode.";
    }

    leaf coding-modulation-mode {
      type enumeration {
        enum fixed {
          description "Fixed coding/modulation.";
        }
        enum adaptive {
          description "Adaptive coding/modulation.";
        }
      }
      mandatory true;
      description
        "A selection of fixed or
         adaptive coding/modulation mode.";
    }

    leaf selected-cm {
      when "../coding-modulation-mode = 'fixed'";
      type identityref {
        base coding-modulation;
      }
      mandatory true;
      description
        "Selected fixed coding/modulation.";
    }
```

```
    leaf selected-min-acm {
      when "../coding-modulation-mode = 'adaptive'";
      type identityref {
        base coding-modulation;
      }
      mandatory true;
      description
        "Selected minimum coding/modulation.
         Adaptive coding/modulation shall not go
         below this value.";
    }

    leaf selected-max-acm {
      when "../coding-modulation-mode = 'adaptive'";
      type identityref {
        base coding-modulation;
      }
      mandatory true;
      description
        "Selected maximum coding/modulation.
         Adaptive coding/modulation shall not go
         above this value.";
    }

    leaf if-loop {
      type enumeration {
        enum disabled {
          description "Disables the IF Loop.";
        }
        enum client {
          description "Loops the signal back to the client side.";
        }
        enum radio {
          description "Loops the signal back to the radio side.";
        }
      }
      default "disabled";
      description
        "Enable (client/radio) or disable (disabled) the IF loop,
        which loops the signal back to the client side or the
        radio side.";
    }
```

```
    leaf rf-loop {
      type enumeration {
        enum disabled {
          description "Disables the RF Loop.";
        }
        enum client {
          description "Loops the signal back to the client side.";
        }
        enum radio {
          description "Loops the signal back to the radio side.";
        }
      }
      default "disabled";
      description
        "Enable (client/radio) or disable (disabled) the RF loop,
        which loops the signal back to the client side or
        the radio side.";
    }

    container ct-performance-thresholds {
      description
        "Specification of thresholds for when alarms should
         be sent and cleared for various performance counters.";

      leaf received-level-alarm-threshold {
        type power {
          range "-99..-30";
        }
        units "dBm";
        default "-99";
        description
          "Specification of at which received power level an alarm
          should be raised.";
      }

      leaf transmitted-level-alarm-threshold {
        type power {
          range "-99..40";
        }
        units "dBm";
        default "-99";
        description
          "An alarm is sent when the transmitted power level
           is below the specified threshold.";
      }
```

```
      leaf ber-alarm-threshold {
        type enumeration {
          enum "10e-9" {
            description "Threshold at 10e-9.";
          }
          enum "10e-8" {
            description "Threshold at 10e-8.";
          }
          enum "10e-7" {
            description "Threshold at 10e-7.";
          }
          enum "10e-6" {
            description "Threshold at 10e-6.";
          }
          enum "10e-5" {
            description "Threshold at 10e-5.";
          }
          enum "10e-4" {
            description "Threshold at 10e-4.";
          }
          enum "10e-3" {
            description "Threshold at 10e-3.";
          }
          enum "10e-2" {
            description "Threshold at 10e-2.";
          }
          enum "10e-1" {
            description "Threshold at 10e-1.";
          }
        }
        default "10e-6";
        description
          "Specification of at which BER an alarm should
           be raised.";
      }
    }
  }

  /*
   * Radio Link Terminal - Operational state data nodes
   * Currently nothing in addition to the general
   * interface-state model.
   */

  /*
   * Carrier Termination - Operational state data nodes
   */
```

```
  augment "/if:interfaces-state/if:interface" {
    when "if:type = 'mrl:carrier-termination'";
    description
      "Addition of state data nodes for carrier termination to
       the standard Interface state data model, for interfaces
       of the type 'carrier-termination'.";

    leaf tx-oper-status {
      type enumeration {
        enum "off" {
          description "Transmitter is off.";
        }
        enum "on" {
          description "Transmitter is on.";
        }
        enum "standby" {
          description "Transmitter is in standby.";
        }
      }
      description
        "Shows the operative status of the transmitter.";
    }

    leaf actual-transmitted-level {
        type power {
          range "-99..40";
        }
      units "dBm";
      description
        "Actual transmitted power level (0.1 dBm resolution).";
    }

    leaf actual-received-level {
      type power {
        range "-99..-20";
      }
      units "dBm";
      description
        "Actual received power level (0.1 dBm resolution).";
    }

    leaf actual-tx-cm {
      type identityref {
         base coding-modulation;
      }
      description
        "Actual coding/modulation in transmitting direction.";
    }
```

```
    leaf actual-snir {
      type decimal64 {
        fraction-digits 1;
        range "0..99";
      }
      units "dB";
      description
        "Actual signal to noise plus interference ratio.
         (0.1 dB resolution).";
    }

    leaf actual-xpi {
      if-feature xpic;
      type decimal64 {
        fraction-digits 1;
        range "0..99";
      }
      units "dB";
      description
        "The actual carrier to cross-polar interference.
         Only valid if XPIC is enabled. (0.1 dB resolution).";
    }

    container capabilities {
      description
        "Capabilities of the the installed equipment and
         some selected configurations.";

      leaf min-tx-frequency {
        type uint32;
        units "kHz";
        description
          "Minimum Tx frequency possible to use.";
      }

      leaf max-tx-frequency {
        type uint32;
        units "kHz";
        description
          "Maximum Tx frequency possible to use.";
      }
```

```
      leaf min-rx-frequency {
        type uint32;
        units "kHz";
        description
          "Minimum Rx frequency possible to use.";
      }

      leaf max-rx-frequency {
        type uint32;
        units "kHz";
        description
          "Maximum Tx frequency possible to use.";
      }

      leaf available-min-output-power {
        type power;
        units "dBm";
        description
          "The minimum output power supported.";
      }

      leaf available-max-output-power {
        type power;
        units "dBm";
        description
          "The maximum output power supported.";
      }

      leaf available-min-acm {
        type identityref {
          base coding-modulation;
        }
        description
          "Minimum coding-modulation possible to use.";
      }

      leaf available-max-acm {
        type identityref {
          base coding-modulation;
        }
        description
          "Maximum coding-modulation possible to use.";
      }
    }
  }
```

```
  augment "/if:interfaces-state/if:interface/if:statistics" {
    when "../if:type = 'mrl:carrier-termination'";
    description
      "Addition of state data nodes in the container statistics
       for carrier terminations to the standard Interface data
       model, for interfaces of the type 'carrier-termination'.";

    leaf bbe {
      type yang:counter32;
      units "number of block errors";
      description
        "Number of Background Block Errors (BBE) during the
        interval. A BBE is an errored block not occurring as
        part of an SES.";
    }

    leaf es {
      type yang:counter32;
      units "seconds";
      description
      "Number of Errored Seconds (ES) since last
       reset. An ES is a one-second period with
       one or more errored blocks or at least one
       defect.";
      }

    leaf ses {
      type yang:counter32;
      units "seconds";
      description
        "Number of Severely Errored Seconds (SES) during the
         interval. SES is a one-second period which contains
         equal or more than 30% errored blocks or at least
         one defect. SES is a subset of ES.";
    }

    leaf uas {
      type yang:counter32;
      units "seconds";
      description
        "Number of Unavailable Seconds (UAS), that is, the
         total time that the node has been unavailable during
         a fixed measurement interval.";
    }
```

```
    leaf min-rltm {
      type power {
        range "-99..-20";
      }
      units "dBm";
      description
        "Minimum received power level since last reset.";
    }

    leaf max-rltm {
      type power {
        range "-99..-20";
      }
      units "dBm";
      description
        "Maximum received power level since last reset.";
    }

    leaf min-tltm {
      type power {
        range "-99..40";
      }
      units "dBm";
      description
        "Minimum transmitted power level since last reset.";
    }

    leaf max-tltm {
      type power {
        range "-99..40";
      }
      units "dBm";
      description
        "Maximum transmitted power level since last reset.";
    }
  }

  /*
   * Radio Link Protection Groups - Configuration data nodes
   */

  container radio-link-protection-groups {
    description
      "Configuration of radio link protected groups
      (1+1) of carrier terminations in a radio link.
      More than one protected group per radio-link-terminal
      is allowed.";
```

```
    list radio-link-protection-group {
      key "name";
      description
      "List of protected groups of carrier terminations
      in a radio link.";

      leaf name {
        type string;
        description
          "Name used for identification of the radio
           link protection group";
      }

      leaf protection-architecture-type {
        type identityref{
          base protection-architecture-type;
        }
        default "one-plus-one-type";
        description
          "The type of protection architecture
          used, e.g. one carrier termination
          protecting one carrier termination.";
      }

      leaf protection-operation-type {
        type enumeration {
          enum "non-revertive" {
            description
              "In non revertive operation, the
              traffic does not return to the
              working carrier termination if the
              switch requests are terminated. ";
              }
          enum "revertive" {
            description
              "In revertive operation, the
              traffic always returns to (or
              remains on) the working carrier
              termination if the switch requests
              are terminated. ";
            }
          }
          default "non-revertive";
          description
            "The type of protection operation, i.e.
            revertive or non-revertive operation.";
          }
```

```
      leaf-list working-entity  {
        when "../protection-operation-type =  'revertive'";
        type if:interface-ref;
        must "/if:interfaces/if:interface[if:name = current()]"
           + "/if:type = 'mrl:carrier-termination'" {
           description
             "The type of a working-entity must be
             'carrier-termination'.";
           }
           min-elements 1;
           description
           "The carrier terminations over which the
           traffic normally should be transported
           over when there is no need to use the
           protecting carrier termination.";
        }

      leaf revertive-wait-to-restore {
        when "../protection-operation-type = 'revertive'";
        type uint16;
        units "seconds";
        default "0";
        description
          "The time to wait before switching back
          to the working carrier termination if
          protection-operation-type is revertive.";
        }

      leaf-list radio-link-protection-members {
        type if:interface-ref;
        must "/if:interfaces/if:interface[if:name = current()]"
          + "/if:type = 'mrl:carrier-termination'" {
          description
            "The type of a protection member must
            be 'carrier-termination'.";
          }
          min-elements 2;
          description
            "Association to a group of carrier
            terminations configured for radio link
            protection and used in the radio link terminal.";
        }
```

```
      action protection-external-commands {
        input {
          leaf protection-external-command {
            type identityref {
              base protection-external-commands;
            }
            description
              "Execution of protection external
               commands for trouble shooting purpose.";
          }
        }
      }
    }
}

  /*
  * Radio Link Protection - Operational state data nodes
  */
  container radio-link-protection-groups-state {
    config false;
    description
      "State data for radio link protected groups
      of carrier terminations in a radio link.";
      list radio-link-protection-group {
        key "name";
        description
          "List of protected groups of carrier
          terminations in a radio link.";

      leaf name {
        type string;
        description
          "Name used for identification of the
           radio link protection group.";
      }

      leaf protection-status {
        type identityref {
          base protection-states;
        }
        description
          "Status of the protection, in a group of
          carrier terminations configured in a
          radio link protection mode.";
        }
    }
  }
```

```
  /*
  * XPIC & MIMO - Configuration data nodes
  */

  container xpic-pairs {
    if-feature xpic;
      description
        "Configuration of carrier termination pairs
        for operation in XPIC mode.";

    list xpic-pair {
      key "name";
      description
        "List of carrier termination pairs in XPIC mode.";

    leaf name {
      type string;
      description
        "Name used for identification of the XPIC pair.";
    }
    leaf enabled {
        type boolean;
        default "false";
        description
          "Enable(true)/disable(false) XPIC";
      }

      leaf-list xpic-members {
        type if:interface-ref;
        must "/if:interfaces/if:interface[if:name = current()]"
          + "/if:type = 'mrl:carrier-termination'" {
          description
            "The type of a xpic-member must be
            'carrier-termination'.";
          }
          min-elements 2;
          max-elements 2;
          description
            "Association to XPIC pairs used in the
            radio link terminal.";
           }
         }
  }
```

```
  container mimo-groups {
    if-feature mimo;
    description
      "Configuration of carrier terminations
      for operation in MIMO mode.";

      list mimo-group {
        key "name";
        description
          "List of carrier terminations in MIMO mode.";

      leaf name {
        type string;
        description
        "Name used for identification of the MIMO group.";
      }

      leaf enabled {
        type boolean;
        default "false";
        description
          "Enable(true)/disable(false) MIMO";
    }

      leaf-list mimo-members {
        type if:interface-ref;
        must "/if:interfaces/if:interface[if:name = current()]"
           + "/if:type = 'mrl:carrier-termination'" {
           description
             "The type of a mimo-member must be
             'carrier-termination'.";
           }
           min-elements 2;
           description
             "Association to a MIMO group if used in
             the radio link terminal.";

        }
      }
    }
}
<CODE ENDS>
```

5. 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 operations and content.

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., <edit-config>) to these data nodes without proper protection can have a negative effect on network operations.

The security considerations of [RFC7223] also apply to this document.

6. IANA Considerations

TBD.

7. References

7.1. Normative References

[RFC7223] Bjorklund M., "A YANG Data Model for Interface Management", RFC 7223, DOI 10.17487/RFC7223, May 2014, <http://www.rfc-editor.org/info/rfc7223>.

7.2. Informative References

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Ahlberg J., et al., " A framework for Management and Control of microwave and millimeter wave interface parameters ", draft-ietf-ccamp-microwave-framework-00 (work in progress), December 2016.

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Ahlberg J., Carlson J., Lund H., Olausson T., Ye M., and Vaupotic M., "Microwave Radio Link YANG Data Models", draft-ahlberg-ccamp-microwave-radio-link-01 (work in progress), May 2016.

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[RFC6241] Enns, R., Bjorklund, M., Schoenwaelder, J., and A.Bierman, "Network Configuration Protocol (NETCONF)",RFC 6241, June 2011.

[RFC6242] Wasserman, M., "Using the NETCONF Protocol over SecureShell (SSH)", RFC 6242, June 2011.

[RFC6536] Bierman, A. and M. Bjorklund, "Network ConfigurationProtocol (NETCONF) Access Control Model", RFC 6536,March 2012.

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March 11, 2017

OTN Tunnel YANG Model
draft-sharma-ccamp-otn-tunnel-model-01

Abstract

This document describes the YANG data model for OTN Tunnels.

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. 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, which is an abstract model to create TE Tunnels.

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 . 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. Model Overview

3.1. Mux Service in Multi-Domain OTN Network

```
                                OTN Mux Service
                    <---------------------------------->

    XXXXXXXXXXX          XXXXXXXXXXXXXXXXXXXXXXXXX         XXXXXXXXX
   XX         XX       XX                        XX      XX         XX
  XX   +---+    X      XX +---+           +---+    X     XX  +---+   XX
  X    |NE1+--------+-----+NE2+-----------+NE3+--------+-X---+NE4|    X
  X    +---+   XX   ^  X  +---+           +---+   XX   ^ XX  +---+    X
   XX         XX    |   XX                       XX    |  XX        XX
    XXXXXXXXXXX     |    XXXXXXXXXXXXXXXXXXXXXXXXX     |   XXXXXXXXX
      Domain-1      |            Domain-2              |    Domain-3
                    +                                  +
         Same OTN Service attributes:      Same OTN Service attributes:
         1. Client Signal                  1. Client Signal
         2. Tributary Port Number          2. Tributary Port Number
         3. Tributary Slot Granularity     3. Tributary Slot Granularity
         4. Tributary Slots                4. Tributary Slots
```

Figure 1: OTN Mux Service in a multi-domain network topology

Figure 1 shows a multi-domain OTN network with three domains. In this example, user wants to setup an end-to-end OTN service that passes through Domain-2. In order to create an OTN mux service in Domain-2, user will need to specify the exact details of the client side LO-ODU on NE2 and NE3, so that these service endpoints can be paired with the LO-ODU endpoints on NE1 and NE4, respectively.

Let’s assume that ODU4 is the client side HO-ODU on NE2 and NE3, and the client signal is ODU2. User will need to specify the OTN client signal (ODU2 in this example), the Tributary Port Number (TPN), Tributary Slot Granularities (TSG) and tributary slots to be used.

As shown in the figure above, these service parameters must be the same between NE1 and NE2, and NE3 and NE4.

Once the OTN Mux service is setup in Domain-2, the incoming signal from either NE1 and/or NE4 will be switched inside Domain-2, and delivered to NE at the other end.

3.2. Bookended and Non-BookEnded OTN Tunnel

OTN tunnel model provides support for both bookended and non-bookended OTN tunnels.

For bookended tunnels, the same client signal is present on source and destination endpoints. For example, ODU2e bookended tunnel will have the same ODU2e client signal at both source and destination endpoints.

For non-bookended tunnels, different client signals are present on source and destination endpoints. For example, the client signal can be ODU2e on the source endpoint and the handoff at the destination can be 10GbE-LAN client signal.

3.3. Network and Client side tunnel services

The OTN tunnel model provides support for both network to network and client to client tunnels. For network to network tunnel, network termination points on source and destination node represent source and destination endpoints. For client to client tunnel, client termination points on source and destination node represent source and destination endpoints.

If a client to client tunnel needs to use one or more HO (or server) network to network tunnels, ERO and routing constraints, defined in the base TE model, can be used to route the client tunnel over one or more server tunnels.

3.4. OTN Tunnel YANG Tree

```
module: ietf-otn-tunnel
augment /te:te/te:tunnels/te:tunnel/te:config:
      +--rw payload-treatment?     enumeration
      +--rw src-client-signal?     identityref
      +--rw src-tpn?               uint16
      +--rw src-tsg?               identityref
      +--rw src-tributary-slot-count?    uint16
      +--rw src-tributary-slots
      |  +--rw values*   uint8
      +--rw dst-client-signal?     identityref
      +--rw dst-tpn?               uint16
      +--rw dst-tsg?               identityref
      +--rw dst-tributary-slot-count?    uint16
      +--rw dst-tributary-slots
         +--rw values*   uint8
augment /te:te/te:tunnels/te:tunnel/te:state:
      +--ro payload-treatment?     enumeration
      +--ro src-client-signal?     identityref
      +--ro src-tpn?               uint16
      +--ro src-tsg?               identityref
      +--ro src-tributary-slot-count?    uint16
      +--ro src-tributary-slots
      |  +--ro values*   uint8
      +--ro dst-client-signal?     identityref
      +--ro dst-tpn?               uint16
      +--ro dst-tsg?               identityref
      +--ro dst-tributary-slot-count?    uint16
      +--ro dst-tributary-slots
         +--ro values*   uint8
```

3.5. OTN Tunnel YANG Code

```
  <CODE BEGINS>file "ietf-otn-tunnel@2017-03-11.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-transport-types { prefix "tran-types"; }
    //import yang-ext { prefix ext; revision-date 2013-07-09; }

    organization
```

```
        "IETF CCAMP Working Group";

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

        Editor: Anurag Sharma
                <mailto:AnSharma@infinera.com>

        Editor: Rajan Rao
                <mailto:rrao@infinera.com>

        Editor: Xian Zhang
                <mailto:zhang.xian@huawei.com>

        Editor: Kun Xiang
                <mailto:xiangkun@huawei.com>";

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

    revision "2017-03-11" {
        description
            "Revision 0.3";
        reference "TBD";
    }

    grouping otn-tunnel-endpoint {
        description "Parameters for OTN tunnel.";

                leaf payload-treatment {
            type enumeration {
                enum switching;
                enum transport;
            }
            default switching;
            description
                "Treatment of the incoming payload. Payload can
                either be switched, or transported as is.";
        }

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

```
        }

        leaf src-tpn {
            type uint16 {
                range "0..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 src-tsg {
            type identityref {
                base tran-types:tributary-slot-granularity;
            }
            description
                "Tributary slot granularity. Applicable in case of mux
                services.";
            reference
                "G.709/Y.1331, February 2016: Interfaces for the
                Optical Transport Network (OTN)";
        }

        leaf src-tributary-slot-count {
                type uint16;
                description
                        "Number of tributary slots used at the source.";
        }

        container src-tributary-slots {
            description
                "A list of tributary slots used by the client
                service. Applicable in case of mux services.";
            leaf-list values {
                type uint8;
                description
                        "Tributary tributary slot value.";
                reference
                    "G.709/Y.1331, February 2016: Interfaces for the
                        Optical Transport Network (OTN)";
            }
        }

        leaf dst-client-signal {
            type identityref {
```

```
                    base tran-types:client-signal;
            }
            description
                    "Client signal at the destination endpoint of
                    the tunnel.";
        }

        leaf dst-tpn {
            type uint16 {
                range "0..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 dst-tsg {
            type identityref {
                base tran-types:tributary-slot-granularity;
            }
            description
                "Tributary slot granularity. Applicable in case of mux
                services.";
            reference
                "G.709/Y.1331, February 2016: Interfaces for the
                Optical Transport Network (OTN)";
        }

        leaf dst-tributary-slot-count {
            type uint16;
            description
                "Number of tributary slots used at the destination.";
        }

        container dst-tributary-slots {
            description
                "A list of tributary slots used by the client
                service. Applicable in case of mux services.";
            leaf-list values {
                type uint8;
                description
                        "Tributary slot value.";
                reference
                    "G.709/Y.1331, February 2016: Interfaces for the
                        Optical Transport Network (OTN)";
```

```
            }
        }
    }

    /*
    Note: Comment has been given to authors of TE Tunnel model to add
    tunnel-types to the model in order to identify the technology
    type of the service.

    grouping otn-service-type {
        description
          "Identifies the OTN Service type.";
        container otn-service {
          presence "Indicates OTN Service.";
          description
            "Its presence identifies the OTN Service type.";
        }
      } // otn-service-type

    augment "/te:te/te:tunnels/te:tunnel/te:tunnel-types" {
        description
                "Introduce OTN service type for tunnel.";
        ext:augment-identifier otn-service-type-augment;
        uses otn-service-type;
    }
    */

    /*
    Note: Comment has been given to authors of TE Tunnel model to add
    list of endpoints under config to support P2MP tunnel.
    */
    augment "/te:te/te:tunnels/te:tunnel/te:config" {
        description
                "Augment with additional parameters required for OTN
                service.";
        //ext:augment-identifier otn-tunnel-endpoint-config-augment;
        uses otn-tunnel-endpoint;
    }

    augment "/te:te/te:tunnels/te:tunnel/te:state" {
        description
                "Augment with additional parameters required for OTN
                service.";
        //ext:augment-identifier otn-tunnel-endpoint-state-augment;
        uses otn-tunnel-endpoint;
    }

    /*
```

```
    Note: Comment has been given to authors of TE Tunnel model to add
    tunnel-lifecycle-event to the model. This notification is reported
    for all lifecycle changes (create, delete, and update) to the
    tunnel or lsp.
    augment "/te:tunnel-lifecycle-event" {
        description
          "OTN service event";
        uses otn-service-type;
        uses otn-tunnel-params;

        list endpoint {
          key
            "endpoint-address tp-id";
          description
            "List of Tunnel Endpoints.";
          uses te:tunnel-endpoint;
          uses otn-tunnel-params;
        }
      }
    */
}

<CODE ENDS>
```

3.6. Transport Types YANG Code

```
   <CODE BEGINS> file "ietf-transport-types@2016-10-25.yang"

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

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

         Editor: Anurag Sharma
                 <mailto:AnSharma@infinera.com>

         Editor: Rajan Rao
                 <mailto:rrao@infinera.com>

         Editor: Xian Zhang
```

```
                 <mailto:zhang.xian@huawei.com>";

     description
         "This module defines transport types.";

     revision "2016-10-25" {
         description
             "Revision 0.2";
         reference "TBD";
     }

     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 tributary-protocol-type {
         description
                 "Base identity for protocol framing used by
                 tributary signals.";
     }

     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)";
    }

    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).";
     }

     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.";
       }

     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.";
    }
}
 <CODE ENDS>
```

4. Security Considerations

TBD.

5. IANA Considerations

TBD.

6. Acknowledgements

TBD.

7. Normative References

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[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <http://www.rfc-editor.org/info/rfc2119>.

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                                                            May 25, 2017

OTN Tunnel YANG Model
draft-sharma-ccamp-otn-tunnel-model-02

Abstract

This document describes the YANG data model for OTN Tunnels.

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].

Status of This Memo

Table of Contents

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, which is an abstract model to create TE Tunnels.

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-rfc6087bis]. 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. Model Overview

3.1. Mux Service in Multi-Domain OTN Network

```
                              OTN Mux Service
                        <---------------------------------->

     XXXXXXXXXXX         XXXXXXXXXXXXXXXXXXXXXXXXX        XXXXXXXXX
    XX         XX       XX                       XX      XX         XX
   XX   +---+    X      XX +---+          +---+    X     XX  +---+   XX
   X    |NE1+--------+-----+NE2+-----------+NE3+--------+-X---+NE4|    X
   X    +---+   XX   ^  X  +---+          +---+   XX   ^ XX  +---+    X
    XX         XX    |   XX                      XX    |  XX        XX
     XXXXXXXXXXX     |    XXXXXXXXXXXXXXXXXXXXXXXXX    |   XXXXXXXXX
       Domain-1      |             Domain-2            |    Domain-3
                     +                                 +
         Same OTN Service attributes:      Same OTN Service attributes:
         1. Client Signal                  1. Client Signal
         2. Tributary Port Number          2. Tributary Port Number
         3. Tributary Slot Granularity     3. Tributary Slot Granularity
         4. Tributary Slots                4. Tributary Slots
```

Figure 1: OTN Mux Service in a multi-domain network topology

Figure 1 shows a multi-domain OTN network with three domains. In this example, user wants to setup an end-to-end OTN service that passes through Domain-2. In order to create an OTN mux service in Domain-2, user will need to specify the exact details of the client side LO-ODU on NE2 and NE3, so that these service endpoints can be paired with the LO-ODU endpoints on NE1 and NE4, respectively.

Let’s assume that ODU4 is the client side HO-ODU on NE2 and NE3, and the client signal is ODU2. User will need to specify the OTN client signal (ODU2 in this example), the Tributary Port Number (TPN), Tributary Slot Granularities (TSG) and tributary slots to be used. As shown in the figure above, these service parameters must be the same between NE1 and NE2, and NE3 and NE4.

Once the OTN Mux service is setup in Domain-2, the incoming signal from either NE1 and/or NE4 will be switched inside Domain-2, and delivered to NE at the other end.

3.2. Bookended and Non-BookEnded OTN Tunnel

OTN tunnel model provides support for both bookended and non-bookended OTN tunnels.

For bookended tunnels, the same client signal is present on source and destination endpoints. For example, ODU2e bookended tunnel will have the same ODU2e client signal at both source and destination endpoints.

For non-bookended tunnels, different client signals are present on source and destination endpoints. For example, the client signal can be ODU2e on the source endpoint and the handoff at the destination can be 10GbE-LAN client signal.

3.3. Network and Client side tunnel services

The OTN tunnel model provides support for both network to network and client to client tunnels. For network to network tunnel, network termination points on source and destination node represent source and destination endpoints. For client to client tunnel, client termination points on source and destination node represent source and destination endpoints.

If a client to client tunnel needs to use one or more HO (or server) network to network tunnels, ERO and routing constraints, defined in the base TE model, can be used to route the client tunnel over one or more server tunnels.

3.4. OTN Tunnel YANG Tree

```
   module: ietf-otn-tunnel
   augment /te:te/te:tunnels/te:tunnel/te:config:
         +--rw payload-treatment?     enumeration
         +--rw src-client-signal?     identityref
         +--rw src-tpn?               uint16
         +--rw src-tsg?               identityref
         +--rw src-tributary-slot-count?    uint16
         +--rw src-tributary-slots
         |  +--rw values*   uint8
         +--rw dst-client-signal?     identityref
         +--rw dst-tpn?               uint16
         +--rw dst-tsg?               identityref
         +--rw dst-tributary-slot-count?    uint16
         +--rw dst-tributary-slots
            +--rw values*   uint8
   augment /te:te/te:tunnels/te:tunnel/te:state:
         +--ro payload-treatment?     enumeration
         +--ro src-client-signal?     identityref
         +--ro src-tpn?               uint16
         +--ro src-tsg?               identityref
         +--ro src-tributary-slot-count?    uint16
         +--ro src-tributary-slots
         |  +--ro values*   uint8
         +--ro dst-client-signal?     identityref
         +--ro dst-tpn?               uint16
         +--ro dst-tsg?               identityref
         +--ro dst-tributary-slot-count?    uint16
         +--ro dst-tributary-slots
            +--ro values*   uint8
```

3.5. OTN Tunnel YANG Code

```
   <CODE BEGINS>file "ietf-otn-tunnel@2017-05-25.yang"

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

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

       import ietf-te { prefix "te"; }
       import ietf-transport-types { prefix "tran-types"; }
       //import yang-ext { prefix ext; revision-date 2013-07-09; }
```

```
       organization
           "IETF CCAMP Working Group";

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

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

           Editor: Zheyu Fan
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                   <mailto:rrao@infinera.com>

           Editor: Sergio Belotti
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           Editor: Victor Lopez
                   <mailto:victor.lopezalvarez@telefonica.com>

           Editor: Yunbo Li
                   <mailto:liyunbo@chinamobile.com>";

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

       revision "2017-05-25" {
           description
               "Revision 0.3";
           reference
               "draft-sharma-ccamp-otn-tunnel-model-02.txt";
       }

       grouping otn-tunnel-endpoint {
           description "Parameters for OTN tunnel.";

           leaf payload-treatment {
               type enumeration {
                   enum switching;
                   enum transport;
               }
               default switching;
               description
```

```
                "Treatment of the incoming payload. Payload can
                either be switched, or transported as is.";
        }

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

        leaf src-tpn {
            type uint16 {
                range "0..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 src-tsg {
            type identityref {
                base tran-types:tributary-slot-granularity;
            }
            description
                "Tributary slot granularity. Applicable in case of
                 mux services.";
            reference
                "G.709/Y.1331, February 2016: Interfaces for the
                Optical Transport Network (OTN)";
        }

        leaf src-tributary-slot-count {
                type uint16;
                description
                    "Number of tributary slots used at the source.";
        }

        container src-tributary-slots {
            description
                "A list of tributary slots used by the client
                service. Applicable in case of mux services.";
            leaf-list values {
```

```
                   type uint8;
                   description
                           "Tributary tributary slot value.";
                   reference
                       "G.709/Y.1331, February 2016: Interfaces for the
                           Optical Transport Network (OTN)";
               }
           }

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

           leaf dst-tpn {
               type uint16 {
                   range "0..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 dst-tsg {
               type identityref {
                   base tran-types:tributary-slot-granularity;
               }
               description
                   "Tributary slot granularity. Applicable in case of
                    mux services.";
               reference
                   "G.709/Y.1331, February 2016: Interfaces for the
                    Optical Transport Network (OTN)";
           }

           leaf dst-tributary-slot-count {
               type uint16;
               description
                   "Number of tributary slots used at the destination.";
           }
```

```
            container dst-tributary-slots {
                description
                    "A list of tributary slots used by the client
                    service. Applicable in case of mux services.";
                leaf-list values {
                    type uint8;
                    description
                            "Tributary slot value.";
                    reference
                        "G.709/Y.1331, February 2016: Interfaces for the
                            Optical Transport Network (OTN)";
                }
            }
        }

        /*
        Note: Comment has been given to authors of TE Tunnel model to add
        tunnel-types to the model in order to identify the technology
        type of the service.

        grouping otn-service-type {
            description
              "Identifies the OTN Service type.";
            container otn-service {
              presence "Indicates OTN Service.";
              description
                "Its presence identifies the OTN Service type.";
            }
          } // otn-service-type

        augment "/te:te/te:tunnels/te:tunnel/te:tunnel-types" {
            description
                    "Introduce OTN service type for tunnel.";
            ext:augment-identifier otn-service-type-augment;
            uses otn-service-type;
        }
        */

        /*
        Note: Comment has been given to authors of TE Tunnel model to add
        list of endpoints under config to support P2MP tunnel.
        */
        augment "/te:te/te:tunnels/te:tunnel/te:config" {
            description
                    "Augment with additional parameters required for OTN
                    service.";
            //ext:augment-identifier otn-tunnel-endpoint-config-augment;
            uses otn-tunnel-endpoint;
```

```
       }

       augment "/te:te/te:tunnels/te:tunnel/te:state" {
           description
                   "Augment with additional parameters required for OTN
                   service.";
           //ext:augment-identifier otn-tunnel-endpoint-state-augment;
           uses otn-tunnel-endpoint;
       }

       /*
       Note: Comment has been given to authors of TE Tunnel model to
       add tunnel-lifecycle-event to the model. This notification is
       reported for all lifecycle changes (create, delete, and update)
       to the tunnel or lsp.
       augment "/te:tunnel-lifecycle-event" {
           description
             "OTN service event";
           uses otn-service-type;
           uses otn-tunnel-params;

           list endpoint {
             key
               "endpoint-address tp-id";
             description
               "List of Tunnel Endpoints.";
             uses te:tunnel-endpoint;
             uses otn-tunnel-params;
           }
         }
       */
   }
   <CODE ENDS>
```

3.6. Transport Types YANG Code

```
   <CODE BEGINS> file "ietf-transport-types@2017-05-25.yang"

   module ietf-transport-types {
       namespace "urn:ietf:params:xml:ns:yang:ietf-transport-types";
       prefix "tran-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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            Editor: Victor Lopez
                    <mailto:victor.lopezalvarez@telefonica.com>

            Editor: Yunbo Li
                    <mailto:liyunbo@chinamobile.com>";

        description
            "This module defines transport types.";

        revision "2017-05-25" {
            description
                "Revision 0.3";
            reference
                "draft-sharma-ccamp-otn-tunnel-model-02.txt";
        }

        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 tributary-protocol-type {
            description
                "Base identity for protocol framing used by
                 tributary signals.";
        }

        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)";
       }

       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).";
        }

        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.";
         }

       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.";
        }
    }
    <CODE ENDS>
```

4. Security Considerations

TBD.

5. IANA Considerations

TBD.

6. Acknowledgements

TBD.

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Transport Northbound Interface Use Cases
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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 describes the key use cases and requirements for transport network control and management. It reviews proposed and existing IETF transport network data models, their applicability, and highlights gaps and requirements.

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Table of Contents

1. Introduction

A common open interface to each domain controller/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 assumes a reference architecture, including interfaces, based on the Abstraction and Control of Traffic-Engineered Networks (ACTN), defined in [ACTN-Frame].

The focus of the current version is on the MPI (interface between the Multi Domain Service Coordinator (MDSC) and a Physical Network Controller (PNC), controlling a transport network domain).

The relationship between the current IETF YANG models and the type of ACTN interfaces can be found in [ACTN-YANG].

The ONF Technical Recommendations for Functional Requirements for the transport API, may be found in [ONF TR-527]. Furthermore, ONF transport API multi-layer examples may be found in [ONF GitHub].

This document describes use cases that could be used for analyzing the applicability of the existing models defined by the IETF for transport networks

Considerations about the CMI (interface between the Customer Network Controller (CNC) and the MDSC) are for further study.

2. Conventions used in this document

For discussion in future revisions of this document.

3. Use Case 1: Single-domain with single-layer

3.1. Reference Network

The current considerations discussed in this document are based on the following reference networks:

- single transport domain: OTN network

It is expected that future revisions of the document will include additional reference networks.

3.1.1. Single Transport Domain - OTN Network

Figure 1 shows the network physical topology composed of a single-domain transport network providing transport services to an IP network through five access links.

```
        ................................................
        :                 IP domain                    :
        :        ..............................        :
        :        :  ........................  :        :
        :        :  :                      :  :        :
        :        :  :      S1 -------- S2 ------ C-R4  :
        :        :  :     /             |  :  :        :
        :        :  :    /              |  :  :        :
        :  C-R1 ------ S3 ----- S4      |  :  :        :
        :        :  :    \        \     |  :  :        :
        :        :  :     \        \    |  :  :        :
        :        :  :      S5       \   |  :  :        :
        :  C-R2 -----+    /  \       \  |  :  :        :
        :        :  : \  /    \       \ |  :  :        :
        :        :  :  S6 ---- S7 ---- S8 ------ C-R5  :
        :        :  : /                    :  :        :
        :  C-R3 -----+                     :  :        :
        :        :  :   Transport domain   :  :        :
        :        :  :                      :  :        :
        :........:  :......................:  :........:
```

Figure 1 Reference network for Use Case 1

The IP and transport (OTN) domains are respectively composed by five routers C-R1 to C-R5 and by eight ODU switches S1 to S8. The transport domain acts as a transit domain providing connectivity to the IP layer.

The behavior of the transport domain is the same whether the ingress/egress nodes in the IP domain, supporting an IP service, are directly attached to the transport domain or there are other routers in between the ingress/egress nodes of the IP domain and the routers directly attached to the transport network.

```
                             +-----+
                             | CNC |
                             +-----+
                                |
                                |CMI I/F
                                |
                     +-----------------------+
                     |         MDSC          |
                     +-----------------------+
                                |
                                |MPI I/F
                                |
                            +-------+
                            |  PNC  |
                            +-------+
                                |
                              -----
                            (       )
                           (   OTN   )
                          ( Physical  )
                           ( Network )
                            (       )
                              -----
```

Figure 2 Controlling Hierarchy for Use Case 1

The mapping of the client IP traffic on the physical link between the routers and the transport network is made in the IP routers only and is not controlled by the transport PNC and is transparent to the transport nodes.

The control plane architecture follows the ACTN architecture and framework document [ACTN-Frame]. The Client Controller act as a client with respect to the Multi-Domain Service Coordinator (MDSC) via the Controller-MDSC Interface (CMI). The MDSC is connected to a plurality of Physical Network Controllers (PNCs), one for each domain, via a MDSC-PNC Interface (MPI). Each PNC is responsible only for the control of its domain and the MDSC is the only entity capable of multi-domain functionalities as well as of managing the inter-domain links. The key point of the whole ACTN framework is detaching 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.

In this section, we address the case of an IP and a Transport PNC having respectively an IP a Transport MPI. The interface within the scope of this document is the Transport MPI while the IP

Network MPI is out of its scope and considerations about the CMI are for further study.

3.2. Topology Abstractions

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.

[TE-Topo] describes a YANG base model for TE topology without any technology specific parameters. Moreover, it defines how to abstract for TE-network topologies.

[ACTN-Abstraction] 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-Abstraction], there are three types of topology:

- o White topology: This is a case where the Physical Network Controller (PNC) provides the actual network topology to the Multi-domain Service Coordinator (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.

For single-domain with single-layer use-case, the white topology may be disseminated from the PNC to the MDSC in most cases. There may be some exception to this in the case where the underlay network may have complex optical parameters, which do not warrant the distribution of such details to the MDSC. In such case, the topology disseminated from the PNC to the MDSC may not have the entire TE information but a streamlined TE information. This case would for single-domain with single-layer use-case, the white topology may be disseminated from the PNC to the MDSC in most cases. There may be some exception to this in the case where the underlay network may have complex optical parameters, which do not warrant the distribution of such details to the MDSC. In such case, the topology disseminated from the PNC to the MDSC may not have the entire TE information but a streamlined TE information. This case would incur another action from the MDSC's standpoint when provisioning a path. The MDSC may make a path compute request to the PNC to verify the feasibility of the estimated path before making the final provisioning request to the PNC, as outlined in [Path-Compute].

Topology abstraction for the CMI is for further study (to be addressed in future revisions of this document).

3.3. Service Configuration

In the following use cases, the Multi Domain Service Coordinator (MDSC) needs to be capable to request service connectivity from the transport Physical Network Controller (PNC) 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.

As described in section 3.1.1, the control of different adaptations inside IP routers, C-Ri (PKT -> foo) and C-Rj (foo -> PKT), are assumed to be performed by means that are not under the control of, and not visible to, transport PNC. Therefore, these mechanisms are outside the scope of this document.

3.3.1. ODU Transit

This use case assumes that the physical link interconnecting IP routers and transport network is an OTN link.

The physical/optical interconnection is supposed to be a pre-configured and not exposed via MPI to MDSC.

If we consider the case of a 10Gb IP link between C-R1 to C-R3, we need to instantiate an ODU2 end-to-end connection between C-R1 and C-R3, crossing transport nodes S3, S5, and S6.

The traffic flow between C-R1 and C-R3 can be summarized as:

C-R1 (PKT -> ODU2), S3 (ODU2), S5 (ODU2), S6 (ODU2),
C-R3 (ODU2 -> PKT)

The MDSC should be capable via MPI interface to request the setup of ODU2 transit service with enough information that can permit transport PNC to instantiate and control the ODU2 segment through nodes S3, S5, S6.

3.3.2. EPL over ODU

This use case assumes that the physical link interconnecting IP routers and transport network is an Ethernet link.

If we consider the case of a 10Gb IP link between C-R1 to C-R3, we need to instantiate an EPL service between C-R1 and C-R3 supported by an ODU2 end-to-end connection between S3 and S6, crossing transport node S5.

The traffic flow between C-R1 and C-R3 can be summarized as:

C-R1 (PKT -> ETH), S3 (ETH -> ODU2), S5 (ODU2),
S6 (ODU2 -> ETH), C-R3 (ETH-> PKT)

The MDSC should be capable via MPI i/f to request the setup of EPL service with enough information that can permit transport PNC to instantiate and control the ODU2 end-to-end connection through nodes S3, S5, S6, as well as the adaptation functions inside S3 and S6: S3&S6 (ETH -> ODU2) and S9&S6 (ODU2 -> ETH).

3.3.3. Other OTN Client Services

[ITU-T G.709-2016] 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,).

This use case assumes that the physical links interconnecting IP routers and transport network are any one of these possible options.

If we consider the case of a 10Gb IP link between C-R1 to C-R3 using SDH physical links, we need to instantiate an STM-64 Private Line service between C-R1 and C-R3 supported by an ODU2 end-to-end connection between S3 and S6, crossing transport node S5.

The traffic flow between C-R1 and C-R3 can be summarized as:

C-R1 (PKT -> STM-64), S3 (STM-64 -> ODU2), S5 (ODU2),
S6 (ODU2 -> STM-64), C-R3 (STM-64 -> PKT)

The MDSC should be capable via MPI i/f to request the setup of an STM-64 Private Line service with enough information that can permit transport PNC to instantiate and control the ODU2 end-to-end connection through nodes S3, S5, S6, as well as the adaptation functions inside S3 and S6: S3&S6 (STM-64 -> ODU2) and S9&S3 (STM-64 -> PKT).

3.3.4. EVPL over ODU

For future revision.

3.3.5. EVPLAN and EVPTree Services

For future revision.

3.3.6. Virtual Network Services

For future revision

3.4. Multi-functional Access Links

For future revision

4. Use Case 2: Single-domain with multi-layer

For future revision

5. Use Case 3: Multi-domain with single-layer

For future revision

6. Use Case 4: Multi-domain and multi-layer

For future revision

7. Security Considerations

For further study

8. IANA Considerations

This document requires no IANA actions.

9. References

9.1. Normative References

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[ACTN-YANG] Zhang, X. et al., "Applicability of YANG models for Abstraction and Control of Traffic Engineered Networks", draft-zhang-teas-actn-yang, work in progress.

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Transport Northbound Interface Applicability Statement and Use Cases
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Status of this Memo

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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 describes the key use cases and requirements for transport network control and management. It reviews proposed and existing IETF transport network data models, their applicability, and highlights gaps and requirements.

Table of Contents

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 describes key use cases for analyzing the applicability of the existing models defined by the IETF for transport networks. The intention of this document is to become an applicability statement that provides detailed descriptions of how IETF transport models are applied to solve the described use cases and requirements.

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).

The relationship between the current IETF YANG models and the type of ACTN interfaces can be found in [ACTN-YANG].

The ONF Technical Recommendations for Functional Requirements for the transport API in [ONF TR-527] and the ONF transport API multi-layer examples in [ONF GitHub] have been considered as an input for this work.

Considerations about the CMI (interface between the Customer Network Controller (CNC) and the MDSC) are outside the scope of this document.

2. Terminology

E-LINE: Ethernet Line

EPL: Ethernet Private Line

EVPL: Ethernet Virtual Private Line

OTH: Optical Network Hierarchy

OTN: Optical Transport 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:

```
C-R1 (|PKT| -> ODU2), S3 (|ODU2|), S5 (|ODU2|), S6 (|ODU2|),
C-R3 (ODU2 -> |PKT|)
```

Node C-R1 is switching at the packet (PKT) layer and mapping packets into a 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 C-R3. Node C-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.

4. Use Case 1: Single-domain with single-layer

4.1. Reference Network

The current considerations discussed in this document are based on the following reference networks:

- single transport domain: OTN network

4.1.1. Single Transport Domain - OTN Network

As shown in Figure 1 the network physical topology composed of a single-domain transport network providing transport services to an IP network through five access links.

```
           ................................................
           :                 IP domain                    :
           :        ..............................        :
           :        :  ........................  :        :
           :        :  :                      :  :        :
           :        :  :      S1 -------- S2 ------ C-R4  :
           :        :  :     /             |  :  :        :
           :        :  :    /              |  :  :        :
           :  C-R1 ------ S3 ----- S4      |  :  :        :
           :        :  :    \        \     |  :  :        :
           :        :  :     \        \    |  :  :        :
           :        :  :      S5       \   |  :  :        :
           :  C-R2 -----+    /  \       \  |  :  :        :
           :        :  : \  /    \       \ |  :  :        :
           :        :  :  S6 ---- S7 ---- S8 ------ C-R5  :
           :        :  : /                    :  :        :
           :  C-R3 -----+                     :  :        :
           :        :  :   Transport domain   :  :        :
           :        :  :                      :  :        :
           :........:  :......................:  :........:
```

Figure 1 Reference network for Use Case 1

The IP and transport (OTN) domains are respectively composed by five routers C-R1 to C-R5 and by eight ODU switches S1 to S8. The transport domain acts as a transit network providing connectivity for IP layer services.

The behavior of the transport domain is the same whether the ingress or egress service nodes in the IP domain are only attached to the transport domain, or if there are other routers in between the ingress or egress nodes of the IP domain not also attached to the transport domain. In other words, the behavior of the transport network does not depend on whether C-R1, C-R2, ..., C-R5 are PE or P routers for the IP services.

The transport domain control plane architecture follows the ACTN architecture and framework document [ACTN-Frame], and functional components:

o Customer Network Controller (CNC) act as a client with respect to the Multi-Domain Service Coordinator (MDSC) via the CNC-MDSC Interface (CMI);

o MDSC is connected to a plurality of Physical Network Controllers (PNCs), one for each domain, via a MDSC-PNC Interface (MPI). Each PNC is responsible only for the control of its domain and the MDSC is the only entity capable of multi-domain functionalities as well as of managing the inter-domain links;

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.

```
                              +-----+
                              | CNC |
                              +-----+
                                 |
                                 |CMI I/F
                                 |
                      +-----------------------+
                      |         MDSC          |
                      +-----------------------+
                                 |
                                 |MPI I/F
                                 |
                             +-------+
                             |  PNC  |
                             +-------+
                                 |
                               -----
                             (       )
                            (   OTN   )
                           ( Physical  )
                            ( Network )
                             (       )
                               -----
```

Figure 2 Controlling Hierarchy for Use Case 1

Once the service request is processed by the MDSC the mapping of the client IP traffic between the routers (across the transport network) is made in the IP routers only and is not controlled by the transport PNC, and therefore transparent to the transport nodes.

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."

[TE-Topo] describes a YANG base model for TE topology without any technology specific parameters. Moreover, it defines how to abstract for TE-network topologies.

[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 Physical Network Controller (PNC) provides the actual network topology to the multi-domain Service Coordinator (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.

For single-domain with single-layer use-case, the white topology may be disseminated from the PNC to the MDSC in most cases. There may be some exception to this in the case where the underlay network may have complex optical parameters, which do not warrant the distribution of such details to the MDSC. In such case, the topology disseminated from the PNC to the MDSC may not have the entire TE information but a streamlined TE information. This case would incur another action from the MDSC's standpoint when provisioning a path. The MDSC may make a path compute request to the PNC to verify the feasibility of the estimated path before making the final provisioning request to the PNC, as outlined in [Path-Compute].

Topology abstraction for the CMI is for further study (to be addressed in future revisions of this document).

4.3. Service Configuration

In the following use cases, the Multi Domain Service Coordinator (MDSC) needs to be capable to request service connectivity from the transport Physical Network Controller (PNC) 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.

As described in section 4.1.1, the control of different adaptations inside IP routers, C-Ri (PKT -> foo) and C-Rj (foo -> PKT), are assumed to be performed by means that are not under the control of, and not visible to, transport PNC. Therefore, these mechanisms are outside the scope of this document.

4.3.1. ODU Transit

This use case assumes that the physical links interconnecting the IP routers and the transport network are OTN links. The physical/optical interconnection below the ODU layer is supposed to be pre-configured and not exposed at the MPI to the MDSC.

To setup a 10Gb IP link between C-R1 to C-R3, an ODU2 end-to-end data plane connection needs to be created between C-R1 and C-R3, crossing transport nodes S3, S5, and S6.

The traffic flow between C-R1 and C-R3 can be summarized as:

C-R1 (|PKT| -> ODU2), S3 (|ODU2|), S5 (|ODU2|), S6 (|ODU2|),
C-R3 (ODU2 -> |PKT|)

The MDSC should be capable via the MPI to request the setup of an ODU2 transit service with enough information that enable the transport PNC to instantiate and control the ODU2 data plane connection segment through nodes S3, S5, S6.

4.3.2. EPL over ODU

This use case assumes that the physical links interconnecting the IP routers and the transport network are Ethernet links.

In order to setup a 10Gb IP link between C-R1 to C-R3, an EPL service needs to be created between C-R1 and C-R3, supported by an ODU2 end-to-end connection between S3 and S6, crossing transport node S5.

The traffic flow between C-R1 and C-R3 can be summarized as:

C-R1 (|PKT| -> ETH), S3 (ETH -> |ODU2|), S5 (|ODU2|),
S6 (|ODU2| -> ETH), C-R3 (ETH-> |PKT|)

The MDSC should be capable via the MPI to request the setup of an EPL service with enough information that can permit the transport PNC to instantiate and control the ODU2 end-to-end data plane connection through nodes S3, S5, S6, as well as the adaptation functions inside S3 and S6: S3&S6 (ETH -> ODU2) and S9&S6 (ODU2 -> ETH).

4.3.3. Other OTN Client Services

[ITU-T G.709-2016] 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.).

This use case assumes that the physical links interconnecting the IP routers and the transport network are any one of these possible options.

In order to setup a 10Gb IP link between C-R1 to C-R3 using, for example STM-64 physical links between the IP routers and the transport network, an STM-64 Private Line service needs to be created between C-R1 and C-R3, supported by an ODU2 end-to-end data plane connection between S3 and S6, crossing transport node S5.

The traffic flow between C-R1 and C-R3 can be summarized as:

```
C-R1 (|PKT| -> STM-64), S3 (STM-64 -> |ODU2|), S5 (|ODU2|),
S6 (|ODU2| -> STM-64), C-R3 (STM-64 -> |PKT|)
```

The MDSC should be capable via the MPI to request the setup of an STM-64 Private Line service with enough information that can permit the transport PNC to instantiate and control the ODU2 end-to-end connection through nodes S3, S5, S6, as well as the adaptation functions inside S3 and S6: S3&S6 (STM-64 -> ODU2) and S9&S3 (STM-64 -> PKT).

4.3.4. EVPL over ODU

This use case assumes that the physical links interconnecting the IP routers and the transport network are Ethernet links and that different Ethernet services (e.g, EVPL) can share the same physical link using different VLANs.

In order to setup two 1Gb IP links between C-R1 to C-R3 and between C-R1 and C-R4, 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 S2, crossing transport node S1.

Since the two EVPL services are sharing the same Ethernet physical link between C-R1 and S3, different VLAN IDs are associated with different EVPL services: for example VLAN IDs 10 and 20 respectively.

The traffic flow between C-R1 and C-R3 can be summarized as:

```
C-R1 (|PKT| -> VLAN), S3 (VLAN -> |ODU0|), S5 (|ODU0|),
S6 (|ODU0| -> VLAN), C-R3 (VLAN -> |PKT|)
```

The traffic flow between C-R1 and C-R4 can be summarized as:

```
C-R1 (|PKT| -> VLAN), S3 (VLAN -> |ODU0|), S1 (|ODU0|),
S2 (|ODU0| -> VLAN), C-R4 (VLAN -> |PKT|)
```

The MDSC should be capable via the MPI to request the setup of these EVPL services with enough information that can permit the transport PNC to instantiate and control the ODU0 end-to-end data plane connections as well as the adaptation functions on the boundary nodes: S3&S2&S6 (VLAN -> ODU0) and S3&S2&S6 (ODU0 -> VLAN).

4.3.5. EVPLAN and EVPTree Services

This use case assumes that the physical links interconnecting the IP routers and the transport network are Ethernet links and that different Ethernet services (e.g, EVPL, EVPLAN and EVPTree) can 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.

In order to setup an IP subnet between C-R1, C-R2, C-R3 and C-R4, 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 S2, crossing transport node S1.

In order to support this EVPLAN/EVPTree service, some Ethernet Bridging capabilities are required on some nodes at the edge of the transport network: for example Ethernet Bridging capabilities can be configured in nodes S3 and S6 but not in node S2.

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 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 MAC bridging function in node S3 is needed to select, based on the MAC Destination Address, whether the Ethernet frames form C-R1 should be sent to the ODUflex terminating on node S6 or to the other ODUflex terminating on node S2.

The MAC bridging function in node S6 is needed to select, based on the MAC Destination Address, whether the Ethernet frames received from the ODUflex should be set to C-R2 or C-R3, as well as whether the Ethernet frames received from C-R2 (or C-R3) should be sent to C-R3 (or C-R2) or to the ODUflex.

For example, the traffic flow between C-R1 and C-R3 can be summarized as:

```
C-R1 (|PKT| -> VLAN), S3 (VLAN -> |MAC| -> |ODUflex|),
S5 (|ODUflex|), S6 (|ODUflex| -> |MAC| -> VLAN),
C-R3 (VLAN -> |PKT|)
```

The MAC bridging function in node S3 is also needed to select, based on the MAC Destination Address, whether the Ethernet frames one ODUflex should be sent to C-R1 or to the other ODUflex.

For example, the traffic flow between C-R3 and C-R4 can be summarized as:

```
C-R3 (|PKT| -> VLAN), S6 (VLAN -> |MAC| -> |ODUflex|),
S5 (|ODUflex|), S3 (|ODUflex| -> |MAC| -> |ODUflex|),
S1 (|ODUflex|), S2 (|ODUflex| -> VLAN), C-R4 (VLAN -> |PKT|)
```

In node S2 there is no need for any MAC bridging function since all the Ethernet frames received from C-R4 should be sent to the ODUflex toward S3 and viceversa.

The traffic flow between C-R1 and C-R4 can be summarized as:

```
C-R1 (|PKT| -> VLAN), S3 (VLAN -> |MAC| -> |ODUflex|),
S1 (|ODUflex|), S2 (|ODUflex| -> VLAN), C-R4 (VLAN -> |PKT|)
```

The MDSC should be capable via the MPI to request the setup of this EVPLAN/EVPTree services with enough information that can permit the transport PNC to instantiate and control the ODUflex end-to-end data plane connections as well as the Ethernet Bridging and adaptation functions on the boundary nodes: S3&S6 (VLAN -> MAC -> ODU2), S3&S6 (ODU2 -> ETH -> VLAN), S2 (VLAN -> ODU2) and S2 (ODU2 -> VLAN).

4.4. Multi-functional Access Links

This use case assumes that 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 an 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 C-R1 and S3 is a multi-functional access link while the physical links between C-R3 and S6 and between C-R4 and S2 are STM-64 and 10GE physical links respectively, it is possible at the MPI to configure either an STM-

64 Private Line service between C-R1 and C-R3 or an EPL service between C-R1 and C-R4.

The traffic flow between C-R1 and C-R3 can be summarized as:

```
C-R1 (|PKT| -> STM-64), S3 (STM-64 -> |ODU2|), S5 (|ODU2|),
S6 (|ODU2| -> STM-64), C-R3 (STM-64 -> |PKT|)
```

The traffic flow between C-R1 and C-R4 can be summarized as:

```
C-R1 (|PKT| -> ETH), S3 (ETH -> |ODU2|), S1 (|ODU2|),
S2 (|ODU2| -> ETH), C-R4 (ETH-> |PKT|)
```

The MDSC should be capable via the MPI to request the setup of either service with enough information that can permit the transport PNC to instantiate and control the ODU2 end-to-end data plane connection as well as the adaptation functions inside S3 and S2 or S6.

4.5. Protection Requirements

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.

The MDSC needs to be capable to request the transport PNC to configure protection when requesting the setup of the connectivity services described in section 4.3.

Since in this use case it is assumed that switching within the transport network domain is performed only in one layer, also protection switching within the transport network domain can only be provided at the OTN ODU layer, for all the services defined in section 4.3.

It may be necessary to consider not only protection, but also restoration functions in the future. 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.

4.5.1. Linear Protection

It is possible to protect any service defined in section 4.3 from failures within the OTN transport domain by configuring OTN linear protection in the data plane between node S3 and node S6.

It is assumed that the OTN linear protection is configured to with 1+1 unidirectional protection switching type, as defined in [ITU-T G.808.1-2014] and [ITU-T G.873.1-2014], as well as in [RFC4427].

In these scenarios, a working transport entity and a protection transport entity, as defined in [ITU-T G.808.1-2014], (or a working LSP and a protection LSP, as defined in [RFC4427]) should be configured in the data plane, for example:

Working transport entity: S3, S5, S6

Protection transport entity: S3, S4, S8, S7, S6

The Transport PNC should be capable to report to the MDSC which is the active transport entity, as defined in [ITU-T G.808.1-2014], 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.

5. Use Case 2: Single-domain with multi-layer

5.1. Reference Network

The current considerations discussed in this document are based on the following reference network:

- single transport domain: OTN and OCh multi-layer network

In this use case, the same reference network shown in Figure 1 is considered. The only difference is that all the transport nodes are capable to switch in the ODU as well as in the OCh layer.

All the physical links within the transport network are therefore assumed to be OCh links. Therefore, with the exception of the access links, no ODU internal link exists before an OCh end-to-end data plane connection is created within the network.

The controlling hierarchy is the same as described in Figure 2.

The interface within the scope of this document is the Transport MPI which should be capable to control both the OTN and OCh layers.

5.2. Topology Abstractions

A grey topology type B abstraction is assumed: abstract nodes and links exposed at the MPI corresponds 1:1 with the physical nodes and links controlled by the PNC but the PNC abstracts/hides at least some optical parameters to be used within the OCh layer.

5.3. Service Configuration

The same service scenarios, as described in section 4.3, are also applicable to these use cases with the only difference that end-to-end OCh data plane connections will need to be setup before ODU data plane connections.

6. Use Case 3: Multi-domain with single-layer

6.1. Reference Network

In this section we focus on a multi-domain reference network with homogeneous technologies:

- multiple transport domains: OTN networks

Figure 3 shows the network physical topology composed of three transport network domains providing transport services to an IP customer network through eight access links:

```
                ........................
   ..........   :                      :
   :        :   :   Network domain 1   :   .............
   :Customer:   :                      :   :           :
   :domain 1:   :     S1 -------+      :   :  Network  :
   :        :   :    /           \     :   :  domain 3 :   ..........
   :  C-R1 ------- S3 ----- S4    \    :   :           :   :        :
   :        :   :    \        \    S2 --------+        :   :Customer:
   :        :   :     \        \    |  :   :   \       :   :domain 3:
   :        :   :      S5       \   |  :   :    \      :   :        :
   :  C-R2 ------+    /  \       \  |  :   :    S31 --------- C-R7  :
   :        :   : \  /    \       \ |  :   :   /   \   :   :        :
   :        :   :  S6 ---- S7 ---- S8 ------ S32   S33 ------ C-R8  :
   :        :   : /        |       |   :   : / \   /   :   :........:
   :  C-R3 ------+         |       |   :   :/   S34    :
   :        :   :..........|.......|...:   /    /      :
   :........:              |       |      /:.../.......:
                           |       |     /    /
                ...........|.......|..../..../...
                :          |       |   /    /   :    ..........
                : Network  |       |  /    /    :    :        :
                : domain 2 |       | /    /     :    :Customer:
                :         S11 ---- S12   /      :    :domain 2:
                :        /          | \ /       :    :        :
                :     S13     S14   | S15 ------------- C-R4  :
                :     |  \   /   \  |    \      :    :        :
                :     |   S16     \ |     \     :    :        :
                :     |  /         S17 -- S18 --------- C-R5  :
                :     | /             \   /     :    :        :
                :    S19 ---- S20 ---- S21 ------------ C-R6  :
                :                               :    :        :
                :...............................:    :........:
```

Figure 3 Reference network for Use Case 3

It is worth noting that the network domain 1 is identical to the transport domain shown in Figure 1.

```
                      --------------
                     |    Client    |
                     |  Controller  |
                      --------------
                            |
        ....................|.......................
                            |
                     ----------------
                    |                |
                    |      MDSC      |
                    |                |
                     ----------------
                       /   |    \
                      /    |     \
       ............../.....|......\................
                    /      |       \
                   /   ----------   \
                  /   |   PNC2   |   \
                 /     ----------     \
        ----------         |           \
       |   PNC1   |      -----          \
        ----------     (       )      ----------
            |         (         )    |   PNC3   |
          -----      (  Network  )    ----------
        (       )    (  Domain 2 )        |
       (         )    (         )       -----
      (  Network  )    (       )      (       )
      (  Domain 1 )      -----       (         )
       (         )                  (  Network  )
        (       )                   (  Domain 3 )
          -----                      (         )
                                      (       )
                                        -----
```

Figure 4 Controlling Hierarchy for Use Case 3

In this section we address the case where the CNC controls the customer IP network and requests transport connectivity among IP routers, via the CMI, to an MDSC which coordinates, via three MPIs, the control of a multi-domain transport network through three PNCs.

The interfaces within the scope of this document are the three MPIs while the interface between the CNC and the IP routers is out of its scope and considerations about the CMI are outside the scope of this document.

6.2. Topology Abstractions

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.

As an example, we can assume that:

- o PNC1 provides a white topology abstraction (likewise use case 1 described in section 4.2)

- o PNC2 provides a type A grey topology abstraction

- o PNC3 provides a type B grey topology abstraction, with two abstract nodes (AN31 and AN32). They abstract respectively nodes S31+S33 and nodes S32+S34. At the MPI, 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 the PNC.

The MDSC should be capable to glue together these different abstract topologies to build its own view of the multi-domain network topology. This might require proper administrative configuration or other mechanisms (to be defined/analysed).

6.3. Service Configuration

In the following use cases, it is assumed that the CNC is capable to request service connectivity from the MDSC to support IP routers connectivity.

The same service scenarios, as described in section 4.3, are also application to this use cases with the only difference that the two IP routers to be interconnected are attached to transport nodes which belong to different PNCs domains and are under the control of the CNC.

Likewise, the service scenarios in section 4.3, the type of services could depend of the type of physical links (e.g. OTN link, ETH link or SDH link) between the customer’s routers and the multi-domain transport network and the configuration of the different adaptations inside IP routers is performed by means that are outside the scope of this document because not under control of and not visible to the MDSC nor to the PNCs. It is 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.

It is also assumed that the CNC is capable via the CMI to request the MDSC the setup of these services with enough information that enable the MDSC to coordinate the different PNCs to instantiate and control the ODU2 data plane connection through nodes S3, S1, S2, S31, S33, S34, S15 and S18, as well as the adaptation functions inside nodes S3 and S18, when needed.

As described in section 6.2, the MDSC should have its own view of the end-to-end network topology and use it for its own path computation to understand that it needs to coordinate with PNC1, PNC2 and PNC3 the setup and control of a multi-domain ODU2 data plane connection.

6.3.1. ODU Transit

In order to setup a 10Gb IP link between C-R1 and C-R5, an ODU2 end-to-end data plane connection needs be created between C-R1 and C-R5, crossing transport nodes S3, S1, S2, S31, S33, S34, S15 and S18 which belong to different PNC domains.

The traffic flow between C-R1 and C-R5 can be summarized as:

```
C-R1 (|PKT| -> ODU2), S3 (|ODU2|), S1 (|ODU2|), S2 (|ODU2|),
S31 (|ODU2|), S33 (|ODU2|), S34 (|ODU2|),
S15 (|ODU2|), S18 (|ODU2|), C-R5 (ODU2 -> |PKT|)
```

6.3.2. EPL over ODU

In order to setup a 10Gb IP link between C-R1 and C-R5, an EPL service needs to be created between C-R1 and C-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 C-R1 and C-R5 can be summarized as:

```
C-R1 (|PKT| -> ETH), S3 (ETH -> |ODU2|), S1 (|ODU2|),
S2 (|ODU2|), S31 (|ODU2|), S33 (|ODU2|), S34 (|ODU2|),
S15 (|ODU2|), S18 (|ODU2| -> ETH), C-R5 (ETH -> |PKT|)
```

6.3.3. Other OTN Client Services

In order to setup a 10Gb IP link between C-R1 and C-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 C-R1 and C-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 C-R1 and C-R5 can be summarized as:

```
C-R1 (|PKT| -> STM-64), S3 (STM-64 -> |ODU2|), S1 (|ODU2|),
S2 (|ODU2|), S31 (|ODU2|), S33 (|ODU2|), S34 (|ODU2|),
S15 (|ODU2|), S18 (|ODU2| -> STM-64), C-R5 (STM-64 -> |PKT|)
```

6.3.4. EVPL over ODU

In order to setup two 1Gb IP links between C-R1 to C-R3 and between C-R1 and C-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.

The VLAN configuration on the access links is the same as described in section 4.3.4.

The traffic flow between C-R1 and C-R3 is the same as described in section 4.3.4.

The traffic flow between C-R1 and C-R5 can be summarized as:

```
C-R1 (|PKT| -> VLAN), S3 (VLAN -> |ODU2|), S1 (|ODU2|),
S2 (|ODU2|), S31 (|ODU2|), S33 (|ODU2|), S34 (|ODU2|),
S15 (|ODU2|), S18 (|ODU2| -> VLAN), C-R5 (VLAN -> |PKT|)
```

6.3.5. EVPLAN and EVPTree Services

In order to setup an IP subnet between C-R1, C-R2, C-R3 and C-R7, 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.

The VLAN configuration on the access links is the same as described in section 4.3.5.

The configuration of the Ethernet Bridging capabilities on nodes S3 and S6 is the same as described in section 4.3.5 while the configuration on node S18 similar to the configuration of node S2 described in section 4.3.5.

The traffic flow between C-R1 and C-R3 is the same as described in section 4.3.5.

The traffic flow between C-R1 and C-R5 can be summarized as:

```
C-R1 (|PKT| -> VLAN), S3 (VLAN -> |MAC| -> |ODUflex|),
S1 (|ODUflex|), S2 (|ODUflex|), S31 (|ODUflex|),
S33 (|ODUflex|), S34 (|ODUflex|),
S15 (|ODUflex|), S18 (|ODUflex| -> VLAN), C-R5 (VLAN -> |PKT|)
```

6.4. Multi-functional Access Links

The same considerations of section 4.4 apply with the only difference that the ODU data plane connections could be setup across multiple PNC domains.

For example, if the physical link between C-R1 and S3 is a multi-functional access link while the physical links between C-R7 and S31 and between C-R5 and S18 are STM-64 and 10GE physical links respectively, it is possible to configure either an STM-64 Private Line service between C-R1 and C-R7 or an EPL service between C-R1 and C-R5.

The traffic flow between C-R1 and C-R7 can be summarized as:

```
C-R1 (|PKT| -> STM-64), S3 (STM-64 -> |ODU2|), S1 (|ODU2|),
S2 (|ODU2|), S31 (|ODU2| -> STM-64), C-R3 (STM-64 -> |PKT|)
```

The traffic flow between C-R1 and C-R5 can be summarized as:

```
C-R1 (|PKT| -> ETH), S3 (ETH -> |ODU2|), S1 (|ODU2|),
S2 (|ODU2|), S31 (|ODU2|), S33 (|ODU2|), S34 (|ODU2|),
S15 (|ODU2|), S18 (|ODU2| -> ETH), C-R5 (ETH -> |PKT|)
```

6.5. Protection Scenarios

The MDSC needs to be capable to coordinate different PNCs to configure protection switching when requesting the setup of the connectivity services described in section 6.3.

Since in this use case it is assumed that switching within the transport network domain is performed only in one layer, also protection switching within the transport network domain can only be provided at the OTN ODU layer, for all the services defined in section 6.3.

6.5.1. Linear Protection (end-to-end)

In order to protect any service defined in section 6.3 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.

The considerations in section 4.5.1 are also applicable here with the only difference that MDSC needs to coordinate with different PNCs the setup and control of the OTN linear protection as well as of the working and protection transport entities (working and protection LSPs).

Two cases can be considered.

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
```

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
```

6.5.2. Segmented Protection

In order to protect any service defined in section 6.3 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 linear protection is used within a domain, the considerations in section 4.5.1 are also applicable here only for the PNC controlling the domain where intra-domain linear protection is provided.

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

7. Use Case 4: Multi-domain and multi-layer

7.1. Reference Network

The current considerations discussed in this document are based on the following reference network:

- multiple transport domains: OTN and OCh multi-layer networks

In this use case, the reference network shown in Figure 3 is used. The only difference is that all the transport nodes are capable to switch either in the ODU or in the OCh layer.

All the physical links within each transport network domain are therefore assumed to be OCh links, while the inter-domain links are assumed to be ODU links as described in section 6.1 (multi-domain with single layer - OTN network).

Therefore, with the exception of the access and inter-domain links, no ODU link exists within each domain before an OCh single-domain end-to-end data plane connection is created within the network.

The controlling hierarchy is the same as described in Figure 4.

The interfaces within the scope of this document are the three MPIs which should be capable to control both the OTN and OCh layers within each PNC domain.

7.2. Topology Abstractions

Each PNC should provide the MDSC a topology abstraction of its own network topology as described in section 5.2.

As an example, it is assumed that:

- o PNC1 provides a type A grey topology abstraction (likewise in use case 2 described in section 5.2)

- o PNC2 provides a type B grey topology abstraction (likewise in use case 3 described in section 6.2)

- o PNC3 provides a type B grey topology abstraction with two abstract nodes, likewise in use case 3 described in section 6.2, and hiding at least some optical parameters to be used within the OCh layer, likewise in use case 2 described in section 5.2.

7.3. Service Configuration

The same service scenarios, as described in section 6.3, are also applicable to these use cases with the only difference that single-domain end-to-end OCh data plane connections needs to be setup before ODU data plane connections.

8. Security Considerations

Typically, OTN networks ensure a high level of security and data privacy through hard partitioning of traffic onto isolated circuits.

There may be additional security considerations applied to specific use cases, but common security considerations do exist and these must be considered for controlling underlying infrastructure to deliver transport services:

- o use of RESCONF and the need to reuse security between RESTCONF components;

- o use of authentication and policy to govern which transport services may be requested by the user or application;

o how secure and isolated connectivity may also be requested as an element of a service and mapped down to the OTN level.

9. IANA Considerations

This document requires no IANA actions.

10. References

10.1. Normative References

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11. Acknowledgments

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YANG data model for Flexi-Grid Optical Networks
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Abstract

This document defines a YANG model for managing flexi-grid optical Networks. The model described in this document is composed of two submodels: one to define a flexi-grid traffic engineering database, and other one to describe the flexi-grid paths or media channels. It is grounded on other defined YANG abstract models.

Table of Contents

1. Introduction

Internet-based traffic is dramatically increasing every year. Moreover, such traffic is also becoming more dynamic. Thus, transport networks need to evolve from current DWDM systems towards elastic optical networks, based on flexi-grid transmission and switching technologies. This technology aims at increasing both transport network scalability and flexibility, allowing the optimization of bandwidth usage.

This document presents a YANG model for flexi-grid objects in the dynamic optical network, including the nodes, transponders and links between them, as well as how such links interconnect nodes and transponders.

The YANG model for flexi-grid [RFC7698] networks allows the representation of the flexi-grid optical layer of a network, combined with the underlying physical layer. The model is defined in two YANG modules:

- o Flexi-grid-TED (Traffic Engineering Database): This module defines all the information needed to represent the flexi-grid optical node, transponder and link.
- o Media-channel: This module defines the whole path from a source transponder to the destination through a number of intermediate nodes in the flexi-grid optical network.

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

2. 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].

In this document, these words will appear with that interpretation only when in ALL CAPS. Lower case uses of these words are not to be interpreted as carrying RFC-2119 significance.

In this document, the characters ">>" preceding an indented line(s) indicates a compliance requirement statement using the key words listed above. This convention aids reviewers in quickly identifying or finding the explicit compliance requirements of this RFC.

3. Flexi-grid network topology model overview

YANG is a data modeling language used to model configuration data manipulated by the NETCONF protocol. Several YANG models have already been specified for network configurations. For instance, the work in [I-D.draft-ietf-i2rs-yang-network-topo] has proposed a generic YANG model for network/service topologies and inventories. The work in [I-D.draft-ietf-teas-yang-te-topo] presents a data model to represent, retrieve and manipulate Traffic Engineering (TE) Topologies. These models serve as base models that other technology specific models can augment. A YANG model has also been proposed in [I-D.draft-dharini-ccamp-dwdm-if-yang] to manage single channel optical interface parameters of DWDM applications, and in

[I-D.draft-ietf-ccamp-wson-yang] another model has been specified for the routing and wavelength assignment TE topology in wavelength switched optical networks (WSONs). None of them are specific for flexi-grid technology.

Then, as stated before, we propose a model to describe a flexi-grid topology that is split in two YANG sub-modules:

- o Flexi-grid-TED: In order to be compatible with existing proposals, we augment the definitions contained in [I-D.draft-ietf-i2rs-yang-network-topo] and [I-D.draft-ietf-teas-yang-te-topo], by defining the different elements we can find in a flexi-grid network: a node, a transponder and a link. For that, each of those elements is defined as a container that includes a group of attributes. References to the elements are provided to be later used in the definition of a media channel. It also includes the data types for the type of modulation, the flexi-grid technology, the FEC, etc.
- o Media-channel: This module defines the whole path from a source transponder to the destination through a number of intermediate nodes and links. For this, it takes the information defined before in the flexi-grid TED.

The following section provides a detailed view of each module.

4. Main building blocks

Subsections below detail each of the defined YANG modules. They are listed in Appendix A.

4.1. Flexi-grid TED

The description of the three main components, flexi-grid-node, flexi-grid-transponder and flexi-grid-link is provided below. flexi-grid-sliceable-transponders are also defined.

<flexi-grid-node> ::= <config> <state>

<flexi-grid-node>: This element designates a node in the network.

<config> ::= <flexi-grid-node-attributes-config>

<config>: Contains the configuration of a node.
<flexi-grid-node-attributes-config> ::= <list-interface>
<connectivity_matrix>

<flexi-grid-node-attributes-config>: Contains all the attributes related to the node configuration, such as its interfaces or its management addresses.

```
<list-interface> ::= <name> <port-number>
<input-port> <output-port> <description>
<interface-type>
[<numbered-interface> / <unnumbered-interface>]

    <list-interface>: The list containing all the
    information of the interfaces.

    <name>: Determines the interface name.

    <port-number>: Port number of the interface.

    <input-port>: Boolean value that defines
    whether the interface is input or not.

    <output-port>: Boolean value that defines
    whether the interface is output or not.

    <description>: Description of the usage of
    the interface.

    <interface-type>: Determines if the interface
    is numbered or unnumbered.

    <numbered-interface> ::= <n-i-ip-address>
        <numbered-interface>: An interface with
        its own IP address.

        <n-i-ip-address>: Only available if
        <interface-type> is "numbered-interface".
        Determines the IP address of the interface.

    <unnumbered-interface> ::= <u-i-ip-address>
    <label>
        <unnumbered-interface>: A interface that
        needs a label to be unique.

        <u-i-ip-address>: Only available if
        <interface-type> is "numbered-interface".
        Determines the node IP address, which with
        the label defines the interface.

        <label>: Label that determines the
        interface, joint with the node IP address.

<connectivity-matrix> ::= <connections>

    <connectivity-matrix>: Determines whether a
    connection port in/port out exists.

    <connections> ::= <input-port-id>
    <output-port-id>
```

<flexi-grid-transponder> ::= <transponder-type> <config> <state>

<flexi-grid-transponder>: This item designates a transponder of a node.

<transponder-type>: Contains the type of the transponder.

<config> ::= <flexi-grid-transponder-attributes-config>

<config>: Contains the configuration of a transponder.

<flexi-grid-transponder-attributes-config> ::=
<available-modulation> <modulation-type>
<available-FEC> <FEC-enabled> [<FEC-type>]

<flexi-grid-transponder-attributes>: Contains all the attributes related to the transponder, such as whether it has FEC enabled or not, or its modulation type.

<available-modulation>: It provides a list of the modulations available at this transponder.

<modulation-type>: Determines the type of modulation in use: QPSK, QAM16, QAM64...

<available-FEC>: It provides a list of the FEC algorithms available at this transponder.

<FEC-enabled>: Boolean value that determines whether is the FEC enabled or not.

<FEC-type>: Determines the type of FEC in use: reed-solomon, hamming-code, enum golay, BCH...

<state> ::= <flexi-grid-transponder-attributes-config>
<flexi-grid-transponder-attributes-state>

<state>: Contains the state of a transponder.

<flexi-grid-transponder-attributes-config>: See above.

<flexi-grid-transponder-attributes-state>: Contains the state of a transponder.

<flexi-grid-sliceable-transponder> ::= <transponder-type> <config>
<state>

<flexi-grid-sliceable-transponder>: A list of transponders.

<transponder-type>: Contains the type of the transponder.

<config> ::= <flexi-grid-transponder-attributes-config>
<flexi-grid-sliceable-transponder-attributes-config>

<flexi-grid-transponder-attributes-config>: See above.

<flexi-grid-sliceable-transponder-attributes-config> ::=
<transponder-list>

<flexi-grid-sliceable-transponder-attributes-config>:
Contains the configuration of a sliceable transponder

<transponder-list> ::= <carrier-id>
<transponder-list>: A list of transponders.

<carrier-id>: An identifier for each one of the
transponders in the list.

<state> ::= <flexi-grid-transponder-attributes-state>
<flexi-grid-sliceable-transponder-attributes-state>
<flexi-grid-transponder-attributes-config>
<flexi-grid-sliceable-transponder-attributes-config>

<state>: Contains the state of a sliceable transponder.

<flexi-grid-transponder-attributes-state>: See above.

<flexi-grid-sliceable-transponder-attributes-state>:
Contains the state attributes of a sliceable transponders.

<flexi-grid-transponder-attributes-config>: See above.

<flexi-grid-sliceable-transponder-attributes-config>: See
above.

<link> ::= <config> <state>

<link>: This element describes all the information of a link.

<config> ::= <flexi-grid-link-attributes-config>

<config>: Contains the configuration of a link.

```
         <flexi-grid-link-attributes-config> ::= <technology-type>
         <available-label-flexi-grid> <N-max> <base-frequency>
         <nominal-central-frequency-granularity>
         <slot-width-granularity>

            <flexi-grid-link-attributes>: Contains all the
            attributes related to the link, such as its unique id,
            its N value, its latency, etc.

            <link-id>: Unique id of the link.

            <available-label-flexi-grid>: Array of bits that
            determines, with each bit, the availability of each
            interface for flexi-grid technology.

            <N-max>: The max value of N in this link, being N
            the number of slots.

            <base-frequency>: The default central frequency
            used in the link.

            <nominal-central-frequency-granularity>: It is the
            spacing between allowed nominal central frequencies
            and it is set to 6.25 GHz (note: sometimes referred
            to as 0.00625 THz).

            <slot-width-granularity>: 12.5 GHz, as defined
            in G.694.1.
    <state> ::= <flexi-grid-link-attributes-config>
    <flexi-grid-link-attributes-state>

        <state>: Contains the state of a link.

        <flexi-grid-link-attributes-config>: See above.

        <flexi-grid-link-attributes-state>: Contains all the
        the information related to the state of a link.
```

4.2. Media-channel/network-media-channel

The model defines two types of media channels, following the terminology summarized in [RFC7698]:

- o media-channel, which represents a (effective) frequency slot supported by a concatenation of media elements (fibers, amplifiers, filters, switching matrices...);
- o network-media-channel: It is a media channel that transports an Optical Tributary Signal. In the model, the network media channel has as end-points transponders, which are the source and destination of the optical signal.

The description of these components is provided below:

<media-channel> ::= <source> <destination> <link-channel> <effective-freq-slot>

<media-channel>: Determines a media-channel and its components.

<source > ::= <source-node> <source-port>

<source>: In a media-channel, the source is a node and a port.

<source-node>: Reference to the source node of the media channel.

<source-port>: Reference to the source port in the source <node.

<destination> ::= <destination-node> <destination-port>

<destination>: In a media-channel, the destination is a node and a port.

<destination-node>: Reference to the destination node of the media channel.

<destination-port>: Reference to the destination port in the destination node.

<link-channel> ::= <link-id> <N> <M> <source-node> <source-port> <destination-node> <destination-port> <link> <bidirectional>

<link-channel>: Defines a list with each of the links between elements in the media channel.

<link-id>: Unique identifier for the link channel

<N>: N used for this link channel.

<M>: M used for this link channel.

<source-node>: Reference to the source node of this link channel.

<source-port>: Reference to the source port of this link channel.

<destination-node>: Reference to the destination node of this link channel.

<destination-port>: Reference to the destination port of this link channel.

<link>: Reference to the link of this link channel.

<bidirectional>: Indicates if this link is bidirectional or not.

```
     <effective-freq-slot> ::= <N> <M>

          <effective-freq-slot>: Defines the effective frequency slot of
          the media channel, which could be different from the one
          defined in the link channels.

          <N>: Defines the effective N for this media channel.

          <M>: Defines the effective M for this media channel.

   <network-media-channel> ::= <source> <destination> <link-channel>
   <effective-freq-slot>

     <network-media-channel>: Determines a network media-channel and
     its components.

     <source > ::= <source-node> <source-transponder>

          <source>: In a network media channel, the source is defined by
          a node and a transponder.

          <source-node>: Reference to the source node of the media
          channel.

          <source-transponder>: Reference to the source transponder in
          the source node.

     <destination> ::= <destination-node> <destination-transponder>

          <destination>: In a network media channel, the destination is
          defined by a node and a transponder

          <destination-node>: Reference to the destination node of the
          media channel.

          <destination-port>: Reference to the destination port in the
          destination node.

     <link-channel>: See above, the information is reused for both types
     of media channels.

     <effective-freq-slot>: See above, this information is reused for
     both types of media channels.
```

5. Example of use

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

```
                           Media channel
         <===================================================>
                              Path x
         <--------------------------------------------------->

                  +----------+          +----------+
           Link 1 |Flexi-grid|  Link 2  |Flexi-grid| Link 3
             .--->|   node   |<-------->|   node   |<---.
             |    |    B     |          |    C     |    |
             |    +----------+          +----------+    |
             v                                          v
         +-------------+                      +-------------+
         | Flexi-grid  |                      | Flexi-grid  |
         | transponder |                      | transponder |
         |      A      |                      |      E      |
         +-------------+                      +-------------+
               ^                                      ^
               |             +----------+             |
               |    Link 4   |Flexi-grid|   Link 5    |
               '------------>|   node   |<-----------'
                             |    D     |
                             +----------+
         <--------------------------------------------------->
                              Path y
```

Figure 1. Topology example.

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

1. We define the transponders A and E, including their FEC type, if enabled, and modulation type. We also provide node identifiers and addresses for the transponders, as well as interfaces included in the transponders. Sliceable transponders can also be defined if needed.

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

3. Then, we also define the links 1 to 5 that interconnect nodes and transponders, indicating which flexi-grid labels are available. Other information, such as the slot frequency and granularity are also provided.

Next, we can configure the media channel from the information we have stored in the flexi-grid TED, by querying which elements are available, and planning the resources that have to be provided on each situation. Note that every element in the flexi-grid TED has a reference, and this is the way in which they are called in the media channel.

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

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

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

6. Formal Syntax

The following syntax specification uses the augmented Backus-Naur Form (BNF) as described in [RFC5234].

7. Security Considerations

The transport protocol used for sending the managed information MUST support authentication and SHOULD support encryption.

The defined data-model by itself does not create any security implications.

8. IANA Considerations

The namespace used in the defined models is currently based on the IDEALIST project URI. Future versions of this document could register a URI in the IETF XML registry [RFC3688], as well as in the YANG Module Names registry [RFC6020].

9. References

9.1. Normative References

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9.2. Informative References

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10. Contributors

The model presented in this paper was contributed to by more people than can be listed on the author list. Additional contributors include:

- o Zafar Ali, Cisco Systems
- o Daniel Michaud Vallinoto, Universidad Autonoma de Madrid

11. Acknowledgments

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Appendix A. YANG models

A.1. Flexi-grid TED YANG Model

A.1.1. Yang Model - Tree Structure

```
module: ietf-flexi-grid-topology
flexi-grid-network-type
   augment /nd:networks/nd:network/nd:network-types:
      +--rw flexi-grid-network!
flexi-grid-link-attributes-config
   augment /nd:networks/nd:network/lnk:link/tet:te/tet:config:
      +--rw available-label-flexi-grid*              bits
      +--rw N-max?                                   int32
      +--rw base-frequency?                          decimal64
      +--rw nominal-central-frequency-granularity?   decimal64
      +--rw slot-width-granularity?                  decimal64
flexi-grid-link-attributes-state
   augment /nd:networks/nd:network/lnk:link/tet:te/tet:state:
      +--ro available-label-flexi-grid*              bits
      +--ro N-max?                                   int32
      +--ro base-frequency?                          decimal64
      +--ro nominal-central-frequency-granularity?   decimal64
      +--ro slot-width-granularity?                  decimal64
flexi-grid-node-attributes-config
   augment /nd:networks/nd:network/nd:node/tet:te/tet:config:
      +--rw interfaces* [name]
         +--rw name                     string
         +--rw port-number?             uint32
         +--rw input-port?              boolean
         +--rw output-port?             boolean
         +--rw description?             string
         +--rw type?                    interface-type
         +--rw numbered-interface
         |  +--rw n-i-ip-address?   inet:ip-address
         +--rw unnumbered-interface
            +--rw u-i-ip-address?   inet:ip-address
            +--rw label?            uint32
```

```
flexi-grid-node-attributes-state
   augment /nd:networks/nd:network/nd:node/tet:te/tet:state:
      +--ro interfaces* [name]
         +--ro name                     string
         +--ro port-number?             uint32
         +--ro input-port?              boolean
         +--ro output-port?             boolean
         +--ro description?             string
         +--ro type?                    interface-type
         +--ro numbered-interface
         |  +--ro n-i-ip-address?   inet:ip-address
         +--ro unnumbered-interface
            +--ro u-i-ip-address?   inet:ip-address
            +--ro label?            uint32
flexi-grid-connectivity-matrix-attributes
   augment /nd:networks/nd:network/nd:node/tet:te/tet:config/
   tet:te-node-attributes/tet:connectivity-matrix:
      +--rw connections* [input-port-id]
         +--rw input-port-id     flexi-grid-node-port-ref
         +--rw output-port-id?   flexi-grid-node-port-ref
flexi-grid-connectivity-matrix-attributes
   augment /nd:networks/nd:network/nd:node/tet:te/tet:state/
   tet:te-node-attributes/tet:connectivity-matrix:
      +--ro connections* [input-port-id]
         +--ro input-port-id     flexi-grid-node-port-ref
         +--ro output-port-id?   flexi-grid-node-port-ref
flexi-grid-transponder
   augment /nd:networks/nd:network/nd:node/tet:te/
   tet:tunnel-termination-point:
      +--rw transponder-type           flexi-grid-transponder-type
      +--rw config
      |  +--rw available-modulation*   modulation
      |  +--rw modulation-type?        modulation
      |  +--rw available-FEC*          FEC
      |  +--rw FEC-enabled?            boolean
      |  +--rw FEC-type?               FEC
      +--ro state
         +--ro available-modulation*   modulation
         +--ro modulation-type?        modulation
         +--ro available-FEC*          FEC
         +--ro FEC-enabled?            boolean
         +--ro FEC-type?               FEC
```

```
flexi-grid-sliceable-transponder
   augment /nd:networks/nd:network/nd:node/tet:te/
   tet:tunnel-termination-point:
      +--rw transponder-type           flexi-grid-transponder-type
      +--rw config
      |  +--rw available-modulation*   modulation
      |  +--rw modulation-type?        modulation
      |  +--rw available-FEC*          FEC
      |  +--rw FEC-enabled?            boolean
      |  +--rw FEC-type?               FEC
      |  +--rw transponder-list* [carrier-id]
      |     +--rw carrier-id           uint32
      +--ro state
         +--ro available-modulation*   modulation
         +--ro modulation-type?        modulation
         +--ro available-FEC*          FEC
         +--ro FEC-enabled?            boolean
         +--ro FEC-type?               FEC
         +--ro transponder-list* [carrier-id]
            +--ro carrier-id           uint32
```

A.1.2. YANG Model - Code

```
   <CODE BEGINS> file "ietf-flexi-grid-ted.yang"
module ietf-flexi-grid-ted {
  yang-version 1.1;

  namespace "urn:ietf:params:xml:ns:yang:ietf-flexi-grid-ted";
  prefix "fg-ted";

  import ietf-network {
    prefix "nd";
  }

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

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

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

  organization
         "IETF CCAMP Working Group";

      contact
         "Editor: Jorge E. Lopez de Vergara
                  <jorge.lopez_vergara@uam.es>";
```

```
      description
         "This module contains a collection of YANG definitions for
         a Flexi-Grid Traffic Engineering Database (TED).

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         authors of the code.  All rights reserved.

         Redistribution and use in source and binary forms, with or
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         to the license terms contained in, the Simplified BSD
         License set forth in Section 4.c of the IETF Trust's Legal
         Provisions Relating to IETF Documents
         (http://trustee.ietf.org/license-info).";

      revision 2017-03-01 {
         description
            "version 4.";

         reference
             "RFC XXX: A Yang Data Model for
             Flexi-Grid Optical Networks ";
      }

   typedef flexi-grid-trasponder-type {
         type enumeration {
             enum "flexi-grid-transponder" {
                description
                   "Flexi-grid transponder";
             }
             enum "flexi-grid-sliceable-transponder" {
                description
                   "Flexi-grid sliceable transponder";
             }
         }
         description "Determines the trasponder type:
             flexi-grid-transponder or
             flexi-grid-sliceable-transponder";
   }

  typedef modulation {
         type enumeration {
            enum QPSK {
                description
                "QPSK (Quadrature Phase Shift Keying) modulation";
                }
            enum DP_QPSK {
                description "DP-QPSK (Dual Polarization Quadrature
                Phase Shift Keying) modulation";
                }
            enum QAM16 {
                description "QAM16 (Quadrature Amplitude Modulation
                - 4 bits per symbol) modulation";
                }
```

```
            enum DP_QAM16 {
                description "DP-QAM16 (Dual Polarization
                Quadrature Amplitude Modulation - 4 bits per
                symbol) modulation";
                }
            enum DC_DP_QAM16 {
                description "DC DP-QAM16 (Dual Polarization
                Quadrature Amplitude Modulation - 4 bits per
                symbol) modulation";
                }
         }
         description
            "Enumeration that defines the type of wave modulation";
   }

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

   typedef interface-type {
         type enumeration {
            enum numbered-interface {
                description "The interface is numbered";
            }
            enum unnumbered-interface {
                description "The interface is unnumbered";
            }
         }
         description
            "Enumeration that defines if an interface is numbered or
            unnumbered";
   }
```

```
   /*
      Typedef related to references
   */
      typedef flexi-grid-link-ref {
         type leafref {
            path
               "/nd:networks/nd:network/lnk:link/lnk:link-id";
         }

         description
            "This type is used by data models that need to reference
            a flexi-grid optical link.";
      }

      typedef flexi-grid-node-port-ref {
         type leafref {
            path "/nd:networks/nd:network/nd:node/tet:te/tet:config/"
            +"fg-ted:interfaces/fg-ted:port-number";
         }
         description
            "This type is used by data models that need to reference
            a flexi-grid port.";
      }

      typedef flexi-grid-transponder-ref {
         type leafref {
            path "/nd:networks/nd:network/nd:node/tet:te/"+
            "tet:tunnel-termination-point/tet:tunnel-tp-id";
         }
         description
            "This type is used by data models that need to reference
            a trasponder.";
      }

   grouping flexi-grid-network-type {
         container flexi-grid-network {
            presence "indicates a flexi-grid optical network";
            description "flexi-grid optical network";
         }
         description "If present, it indicates a flexi-grid
         optical TED network";
   }

   grouping flexi-grid-node-attributes-config {
         description "Set of attributes of an optical node.";

         list interfaces {
            key "name";
            unique "port-number";
            description "List of interfaces contained in the node";
            leaf name {
               type string;
               description "Interface name";
            }
```

```
            leaf port-number {
               type uint32;
               description "Number of the port used by the interface";
            }
            leaf input-port {
               type boolean;
               description "Determines if the port is an input port";
            }
            leaf output-port {
               type boolean;
               description
               "Determines if the port is an output port";
            }
            leaf description {
               type string;
               description "Description of the interface";
            }
            leaf type {
               type interface-type;
               description "Determines the type of the interface";
            }
            container numbered-interface {
               when "../fg-ted:type =
               'numbered-interface'" {
                 description
                 "If the interface is a numbered interface";
               }
               description "Container that defines an numbered
               interface with an ip-address";
               leaf n-i-ip-address{
                  type inet:ip-address;
                  description "IP address of the numbered interface";
               }
            }
            container unnumbered-interface {
               when "../fg-ted:type =
               'unnumbered-interface'" {
                 description
                   "If the interface is an unnumbered interface";
               }
               description "Container that defines an unnumbered
               interface with an ip-address and a label";
               leaf u-i-ip-address{
                  type inet:ip-address;
                  description "IP address of the interface";
               }
               leaf label {
                  type uint32;
                  description "Number as label for the interface";
               }
            }
         }
      }
```

```
   grouping flexi-grid-node-attributes-state {
         description "Flexigrid node attributes (state).";
   }
   grouping flexi-grid-link-attributes-config {
         description "Set of attributes of an optical link";
            leaf-list available-label-flexi-grid {
               type bits {
                  bit is-available{
                    description "Set to 1 when it is available";
                  }
               }
               description
                  "Array of bits that determines whether a spectral
                  slot is available or not.";
            }

            leaf N-max {
               type int32;
               description "Maximum number of channels available.";
            }

            leaf base-frequency {
               type decimal64 {
                  fraction-digits 5;
               }
               units THz;
               default 193.1;
               description "Default central frequency";
               reference "rfc7698";
            }
            leaf nominal-central-frequency-granularity {
               type decimal64 {
                  fraction-digits 5;
               }
               units GHz;
               default 6.25;
               description
                  "It is the spacing between allowed nominal central
                  frequencies and it is set to 6.25 GHz";
               reference "rfc7698";
            }

            leaf slot-width-granularity {
               type decimal64 {
                  fraction-digits 5;
               }
               units GHz;
               description "Minimum space between slot widths";
               reference "rfc7698";
            }
   }
```

```
   grouping flexi-grid-link-attributes-state {
      description "Flexigrid link attributes (state)";
   }
   grouping flexi-grid-transponder-attributes-config {
      description "Configuration of an optical transponder";
      leaf-list available-modulation {
         type modulation;
         description
            "List determining all the available modulations";
      }
      leaf modulation-type {
         type modulation;
         description "Modulation type of the wave";
      }
      leaf-list available-FEC {
         type FEC;
         description "List determining all the available FEC";
      }
      leaf FEC-enabled {
         type boolean;
         description
            "Determines whether the FEC is enabled or not";
      }
      leaf FEC-type {
         type FEC;
         description "FEC type of the transponder";
      }
   }

   grouping flexi-grid-transponder-attributes-state {
      description "State of an optical transponder";
   }

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

   grouping flexi-grid-sliceable-transponder-attributes-state {
      description "State of a sliceable transponder.";
      uses flexi-grid-transponder-attributes-state;
   }
```

```
   grouping flexi-grid-connectivity-matrix-attributes {
      description "Connectivity matrix between the input and
          output ports";
      list connections {
         key "input-port-id";
         leaf input-port-id {
            type flexi-grid-node-port-ref;
            description "Identifier of the input port";
         }
         leaf output-port-id {
            type flexi-grid-node-port-ref;
            description "Identifier of the output port";
         }
         description "List of connections between input and
          output ports";
      }
   }

   augment "/nd:networks/nd:network/nd:network-types" {
            uses flexi-grid-network-type;
             description "Augment network-types including flexi-grid
             topology";
   }

  augment "/nd:networks/nd:network/lnk:link/tet:te/tet:config" {
    when "/nd:networks/nd:network/nd:network-types/
  fg-ted:flexi-grid-network" {
      description "Augment only for Flexigrid network.";
    }
    description "Augment link configuration";
    uses flexi-grid-link-attributes-config;
  }

  augment "/nd:networks/nd:network/lnk:link/tet:te/tet:state" {
    when "/nd:networks/nd:network/nd:network-types/
  fg-ted:flexi-grid-network" {
      description "Augment only for Flexigrid network.";
    }
    description "Augment link state";
    uses flexi-grid-link-attributes-config;
    uses flexi-grid-link-attributes-state;
  }

   augment "/nd:networks/nd:network/nd:node/tet:te/tet:config"  {
      when "/nd:networks/nd:network/nd:network-types/
    fg-ted:flexi-grid-network" {
         description "Augment only for Flexigrid network.";
      }
      uses flexi-grid-node-attributes-config;
      description "Augment node config with flexi-grid attributes";
   }
```

```
   augment "/nd:networks/nd:network/nd:node/tet:te/tet:state"  {
      when "/nd:networks/nd:network/nd:network-types/
    fg-ted:flexi-grid-network" {
          description "Augment only for Flexigrid network.";
      }
      uses flexi-grid-node-attributes-config;
      uses flexi-grid-node-attributes-state;
      description "Augment node config with flexi-grid attributes";
   }

   augment "/nd:networks/nd:network/nd:node/tet:te/tet:config"+
         "/tet:te-node-attributes/tet:connectivity-matrix" {
       when "/nd:networks/nd:network/nd:network-types/
     fg-ted:flexi-grid-network" {
           description "Augment only for Flexigrid network.";
       }

      uses flexi-grid-connectivity-matrix-attributes;
      description "Augment node connectivity-matrix for node config";
    }

    augment "/nd:networks/nd:network/nd:node/tet:te/tet:state"+
         "/tet:te-node-attributes/tet:connectivity-matrix" {
       when "/nd:networks/nd:network/nd:network-types/
     fg-ted:flexi-grid-network"{
           description "Augment only for Flexigrid network.";
       }

      uses flexi-grid-connectivity-matrix-attributes;
      description "Augment node connectivity-matrix for node config";
    }

   augment "/nd:networks/nd:network/nd:node/tet:te"+
      "/tet:tunnel-termination-point" {
      when "/nd:networks/nd:network/nd:network-types/
    fg-ted:flexi-grid-network"{
           description "Augment only for Flexigrid network.";
       }

       leaf transponder-type {
            type flexi-grid-trasponder-type;
            description "Type of flexi-grid transponder";
      }
        container state {
          description "State of the transponder";
        }
        container config {
          description "Configuration of the transponder";
        }
       description "Augment node with configuration and state
       for transponder";
   }
```

```
   augment "/nd:networks/nd:network/nd:node/tet:te"+
          "/tet:tunnel-termination-point/fg-ted:config" {
      when "../fg-ted:transponder-type" {
          description "When it is either a flexi-grid transponder
           or a sliceable transponder";
      }
      uses flexi-grid-transponder-attributes-config;
      description "Augment node state with transponder attributes";
   }

   augment "/nd:networks/nd:network/nd:node/tet:te"+
          "/tet:tunnel-termination-point/fg-ted:state" {
      when "../fg-ted:transponder-type"{
          description "When it is either a flexi-grid transponder
           or a sliceable transponder";
      }
      uses flexi-grid-transponder-attributes-state;
      uses flexi-grid-transponder-attributes-config;
      description "Augment node state with transponder attributes";
   }

   augment "/nd:networks/nd:network/nd:node/tet:te"+
          "/tet:tunnel-termination-point/fg-ted:config" {
      when "../fg-ted:transponder-type =
        'flexi-grid-sliceable-transponder'"{
          description
              "When it is a flexi-grid sliceable transponder";
      }
      uses flexi-grid-sliceable-transponder-attributes-config;
      description "Augment node with sliceable transponder
          attributes";
   }

   augment "/nd:networks/nd:network/nd:node/tet:te"+
          "/tet:tunnel-termination-point/fg-ted:state" {
      when "../fg-ted:transponder-type =
      'flexi-grid-sliceable-transponder'"{
          description
              "When it is a flexi-grid sliceable transponder";
     }
     uses flexi-grid-sliceable-transponder-attributes-state;
     uses flexi-grid-sliceable-transponder-attributes-config;
     description "Augment node with sliceable transponder
         attributes";
   }
}

   <CODE ENDS>
```

A.2. Media Channel YANG Model

A.2.1. YANG Model - Tree

```
module: ietf-flexi-grid-media-channel
   +--rw media-channel
   |  +--rw source
   |  |  +--rw source-node?   te-types:te-node-id
   |  |  +--rw source-port?   fg-ted:flexi-grid-node-port-ref
   |  +--rw destination
   |  |  +--rw destination-node?   te-types:te-node-id
   |  |  +--rw destination-port?   fg-ted:flexi-grid-node-port-ref
   |  +--rw effective-freq-slot
   |  |  +--rw N?   int32
   |  |  +--rw M?   int32
   |  +--rw link-channel* [link-id]
   |     +--rw link-id             int32
   |     +--rw N?                  int32
   |     +--rw M?                  int32
   |     +--rw source-node?        te-types:te-node-id
   |     +--rw source-port?        fg-ted:flexi-grid-node-port-ref
   |     +--rw destination-node?   te-types:te-node-id
   |     +--rw destination-port?   fg-ted:flexi-grid-node-port-ref
   |     +--rw link?               fg-ted:flexi-grid-link-ref
   |     +--rw bidireccional?      boolean
   +--rw network-media-channel
      +--rw source
      |  +--rw source-node?          te-types:te-node-id
      |  +--rw source-transponder?   fg-ted:flexi-grid-transponder-ref
      +--rw destination
      |  +--rw destination-node?          te-types:te-node-id
      |  +--rw destination-transponder?
      |             fg-ted:flexi-grid-transponder-ref
      +--rw effective-freq-slot
      |  +--rw N?   int32
      |  +--rw M?   int32
      +--rw link-channel* [link-id]
         +--rw link-id             int32
         +--rw N?                  int32
         +--rw M?                  int32
         +--rw source-node?        te-types:te-node-id
         +--rw source-port?        fg-ted:flexi-grid-node-port-ref
         +--rw destination-node?   te-types:te-node-id
         +--rw destination-port?   fg-ted:flexi-grid-node-port-ref
         +--rw link?               fg-ted:flexi-grid-link-ref
         +--rw bidireccional?      boolean
```

A.2.2. YANG Model - Code

```
   <CODE BEGINS> file "ietf-flexi-grid-media-channel.yang"
module ietf-flexi-grid-media-channel {
   yang-version 1.1;

   namespace
     "urn:ietf:params:xml:ns:yang:ietf-flexi-grid-media-channel";
   prefix "fg-mc";

   import ietf-flexi-grid-ted {
      prefix "fg-ted";
   }

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

   organization
      "IETF CCAMP Working Group";

   contact
      "Editor: Jorge E. Lopez de Vergara
                 <jorge.lopez_vergara@uam.es>";

   description
      "This module contains a collection of YANG definitions for
      a Flexi-Grid media channel.

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      authors of the code.  All rights reserved.

      Redistribution and use in source and binary forms, with or
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      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 2017-03-01 {
      description
         "version 4.";

      reference
         "RFC XXX: A Yang Data Model for Flexi-Grid Optical
         Networks ";
   }
```

```
   container media-channel {
      description
         "Media association that represents both the topology
         (i.e., path through the media) and the resource
         (frequency slot) that it occupies.  As a topological
         construct, it represents a (effective) frequency slot
         supported by a concatenation of media elements (fibers,
         amplifiers, filters, switching matrices...).  This term
         is used to identify the end-to-end physical layer entity
         with its corresponding (one or more) frequency slots
         local at each link filters.";
      reference "rfc7698";
      container source {
         description "Source of the media channel";
         leaf source-node {
            type te-types:te-node-id;
            description "Source node";
         }
         leaf source-port {
            type fg-ted:flexi-grid-node-port-ref;
            description "Source port";
          }
      }
      container destination {
         description "Destination of the media channel";
         leaf destination-node {
            type te-types:te-node-id;
            description "Destination node";
         }
         leaf destination-port {
            type fg-ted:flexi-grid-node-port-ref;
            description "Destination port";
         }
      }
      uses media-channel-attributes;
   }
   container network-media-channel {
      description
         "It is a media channel that transports an Optical
         Tributary Signal ";
      reference "rfc7698";
      container source {
         description "Source of the network media channel";
         leaf source-node {
            type te-types:te-node-id;
            description "Source node";
         }
         leaf source-transponder {
            type fg-ted:flexi-grid-transponder-ref;
            description "Source transponder";
         }
      }
```

```
      container destination {
         description "Destination of the network media channel";
         leaf destination-node {
            type te-types:te-node-id;
            description "Destination node";
         }
         leaf destination-transponder {
            type fg-ted:flexi-grid-transponder-ref;
            description "Destination transponder";
         }
      }
      uses media-channel-attributes;
   }

   grouping media-channel-attributes {
      description "Set of attributes of a media channel";
      container effective-freq-slot {
         description "The effective frequency slot is an attribute
            of a media channel and, being a frequency slot, it is
            described by its nominal central frequency and slot
            width";
         reference "rfc7698";
         leaf N {
            type int32;
            description
               "Is used to determine the Nominal Central
               Frequency. The set of nominal central frequencies
               can be built using the following expression:
                  f = 193.1 THz + n x 0.00625 THz,
               where 193.1 THz is ITU-T ''anchor frequency'' for
               transmission over the C band, n is a positive or
               negative integer including 0.";
            reference "rfc7698";
         }
         leaf M {
            type int32;
            description
               "Is used to determine the slot width. A slot width
               is constrained to be M x SWG (that is, M x 12.5 GHz),
               where M is an integer greater than or equal to 1.";
            reference "rfc7698";
         }
      }
      list link-channel {
         key "link-id";
         description
             "A list of the concatenated elements of the media
             channel.";
         leaf link-id {
            type int32;
            description "Identifier of the link";
         }
```

```
         uses link-channel-attributes;
      }
   }

   grouping link-channel-attributes {
      description
         "A link channel is one of the concatenated elements of
         the media channel.";
      leaf N {
         type int32;
         description
            "Is used to determine the Nominal Central Frequency.
            The set of nominal central frequencies can be built
            using the following expression:
               f = 193.1 THz + n x 0.00625 THz,
            where 193.1 THz is ITU-T ''anchor frequency'' for
            transmission over the C band, n is a positive or
            negative integer including 0.";
         reference "rfc7698";
      }
      leaf M {
         type int32;
            description
               "Is used to determine the slot width. A slot
               width is constrained to be M x SWG (that is,
               M x 12.5 GHz), where M is an integer greater than
               or equal to 1.";
            reference "rfc7698";
      }
      leaf source-node {
         type te-types:te-node-id;
         description "Source node of the link channel";
      }
      leaf source-port {
         type fg-ted:flexi-grid-node-port-ref;
         description "Source port of the link channel";
      }
      leaf destination-node {
         type te-types:te-node-id;
         description "Destination node of the link channel";
      }
      leaf destination-port {
         type fg-ted:flexi-grid-node-port-ref;
         description "Destination port of the link channel";
      }
      leaf link {
         type fg-ted:flexi-grid-link-ref;
         description "Link of the link channel";
      }
```

```
      leaf bidireccional {
         type boolean;
         description
            "Determines whether the link is bidireccional or
            not";
      }
   }
}
```

   <CODE ENDS>

A.3. License

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YANG data model for Flexi-Grid Optical Networks
draft-vergara-ccamp-flexigrid-yang-05.txt

Status of this Memo

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Abstract

This document defines a YANG model for managing flexi-grid optical Networks. The model described in this document defines a flexi-grid traffic engineering database. A complementary module is referenced to detail the flexi-grid media channels.

This module is grounded on other defined YANG abstract models.

Table of Contents

1. Introduction

Internet-based traffic is dramatically increasing every year. Moreover, such traffic is also becoming more dynamic. Thus, transport networks need to evolve from current DWDM systems towards elastic optical networks, based on flexi-grid transmission and switching technologies [RFC7698]. This technology aims at increasing both transport network scalability and flexibility, allowing the optimization of bandwidth usage.

This document presents a YANG model for flexi-grid objects in the dynamic optical network, including the nodes, transponders and links between them, as well as how such links interconnect nodes and transponders.

The YANG model for flexi-grid networks allows the representation of the flexi-grid optical layer of a network, combined with the underlying physical layer.

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

2. 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].

In this document, these words will appear with that interpretation only when in ALL CAPS. Lower case uses of these words are not to be interpreted as carrying RFC-2119 significance.

In this document, the characters ">>" preceding an indented line(s) indicates a compliance requirement statement using the key words listed above. This convention aids reviewers in quickly identifying or finding the explicit compliance requirements of this RFC.

3. Flexi-grid network topology model overview

YANG is a data modeling language used to model configuration data manipulated by the NETCONF protocol. Several YANG models have already been specified for network configurations. For instance, the work in [I-D.draft-ietf-i2rs-yang-network-topo] has proposed a generic YANG model for network/service topologies and inventories. The work in [I-D.draft-ietf-teas-yang-te-topo] presents a data model to represent, retrieve and manipulate Traffic Engineering (TE) Topologies. These models serve as base models that other technology specific models can augment. A YANG model has also been proposed in [I-D.draft-dharini-ccamp-dwdm-if-yang] to manage single channel optical interface parameters of DWDM applications, and in

[I-D.draft-ietf-ccamp-wson-yang] another model has been specified for the routing and wavelength assignment TE topology in wavelength switched optical networks (WSONs). None of them are specific for flexi-grid technology.

Then, as stated before, we propose a model to describe a flexi-grid topology that is split in two YANG sub-modules:

- o Flexi-grid-TED: In order to be compatible with existing proposals, we augment the definitions contained in [I-D.draft-ietf-i2rs-yang-network-topo] and [I-D.draft-ietf-teas-yang-te-topo], by defining the different elements we can find in a flexi-grid network: a node, a transponder and a link. For that, each of those elements is defined as a container that includes a group of attributes. References to the elements are provided to be later used in the definition of a media channel. It also includes the data types for the type of modulation, the flexi-grid technology, the FEC, etc.
- o Media-channel: This module defines the whole path from a source transponder to the destination through a number of intermediate nodes and links. For this, it takes the information defined before in the flexi-grid TED. This module is described in [ID.draft-vergara-ccamp-flexigrid-media-channel-yang]

  The following section provides a detailed view of the first module.

4. Main building blocks of the Flexi-grid TED

This section details the defined YANG module. It is listed below in section 6.

The description of the three main components, flexi-grid-node, flexi-grid-transponder and flexi-grid-link is provided below. flexi-grid-sliceable-transponders are also defined.

<flexi-grid-node> ::= <config> <state>

<flexi-grid-node>: This element designates a node in the network.

<config> ::= <flexi-grid-node-attributes-config>

<config>: Contains the configuration of a node.
<flexi-grid-node-attributes-config> ::= <list-interface>
<connectivity_matrix>

<flexi-grid-node-attributes-config>: Contains all the attributes related to the node configuration, such as its interfaces or its management addresses.

```
                   <list-interface> ::= <name> <port-number>
                   <input-port> <output-port> <description>
                   <interface-type>
                   [<numbered-interface> / <unnumbered-interface>]

                       <list-interface>: The list containing all the
                       information of the interfaces.

                       <name>: Determines the interface name.

                       <port-number>: Port number of the interface.

                       <input-port>: Boolean value that defines
                       whether the interface is input or not.

                       <output-port>: Boolean value that defines
                       whether the interface is output or not.

                       <description>: Description of the usage of
                       the interface.

                       <interface-type>: Determines if the interface
                       is numbered or unnumbered.

                       <numbered-interface> ::= <n-i-ip-address>
                           <numbered-interface>: An interface with
                           its own IP address.

                           <n-i-ip-address>: Only available if
                           <interface-type> is "numbered-interface".
                           Determines the IP address of the interface.

                       <unnumbered-interface> ::= <u-i-ip-address>
                       <label>
                           <unnumbered-interface>: A interface that
                           needs a label to be unique.

                           <u-i-ip-address>: Only available if
                           <interface-type> is "numbered-interface".
                           Determines the node IP address, which with
                           the label defines the interface.

                           <label>: Label that determines the
                           interface, joint with the node IP address.

                   <connectivity-matrix> ::= <connections>

                       <connectivity-matrix>: Determines whether a
                       connection port in/port out exists.

                       <connections> ::= <input-port-id>
                       <output-port-id>
```

```
<flexi-grid-transponder> ::= <transponder-type> <config> <state>


    <flexi-grid-transponder>: This item designates a transponder
    of a node.

    <config> ::= <flexi-grid-transponder-attributes-config>

        <config>: Contains the configuration of a transponder.

        <flexi-grid-transponder-attributes-config> ::=
        <available-operational-mode> <operational-mode>

            <flexi-grid-transponder-attributes>: Contains all the
            attributes related to the transponder.

               <available-operational-mode>: It provides a list of the
               operational modes available at this transponder.

               <operational-mode>: Determines the type of operational
               mode in use.

     <state> ::= <flexi-grid-transponder-attributes-config>
     <flexi-grid-transponder-attributes-state>

         <state>: Contains the state of a transponder.

         <flexi-grid-transponder-attributes-config>: See above.

         <flexi-grid-transponder-attributes-state>: Contains the
         state of a transponder.

 <link> ::= <config> <state>

     <link>: This element describes all the information of a link.

     <config> ::= <flexi-grid-link-attributes-config>

         <config>: Contains the configuration of a link.
```

```
         <flexi-grid-link-attributes-config> ::= <technology-type>
         <available-label-flexi-grid> <N-max> <base-frequency>
         <nominal-central-frequency-granularity>
         <slot-width-granularity>
```

<flexi-grid-link-attributes>: Contains all the attributes related to the link, such as its unique id, its N value, its latency, etc.

<link-id>: Unique id of the link.

<available-label-flexi-grid>: Array of bits that determines, with each bit, the availability of each interface for flexi-grid technology.

<N-max>: The max value of N in this link, being N the number of slots.

<base-frequency>: The default central frequency used in the link.

<nominal-central-frequency-granularity>: It is the spacing between allowed nominal central frequencies and it is set to 6.25 GHz (note: sometimes referred to as 0.00625 THz).

<slot-width-granularity>: 12.5 GHz, as defined in G.694.1.

```
    <state> ::= <flexi-grid-link-attributes-config>
    <flexi-grid-link-attributes-state>
```

<state>: Contains the state of a link.

<flexi-grid-link-attributes-config>: See above.

<flexi-grid-link-attributes-state>: Contains all the the information related to the state of a link.

4.1. Formal Syntax

The previous syntax specification uses the augmented Backus-Naur Form (BNF) as described in [RFC5234].

5. Example of use

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

```
                          Media channel
      <====================================================>
                             Path x
      <---------------------------------------------------->

               +----------+          +----------+
        Link 1 |Flexi-grid|  Link 2  |Flexi-grid| Link 3
          .--->|   node   |<-------->|   node   |<---.
          |    |    B     |          |    C     |    |
          |    +----------+          +----------+    |
          v                                          v
       /-----------\                      /-----------\
      / Flexi-grid  \                    / Flexi-grid  \
      | transponder |                    | transponder |
      \      A      /                    \      E      /
       \-----------/                      \-----------/
            ^                                      ^
            |               +----------+           |
            |    Link 4     |Flexi-grid|   Link 5  |
            '-------------->|   node   |<----------'
                            |    D     |
                            +----------+
      <---------------------------------------------------->
                             Path y
```

Figure 1. Topology example.

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

1. We define the transponders A and E, including their FEC type, if enabled, and modulation type. We also provide node identifiers and addresses for the transponders, as well as interfaces included in the transponders. Sliceable transponders can also be defined if needed.

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

3. Then, we also define the links 1 to 5 that interconnect nodes and transponders, indicating which flexi-grid labels are available. Other information, such as the slot frequency and granularity are also provided.

Next, we can configure the media channel from the information we have stored in the flexi-grid TED, by querying which elements are available, and planning the resources that have to be provided on each situation. Note that every element in the flexi-grid TED has a reference, and this is the way in which they are called in the media channel. We refer to [I-D.draft-vergara-ccamp-flexigrid-media-channel-yang] to complete this example.

6. Flexi-grid TED YANG Model

6.1. Yang Model - Tree Structure

```
module: ietf-flexi-grid-topology
   augment /nd-s:networks/nd-s:network/nd-s:node/tet-s:te/
   tet-s:te-node-attributes:
    +--ro interfaces* [name]
       +--ro name                     string
       +--ro port-number?             uint32
       +--ro input-port?              boolean
       +--ro output-port?             boolean
       +--ro description?             string
       +--ro type?                    interface-type
       +--ro numbered-interface
       |  +--ro n-i-ip-address?   inet:ip-address
       +--ro unnumbered-interface
          +--ro u-i-ip-address?   inet:ip-address
          +--ro label?            uint32
flexi-grid-connectivity-matrix-attributes
   augment /nd:networks/nd:network/nd:node/tet:te/
   tet:te-node-attributes/tet:connectivity-matrices/
   tet:connectivity-matrix:
    +--rw connections* [input-port-id]
       +--rw input-port-id     flexi-grid-node-port-ref
       +--rw output-port-id?   flexi-grid-node-port-ref
flexi-grid-connectivity-matrix-attributes
   augment /nd-s:networks/nd-s:network/nd-s:node/tet-s:te/
   tet-s:te-node-attributes/tet-s:connectivity-matrices/
   tet-s:connectivity-matrix:
    +--ro connections* [input-port-id]
       +--ro input-port-id     flexi-grid-node-port-ref
       +--ro output-port-id?   flexi-grid-node-port-ref
flexi-grid-transponder
   augment /nd:networks/nd:network/nd:node/tet:te/
   tet:tunnel-termination-point:
    +--rw available-operational-mode*   operational-mode
    +--rw operational-mode?             operational-mode
flexi-grid-transponder
   augment /nd-s:networks/nd-s:network/nd-s:node/tet-s:te/
   tet-s:tunnel-termination-point:
    +--ro available-operational-mode*   operational-mode
    +--ro operational-mode?             operational-mode
```

A.2. YANG Model - Code

```
   <CODE BEGINS> file "ietf-flexi-grid-ted@2017-07-03.yang"
module ietf-flexi-grid-ted {
  yang-version 1.1;

  namespace "urn:ietf:params:xml:ns:yang:ietf-flexi-grid-ted";
  prefix "fg-ted";

  import ietf-network {
    prefix "nd";
  }
  import ietf-network-state {
    prefix "nd-s";
  }
  import ietf-network-topology {
    prefix "lnk";
  }
  import ietf-network-topology-state {
    prefix "lnk-s";
  }
  import ietf-te-topology {
    prefix "tet";
  }
  import ietf-te-topology-state {
    prefix "tet-s";
  }
   import ietf-inet-types {
      prefix "inet";
   }

  organization
         "IETF CCAMP Working Group";

      contact
         "Editor: Jorge Lopez de Vergara
                  <jorge.lopez_vergara@uam.es>";
      description
         "This module contains a collection of YANG definitions for
         a Flexi-Grid Traffic Engineering Database (TED).

         Copyright (c) 2017 IETF Trust and the persons identified as
         authors of the code.  All rights reserved.
```

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

      revision 2017-07-03 {
         description
            "version 5.";

         reference
             "RFC XXX: A Yang Data Model for
             Flexi-Grid Optical Networks ";
      }

  /*
    Typedefs
  */


  typedef operational-mode {
    type string;
    description
      "Vendor-specific mode that guarantees interoperability.
       It must be an string with the following format:
       B-DScW-ytz(v) where all these attributes are conformant
       to the ITU-T recomendation";
      reference "ITU-T G.698.2 (11/2009) Section 5.3";
  }

  typedef interface-type {
         type enumeration {
            enum numbered-interface {
                description "The interface is numbered";
            }
            enum unnumbered-interface {
                description "The interface is unnumbered";
            }
         }
         description
            "Enumeration that defines if an interface is numbered or
            unnumbered";
  }
```

```
   /*
      Typedef related to references
   */
      typedef flexi-grid-link-ref {
         type leafref {
            path
               "/nd:networks/nd:network/lnk:link/lnk:link-id";
         }

         description
            "This type is used by data models that need to reference
            a flexi-grid optical link.";
      }

      typedef flexi-grid-node-port-ref {
         type leafref {
            path "/nd:networks/nd:network/nd:node/tet:te/"
            +"tet:te-node-attributes/fg-ted:interfaces/"
            +"fg-ted:port-number";
         }
         description
            "This type is used by data models that need to reference
            a flexi-grid port.";
      }

      typedef flexi-grid-transponder-ref {
         type leafref {
            path "/nd:networks/nd:network/nd:node/tet:te/"+
            "tet:tunnel-termination-point/tet:tunnel-tp-id";
         }
         description
            "This type is used by data models that need to reference
            a trasponder.";
      }

   /*
      Groupings of attributes
   */
   grouping flexi-grid-network-type {
         container flexi-grid-network {
            presence "indicates a flexi-grid optical network";
            description "flexi-grid optical network";
         }
         description "If present, it indicates a flexi-grid
         optical TED network";
   }
```

```
   grouping flexi-grid-node-attributes {
         description "Set of attributes of an optical node.";

         list interfaces {
            key "name";
            unique "port-number"; // TODO Puerto y TP ID
            description "List of interfaces contained in the node";
            leaf name {
               type string;
               description "Interface name";
            }
            leaf port-number {
               type uint32;
               description "Number of the port used by the interface";
            }

            leaf input-port {
               type boolean;
               description "Determines if the port is an input port";
            }
            leaf output-port {
               type boolean;
               description
               "Determines if the port is an output port";
            }
            leaf description {
               type string;
               description "Description of the interface";
            }
            leaf type {
               type interface-type;
               description "Determines the type of the interface";
            }
            container numbered-interface {
               when "../fg-ted:type =
               'numbered-interface'" {
                 description
                 "If the interface is a numbered interface";
               }
               description "Container that defines an numbered
               interface with an ip-address";
               leaf n-i-ip-address{
                  type inet:ip-address;
                  description "IP address of the numbered interface";
               }
            }
```

```
            container unnumbered-interface {
               when "../fg-ted:type =
               'unnumbered-interface'" {
                 description
                   "If the interface is an unnumbered interface";
               }
               description "Container that defines an unnumbered
               interface with an ip-address and a label";
               leaf u-i-ip-address{
                  type inet:ip-address;
                  description "IP address of the interface";
               }
               leaf label {
                  type uint32;
                  description "Number as label for the interface";
               }
            }
         }
      }

   grouping flexi-grid-link-attributes {
         description "Set of attributes of an optical link";
            leaf-list available-label-flexi-grid {
               type bits {
                  bit is-available{
                    description "Set to 1 when it is available";
                  }
               }
               description
                  "Array of bits that determines whether a spectral
                  slot is available or not.";
            }

            leaf N-max {
               type int32;
               description "Maximum number of channels available.";
            }

            leaf base-frequency {
               type decimal64 {
                  fraction-digits 5;
               }
               units THz;
               default 193.1;
               description "Default central frequency";
               reference "rfc7698";
            }
```

```
            leaf nominal-central-frequency-granularity {
               type decimal64 {
                  fraction-digits 5;
               }
               units GHz;
               default 6.25;
               description
                  "It is the spacing between allowed nominal central
                  frequencies and it is set to 6.25 GHz";
               reference "rfc7698";
            }

            leaf slot-width-granularity {
               type decimal64 {
                  fraction-digits 5;
               }
               units GHz;
               default 12.5;
               description "Minimum space between slot widths";
               reference "rfc7698";
            }
   }

   grouping flexi-grid-transponder-attributes {
      description "Configuration of an optical transponder";
      //TODO Validate attributes
      leaf-list available-operational-mode {
         type operational-mode;
         description "List of all vendor-specific supported
         mode identifiers";
      }

      leaf operational-mode {
         type operational-mode;
         description "Vendor-specific mode identifier";
      }
   }
```

```
   grouping flexi-grid-connectivity-matrix-attributes {
      description "Connectivity matrix between the input and
          output ports";
      list connections {
         key "input-port-id";
         leaf input-port-id {
            type flexi-grid-node-port-ref;
            description "Identifier of the input port";
         }
         leaf output-port-id {
            type flexi-grid-node-port-ref;
            description "Identifier of the output port";
         }
         description "List of connections between input and
          output ports";
      }
   }

   /*
      Augments
   */
   augment "/nd:networks/nd:network/nd:network-types" {
            uses flexi-grid-network-type;
             description "Augment network-types including flexi-grid
             topology";
   }
   augment "/nd-s:networks/nd-s:network/nd-s:network-types" {
            uses flexi-grid-network-type;
             description "Augment network-types including flexi-grid
             topology";
   }
  augment "/nd:networks/nd:network/lnk:link/tet:te" +
   "/tet:te-link-attributes" {
    when "/nd:networks/nd:network/nd:network-types/
  fg-ted:flexi-grid-network" {
      description "Augment only for Flexigrid network.";
    }
    description "Augment link configuration";
    uses flexi-grid-link-attributes;
  }

  augment "/nd-s:networks/nd-s:network/lnk-s:link/tet-s:te" +
  "/tet-s:te-link-attributes" {
    when "/nd-s:networks/nd-s:network/nd-s:network-types/
  fg-ted:flexi-grid-network" {
      description "Augment only for Flexigrid network.";
    }

    description "Augment link state";
    uses flexi-grid-link-attributes;
  }
```

```
   augment "/nd:networks/nd:network/nd:node/tet:te" +
   "/tet:te-node-attributes" {
      when "/nd:networks/nd:network/nd:network-types/
    fg-ted:flexi-grid-network" {
         description "Augment only for Flexigrid network.";
      }
      uses flexi-grid-node-attributes;
      description "Augment node config with flexi-grid attributes";
   }

   augment "/nd-s:networks/nd-s:network/nd-s:node/tet-s:te" +
   "/tet-s:te-node-attributes" {
      when "/nd-s:networks/nd-s:network/nd-s:network-types/
    fg-ted:flexi-grid-network" {
         description "Augment only for Flexigrid network.";
      }

      uses flexi-grid-node-attributes;
      description "Augment node state with flexi-grid attributes";
   }
   augment "/nd:networks/nd:network/nd:node/tet:te"+
         "/tet:te-node-attributes/tet:connectivity-matrices/"+
         "tet:connectivity-matrix" {
       when "/nd:networks/nd:network/nd:network-types/
     fg-ted:flexi-grid-network" {
          description "Augment only for Flexigrid network.";
       }

      uses flexi-grid-connectivity-matrix-attributes;
      description "Augment node connectivity-matrix for node config";
    }

    augment "/nd-s:networks/nd-s:network/nd-s:node/tet-s:te"+
         "/tet-s:te-node-attributes/tet-s:connectivity-matrices/"+
         "tet-s:connectivity-matrix" {
       when "/nd-s:networks/nd-s:network/nd-s:network-types/
     fg-ted:flexi-grid-network"{
          description "Augment only for Flexigrid network.";
       }


      uses flexi-grid-connectivity-matrix-attributes;
      description "Augment node connectivity-matrix for node config";
    }
```

```
   augment "/nd:networks/nd:network/nd:node/tet:te"+
          "/tet:tunnel-termination-point" {
      when "/nd:networks/nd:network/nd:network-types/
      fg-ted:flexi-grid-network"{
          description "Augment only for Flexigrid network.";
       }
      uses flexi-grid-transponder-attributes;
      description "Augment node state with transponder attributes";
   }

   augment "/nd-s:networks/nd-s:network/nd-s:node/tet-s:te"+
          "/tet-s:tunnel-termination-point" {
      when "/nd-s:networks/nd-s:network/nd-s:network-types/
     fg-ted:flexi-grid-network"{
          description "Augment only for Flexigrid network.";
       }

      uses flexi-grid-transponder-attributes;
      description "Augment node state with transponder attributes";
   }

}

   <CODE ENDS>
```

A.3. License

7. Security Considerations

The transport protocol used for sending the managed information MUST support authentication and SHOULD support encryption.

The defined data-model by itself does not create any security implications.

8. IANA Considerations

The namespace used in the defined models is currently based on the METRO-HAUL project URI. Future versions of this document could register a URI in the IETF XML registry [RFC3688], as well as in the YANG Module Names registry [RFC6020].

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10. Contributors

The model presented in this paper was contributed to by more people than can be listed on the author list. Additional contributors include:

- o Zafar Ali, Cisco Systems
- o Daniel Michaud Vallinoto, Universidad Autonoma de Madrid

11. Acknowledgments

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March 08, 2017

A YANG Data Model for Optical Transport Network Topology
draft-zhang-ccamp-l1-topo-yang-06

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 draft 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.

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].

Status of This Memo

Table of Contents

1. Introduction

A transport network is a server-layer network designed to provide connectivity services for a client-layer network to carry the client traffic transparently across the server-layer network resources. A transport network 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 [RFC6020]. 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 draft 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].

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.vergara-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 draft is defined in [I-D.ietf-netmod-rfc6087bis]. 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. the YANG Tree

```
module: ietf-otn-topology
augment /nd:networks/nd:network/nd:network-types/tet:te-topology:
   +--rw otn-topology!
augment /nd:networks/nd:network:
   +--rw name?   string
augment /nd:networks/nd:network/nd:node:
   +--rw name?   string
augment /nd:networks/nd:network/lnk:link/tet:te/tet:config:
   +--rw available-odu-info* [priority]
   |  +--rw priority    uint8
   |  +--rw odulist* [odu-type]
   |     +--rw odu-type    identityref
   |     +--rw number?     uint16
   +--rw distance?             uint32
augment /nd:networks/nd:network/lnk:link/tet:te/tet:state:
   +--ro available-odu-info* [priority]
   |  +--ro priority    uint8
   |  +--ro odulist* [odu-type]
   |     +--ro odu-type    identityref
   |     +--ro number?     uint16
   +--ro distance?             uint32
augment /nd:networks/nd:network/nd:node/lnk:termination-point
/tet:te/tet:config:
   +--rw client-facing?             empty
   +--rw tpn?                       uint16
   +--rw tsg?                       identityref
   +--rw protocol-type?             identityref
   +--rw adaptation-type?           adaptation-type
   +--rw sink-adapt-active?         boolean
   +--rw source-adapt-active?       boolean
   +--rw tributary-slots
   |  +--rw values*   uint8
   +--rw supported-payload-types* [index]
      +--rw index           uint16
      +--rw payload-type?   string
augment /nd:networks/nd:network/nd:node/lnk:termination-point/
```

```
   tet:te/tet:state:
      +--ro client-facing?            empty
      +--ro tpn?                      uint16
      +--ro tsg?                      identityref
      +--ro protocol-type?            identityref
      +--ro adaptation-type?          adaptation-type
      +--ro sink-adapt-active?        boolean
      +--ro source-adapt-active?      boolean
      +--ro tributary-slots
      |  +--ro values*   uint8
      +--ro supported-payload-types* [index]
         +--ro index           uint16
         +--ro payload-type?   string
```

3.2. Explanation of the OTN Topology Data Model

As can be seen, from the data tree shown in Section 3.1, the YANG module presented in this draft 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]. The entities and their attributes, such as node, termination points and links, are still applicable for describing an OTN topology and the model presented in this draft only specifies with technology-specific attributes/information. For example, if the data plane complies with ITU-T G.709 (2012) standards, the switching-capability and encoding attributes MUST be filled as OTN-TDM and G.709 ODUk(Digital Path) respectively.

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

One of the main augmentations in this model is that it allows to specify 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.

3.3. The YANG Code

```
  <CODE BEGINS> file " ietf-otn-topology@2017-03-08.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 "nd";
 }

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

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

 import ietf-transport-types {
  prefix "tran-types";
 }

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

  ID-draft editor:
   Xian ZHANG (zhang.xian@huawei.com);
   Anurag Sharma (AnSharma@infinera.com);
  ";

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

 revision 2017-03-08 {
  description
   "Revision 0.2";
  reference
   "draft-zhang-ccamp-l1-topo-yang-05.txt";
 }
```

```
    /*
    typedef
    */

    typedef adaptation-type {
     type enumeration {
      enum CBR {
       description "Constant Bit Rate.";
      }
      enum ATMvp {
       description "ATM VP.";
      }
      enum GFP {
       description "Generic Framing Procedure.";
      }
      enum NULL {
       description "NULL";
      }
      enum PRBS {
       description "Pseudo Random Binary Sequence";
      }
      enum RSn {
       description "SDH/SONET section";
      }
      enum ODUj-21 {
       description "ODU payload type 21";
      }
      enum ETHERNET_PP-OS {
       description "ETHERNET_PP-OS, for ODU 2 only";
      }
      enum CBRx {
       description "CBRx(0.. 1.25G), for ODU0 only";
      }
      enum ODU {
       description "Optical Data Unit";
      }
     }

     description
      "Defines a type representing the adaptation type
      on the termination point.";
    }


    /*
    Groupings
    */
```

```
    grouping otn-topology-type {
     container otn-topology {
      presence "indicates a topology type of Optical
       Transport Network (OTN)-electrical layer.";
       description "otn topology type";
     }
     description "otn-topology-type";
    }

    grouping otn-topology-attributes {
     leaf name {
      type string;
      description "the topology name";
     }
     description "name attribute for otn topology";
    }

    grouping otn-node-attributes {
     description "otn-node-attributes";
     leaf name {
      type string;
      description "a name for this node.";
     }
    }

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

     list available-odu-info{
      key "priority";
      max-elements "8";

      description
       "List of ODU type and number on this link";
      leaf priority {
       type uint8 {
        range "0..7";
       }
       description "priority";
      }

      list odulist {
       key "odu-type";

       description
        "the list of available ODUs per priority level";

       leaf odu-type {
```

```
        type identityref{
         base tran-types:tributary-protocol-type;
        }
        description "the type of ODU";
       }

       leaf number {
        type uint16;
        description "the number of odu type supported";
       }
      }
     }

     leaf distance {
      type uint32;
      description "distance in the unit of kilometers";
     }
   }

    grouping otn-tp-attributes {
     description "otn-tp-attributes";

     leaf client-facing {
      type empty;
      description
       "if present, it means this tp is a client-facing tp.
       adding/dropping client signal flow.";
     }

     leaf tpn {
      type uint16 {
       range "0..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 tran-types:tributary-slot-granularity;
      }
      description "Tributary slot granularity.";
      reference
      "G.709/Y.1331, February 2012: Interfaces for the Optical
      Transport Network (OTN)";
```

```
     }

     leaf protocol-type {
      type identityref {
       base tran-types:tributary-protocol-type;
      }
      description "Protocol type for the Termination Point.";
     }

     leaf adaptation-type {
      type adaptation-type;
      description
      "This attribute indicates the type of the supported
      adaptation function at the termination point.";
      reference
      "G.874.1, January 2002: Optical transport network (OTN):
      Protocol-neutral management information model for the
      network element view.";
     }

     leaf sink-adapt-active {
      type boolean;
      description
      "This attribute allows for activation or deactivation of
      the sink adaptation function. The value of TRUE means active.";

      reference
      "G.874.1, January 2002: Optical transport network (OTN):
      Protocol-neutral management information model for the
      network element view ";
     }

     leaf source-adapt-active {
      type boolean;
      description
      "This attribute allows for activation or deactivation of
      the sink adaptation function. The value of TRUE
      means active.";
      reference
      "G.874.1, January 2002: Optical transport network (OTN):
      Protocol-neutral management information model for
      the network element view ";
     }

      container tributary-slots {
       description
       "A list of tributary slots used by the ODU
       Termination Point.";
```

```
       leaf-list values {
        type uint8;
        description
        "Tributary slot value.";
        reference
        "G.709/Y.1331, February 2012: Interfaces for the
        Optical Transport Network (OTN)";
       }
     }

     list supported-payload-types{
      key "index";

      description "supported payload types of a TP";

      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
       not: the payload type is defined as the generalized PIDs
       in GMPLS.";
      }
     }
    }


    /*
    * Data nodes
    */
    augment "/nd:networks/nd:network/nd:network-types/tet:te-topology" {
     uses otn-topology-type;
     description "augment network types to include otn newtork";
    }

    augment "/nd:networks/nd:network" {
     when "nd:network-types/tet:te-topology/otn-topology" {
      description "Augment only for otn network";
     }
     uses otn-topology-attributes;
     description "Augment network configuration";
```

```
    }

    augment "/nd:networks/nd:network/nd:node" {
     when "../nd:network-types/tet:te-topology/otn-topology" {
      description "Augment only for otn network";
     }
     description "Augment node configuration";
     uses otn-node-attributes;
    }

    augment "/nd:networks/nd:network/lnk:link/tet:te/tet:config" {
     when "../../../nd:network-types/tet:te-topology/otn-topology" {
      description "Augment only for otn network.";
     }
     description "Augment link configuration";

     uses otn-link-attributes;
    }

    augment "/nd:networks/nd:network/lnk:link/tet:te/tet:state" {
     when "../../../nd:network-types/tet:te-topology/otn-topology" {
      description "Augment only for otn network.";
     }
     description "Augment link state";

     uses otn-link-attributes;
    }

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

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

   <CODE ENDS>
```

4. IANA Considerations

TBD.

5. Manageability Considerations

TBD.

6. Security Considerations

The data following the model defined in this draft 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 draft.

The YANG module defined in this document can be accessed via the RESTCONF protocol defined in [I-D.ietf-netconf-restconf], 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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April 25, 2017

A YANG Data Model for Optical Transport Network Topology
draft-zhang-ccamp-l1-topo-yang-07

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 draft 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.

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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This Internet-Draft will expire on October 27, 2017.

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Table of Contents

1. Introduction

A transport network is a server-layer network designed to provide connectivity services for a client-layer network to carry the client traffic transparently across the server-layer network resources. A transport network 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 [RFC6020]. 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 draft 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].

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.vergara-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 draft is defined in [I-D.ietf-netmod-rfc6087bis]. 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. the YANG Tree

```
module: ietf-otn-topology
augment /nd:networks/nd:network/nd:network-types/tet:te-topology:
   +--rw otn-topology!
augment /nd:networks/nd:network:
   +--rw name?   string
augment /nd:networks/nd:network/nd:node:
   +--rw name?   string
augment /nd:networks/nd:network/lnk:link/tet:te/tet:config:
   +--rw available-odu-info* [priority]
   |  +--rw priority    uint8
   |  +--rw odulist* [odu-type]
   |     +--rw odu-type    identityref
   |     +--rw number?     uint16
   +--rw distance?             uint32
augment /nd:networks/nd:network/lnk:link/tet:te/tet:state:
   +--ro available-odu-info* [priority]
   |  +--ro priority    uint8
   |  +--ro odulist* [odu-type]
   |     +--ro odu-type    identityref
   |     +--ro number?     uint16
   +--ro distance?             uint32
augment /nd:networks/nd:network/nd:node/lnk:termination-point
/tet:te/tet:config:
   +--rw client-facing?             empty
   +--rw tpn?                       uint16
   +--rw tsg?                       identityref
   +--rw protocol-type?             identityref
   +--rw adaptation-type?           adaptation-type
   +--rw sink-adapt-active?         boolean
   +--rw source-adapt-active?       boolean
   +--rw tributary-slots
   |  +--rw values*   uint8
   +--rw supported-payload-types* [index]
      +--rw index           uint16
      +--rw payload-type?   string
augment /nd:networks/nd:network/nd:node/lnk:termination-point/
tet:te/tet:state:
```

```
      +--ro client-facing?            empty
      +--ro tpn?                      uint16
      +--ro tsg?                      identityref
      +--ro protocol-type?            identityref
      +--ro adaptation-type?          adaptation-type
      +--ro sink-adapt-active?        boolean
      +--ro source-adapt-active?      boolean
      +--ro tributary-slots
      |  +--ro values*   uint8
      +--ro supported-payload-types* [index]
         +--ro index            uint16
         +--ro payload-type?   string
```

3.2. Explanation of the OTN Topology Data Model

As can be seen, from the data tree shown in Section 3.1, the YANG module presented in this draft 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]. The entities and their attributes, such as node, termination points and links, are still applicable for describing an OTN topology and the model presented in this draft only specifies with technology-specific attributes/information. For example, if the data plane complies with ITU-T G.709 (2012) standards, the switching-capability and encoding attributes MUST be filled as OTN-TDM and G.709 ODUk(Digital Path) respectively.

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

One of the main augmentations in this model is that it allows to specify 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.

3.3. The YANG Code

```
<CODE BEGINS> file "ietf-otn-topology@2017-04-25.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 "nd";
}

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

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

import ietf-transport-types {
 prefix "tran-types";
}

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

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  Xufeng Liu (Xufeng_Liu@jabil.com)
 ";

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

revision 2017-04-25 {
 description
  "Revision 0.3";
 reference
  "draft-zhang-ccamp-l1-topo-yang-07.txt";
}

/*
typedef
*/
```

```
typedef adaptation-type {
 type enumeration {
  enum CBR {
   description "Constant Bit Rate.";
  }
  enum ATMvp {
   description "ATM VP.";
  }
  enum GFP {
   description "Generic Framing Procedure.";
  }
  enum NULL {
   description "NULL";
  }
  enum PRBS {
   description "Pseudo Random Binary Sequence";
  }
  enum RSn {
   description "SDH/SONET section";
  }
  enum ODUj-21 {
   description "ODU payload type 21";
  }
  enum ETHERNET_PP-OS {
   description "ETHERNET_PP-OS, for ODU 2 only";
  }
  enum CBRx {
   description "CBRx(0.. 1.25G), for ODU0 only";
  }
  enum ODU {
   description "Optical Data Unit";
  }
 }

 description
  "Defines a type representing the adaptation type
  on the termination point.";
}


/*
Groupings
*/

grouping otn-topology-type {
 container otn-topology {
  presence "indicates a topology type of Optical
   Transport Network (OTN)-electrical layer.";
```

```
       description "otn topology type";
     }
     description "otn-topology-type";
    }

    grouping otn-topology-attributes {
     leaf name {
      type string;
      description "the topology name";
     }
     description "name attribute for otn topology";
    }

    grouping otn-node-attributes {
     description "otn-node-attributes";
     leaf name {
      type string;
      description "a name for this node.";
     }
    }

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

     list available-odu-info{
      key "priority";
      max-elements "8";

      description
       "List of ODU type and number on this link";
      leaf priority {
       type uint8 {
        range "0..7";
       }
       description "priority";
      }

      list odulist {
       key "odu-type";

       description
        "the list of available ODUs per priority level";

       leaf odu-type {
        type identityref{
         base tran-types:tributary-protocol-type;
        }
        description "the type of ODU";
```

```
       }

       leaf number {
        type uint16;
        description "the number of odu type supported";
       }
      }
     }

     leaf distance {
      type uint32;
      description "distance in the unit of kilometers";
     }
   }

    grouping otn-tp-attributes {
     description "otn-tp-attributes";

     leaf client-facing {
      type empty;
      description
       "if present, it means this tp is a client-facing tp.
       adding/dropping client signal flow.";
     }

     leaf tpn {
      type uint16 {
       range "0..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 tran-types:tributary-slot-granularity;
      }
      description "Tributary slot granularity.";
      reference
      "G.709/Y.1331, February 2012: Interfaces for the Optical
      Transport Network (OTN)";
     }

     leaf protocol-type {
      type identityref {
```

```
         base tran-types:tributary-protocol-type;
        }
        description "Protocol type for the Termination Point.";
       }

       leaf adaptation-type {
        type adaptation-type;
        description
        "This attribute indicates the type of the supported
        adaptation function at the termination point.";
        reference
        "G.874.1, January 2002: Optical transport network (OTN):
        Protocol-neutral management information model for the
        network element view.";
       }

       leaf sink-adapt-active {
        type boolean;
        description
        "This attribute allows for activation or deactivation of
        the sink adaptation function. The value of TRUE means active.";

        reference
        "G.874.1, January 2002: Optical transport network (OTN):
        Protocol-neutral management information model for the
        network element view ";
       }

       leaf source-adapt-active {
        type boolean;
        description
        "This attribute allows for activation or deactivation of
        the sink adaptation function. The value of TRUE
        means active.";
        reference
        "G.874.1, January 2002: Optical transport network (OTN):
        Protocol-neutral management information model for
        the network element view ";
       }

        container tributary-slots {
         description
         "A list of tributary slots used by the ODU
         Termination Point.";
         leaf-list values {
          type uint8;
          description
          "Tributary slot value.";
```

```
        reference
        "G.709/Y.1331, February 2012: Interfaces for the
        Optical Transport Network (OTN)";
       }
     }

     list supported-payload-types{
      key "index";

      description "supported payload types of a TP";

      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
       not: the payload type is defined as the generalized PIDs
       in GMPLS.";
      }
     }
    }


    /*
    * Data nodes
    */
    augment "/nd:networks/nd:network/nd:network-types/tet:te-topology" {
     uses otn-topology-type;
     description "augment network types to include otn newtork";
    }

    augment "/nd:networks/nd:network" {
     when "nd:network-types/tet:te-topology/otn-topology" {
      description "Augment only for otn network";
     }
     uses otn-topology-attributes;
     description "Augment network configuration";
    }

    augment "/nd:networks/nd:network/nd:node" {
     when "../nd:network-types/tet:te-topology/otn-topology" {
```

```
      description "Augment only for otn network";
     }
     description "Augment node configuration";
     uses otn-node-attributes;
    }

    augment "/nd:networks/nd:network/lnk:link/tet:te/tet:config" {
     when "../../../nd:network-types/tet:te-topology/otn-topology" {
      description "Augment only for otn network.";
     }
     description "Augment link configuration";

     uses otn-link-attributes;
    }

    augment "/nd:networks/nd:network/lnk:link/tet:te/tet:state" {
     when "../../../nd:network-types/tet:te-topology/otn-topology" {
      description "Augment only for otn network.";
     }
     description "Augment link state";

     uses otn-link-attributes;
    }

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

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

   <CODE ENDS>
```

4. IANA Considerations

TBD.

5. Manageability Considerations

TBD.

6. Security Considerations

The data following the model defined in this draft 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 draft.

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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March 6, 2017

Framework for GMPLS Control of Optical Transport Networks in G.709 Edition 5

draft-zheng-ccamp-gmpls-g709v5-fwk-00.txt

Abstract

The International Telecommunication Union Telecommunication Standardization Sector (ITU-T) has extended its Recommendations Optical Transport Networks (OTNs, G.709) to edition 5 to support new features, including beyond 100 Gbps (B100G) OTN containers.

This document summarizes the architecture and requirements, and provides corresponding control plane considerations to guide protocol extensions development in support of OTNv5 control mechanisms.

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Table of Contents

1. Introduction

ITU-T G.709v3, published in 2012, defined the interfaces to Optical Transport Network (OTN), supporting a variety of Optical Data Unit (ODU) containers up to 100 Gbps and flexible multiplexing hierarchy. The OTN control plane framework was described in [RFC7062], corresponding signaling and routing extensions were further specified in [RFC7139] and [RFC7138] respectively. Furthermore, there were additional updates made to G.709v4, resulting in additional extensions which are described in [RFC7892] and [RFC7963].

To meet the increasing demand for higher client bit rates, Edition 5 of G.709 [ITU-T G.709v5] has been released to provide beyond 100G capabilities by introducing an ODUCn layer, which contains an optical payload unit(OPUCn).

This document reviews relevant aspects of beyond 100 Gbps (B100G) OTN technology and how it impacts current GMPLS control-plane protocols. It highlights new considerations and proposes how to update the mechanisms described in [RFC7062] to meet B100G control plane requirements.

1.1. Scope

For the purposes of the B100G control plane discussion, the OTN should be considered as a combination of the current OTN ODUk/Cn and the wavelength optical layer. This document focuses on only the control of the ODUk/ODUCn layer. The optical layer control will be addressed in a separate document.

2. Terminology

2.1. 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 RFC-2119 [RFC2119].

2.2. OTN Related Terminologies in this Document

Terminologies from section 2 of [RFC7062] are reused in this document, with the following additional terminologies defined in [ITU-T G.709v5] used in this document:

ODUCn: Optical Data Unit - Cn

OPUCn: Optical Payload Unit- Cn

OTUCn: completely standardized Optical Transport Unit-Cn

3. Optical Transport Network Version 5 Overview

This section provides an overview of new features provided by G.709v5 Optical Transport Network.

3.1. OTN B100G Network

3.1.1. Client Signal Mapping

ODU Type	ODU nominal bit rate
ODU0	1,244,160 Kbps
ODU1	239/238 x 2,488,320 Kbps
ODU2	239/237 x 9,953,280 Kbps
ODU3	239/236 x 39,813,120 Kbps
ODU4	239/227 x 99,532,800 Kbps
ODUCn	n x 239/226 x 99,532,800 Kbps
ODUflex for Constant Bit Rate (CBR) Client signals	239/238 x client signal bit rate
ODUflex for Generic Framing Procedure - Framed (GFP-F) Mapped client signal	Configured bit rate

Table 1: ODU Types and Bit Rates

NOTE: The nominal ODUCn rates are approximately n x 105,258,138.053 kbit/s.

Furthermore, and per [ITU-T G.709v5], the tolerance of ODUCn is +/- 20 ppm. The frame period for ODUCn is 1.163 s. Additionally, it defined 5 Gbps tributary slots for ODU Cn. The number of tributary slots (TS) defined in [ITU-T G.709v5] for each ODU are shown in Table 2.

ODU Server	Nominal TS capacity		
	1.25 Gbit/s	2.5 Gbit/s	5 Gbit/s
ODU0	1	N/A	N/A
ODU1	2	N/A	N/A
ODU2	8	4	N/A
ODU3	32	16	N/A
ODU4	80	N/A	N/A
ODUCn	N/A	N/A	20*n

Table 2: Number of tributary slots (TS)

3.1.2. Supporting clients signals with ODUCn

According to [ITU-T G.709v5], various client signals can be mapped to be supported by ODUCn. Typical client signal includes Ethernet, MPLS and IP. The signal hierarchies can be found in Figure 1.

```
            Client (e.g., IP, Ethernet, MPLS, ...)

                               |

                 OTN client signals (ODUk)

                               |

                             ODUCn
```

|

OTUCn

Figure 1: Mapping Client Signal to ODUCn

Packet streams (e.g., Ethernet, MPLS, IP) which are encapsulated with the generic framing procedure is considered as the client and can be carried by OTN client signals (known as ODUk, including ODU0~4 and ODUflex). Then the OTN client signals will be further mapped into ODUCn containers and multiplexed into OTUCn. It is worth noting that the maximum bit rate for ODUk is 100G (ODU4), which is the same rate of ODUC1. The mapping from ODU client signal to ODU Containers is also required when ODU4 is multiplexed into ODUC1.

Examples of multiplexing can be found as follow:

- ODU0/ ODU1/ ODU2/ ODU3/ ODU4 into ODUC1 multiplexing with 5Gbps TS granularity: ODU0/ ODU1/ ODU2/ ODU3/ ODU4 occupies 1/1/2/8/20 of the 20 TSs for ODUC1. It is worth noting that for ODU0 and ODU1, the 5G TS is only partially occupied.

The type of the transported payload, encoded as the payload type, is set to 22 for ODUCn.

3.2. MSI of ODUCn

When multiplexing an OTN client signal into ODUCn, [ITU-T G.709v5] specifies the information that must be transported in-band to correctly demultiplexing the signal. MSI is used to specify the identifier of each multiplexing section. The MSI information is located in the mapping specific area of the PSI signal and is local to each link.

The MSI information is organized as a set of entries, with n entries for each OPUC TS. The MSI has a fixed length of 40n bytes and indicates the ODTU content of each tributary slot (TS) of an OPUCn.

Two bytes are used for each tributary slot. The information carried by each entry is:

- TS availability bit 1 indicates if the tributary slot is available or unavailable.

- The TS occupation bit 9 indicates if the tributary slot is allocated or unallocated.

- The tributary port number in bits 2 to 8 and 10 to 16 indicates the port number of the ODTUCn.ts that is being transported in this TS; a flexible assignment of tributary port to tributary slots is possible. ODTUC.ts tributary ports are numbered 1 to 10n. The value is set to all-0s when the occupation bit has the value 0 (tributary slot is unallocated).

Tributary Port Number (TPN) indicates the port number of the OTN client signal transported by the ODUCn. The TPN is the same for all the TSs assigned to the transport of the same OTN client signal.

3.3. OTUCn sub rates (OTUCn-M)

An OTUCn with a bit rate that is not an integer multiple of 100 Gbit/s can be described as an OTUCn-M. An OTUCn-M frame contains n instances of OTUC overhead, ODUC overhead and OPUC overhead together with M 5Gbit/s OPUCn TS.

When an OTUCn-M is used to carry an ODUCn (20n-M) TS are marked as unavailable, in the OPUCn multiplex structure identifier (MSI), since they cannot be used to carry a client signal.

4. Connection Management of ODUCn

ODUk based connection management has been described in section 4 of [RFC7062]. In this section the connection management of ODUCn is described, which is independent but used together with ODUk based connection management.

ODUCn based connection management is concerned with controlling the connectivity of ODUCn paths. According to ITU-T G.872, the intermediate nodes with ODUCn do not support the switching of ODUCn time slot. Intermediate ODUCn points are only considered as a forwarding node. Once an ODUCn path is used to transport client signal, the TS occupied will not change across the ODUCn network.

5. GMPLS Implications

5.1. Implications for GMPLS Signaling

For OTNv3 network control, [RFC7139] defines RSVP-TE signaling extensions, extending the base specifications [RFC3473] and [RFC4328].

As described in Section 3, [ITU-T G.709v5] introduced some new features including the ODUCn, OTUCn for beyond 100G control. The mechanisms defined in [RFC7139] do not support such features, and protocol extensions SHALL be necessary to allow them to be controlled by a GMPLS control plane. In summary, the following new signaling aspects SHOULD be considered:

- Support for specifying new signal types and related traffic information: The traffic parameters should be extended in a signaling message to support the new ODUCn;

- Support the new TS granularity: the signaling protocol should be able to identify the TS granularity (i.e., the new 5 Gbps TS granularity) to be used for establishing a Hierarchical LSP that will be used to carry service LSP(s) requiring a specific TS granularity.

- Support for LSP setup of new ODUCn containers with related mapping and multiplexing capabilities: A new label format must be defined to carry the exact TS's allocation information related to the extended mapping and multiplexing hierarchy (for example, ODU4 into ODUCn multiplexing (with 5 Gbps TS granularity)), in order to set up all the possible ODU connections.

- Support for TPN allocation and negotiation: TPN needs to be configured as part of the MSI information (see more information in Section 3.1.2.1). A signaling mechanism must be identified to carry TPN information if the control plane is used to configure MSI information.

- Support for LSP setup of OTUCn sub rates (OTUCn-M) path: based on previous extensions, there should be new signal mechanism to declare the OTUCn-m information.

5.2. Implications for GMPLS Routing

The path computation process needs to select a suitable route for an ODUCn connection request. Evaluation of the available bandwidth on each candidate link is required for path computation. The routing protocol SHOULD be extended to carry sufficient information to represent ODU Traffic Engineering (TE) topology.

The Interface Switching Capability Descriptors defined in [RFC4203] present a new constraint for LSP path computation. [RFC4203] defines the Switching Capability, related Maximum LSP Bandwidth, and Switching Capability specific information. [RFC7138] updates the ISCD to support ODU4, ODU2e and ODUflex. The new Switching Capability specific information provided in [RFC7138] have to be adapted to support new features contained in [ITU-T G.709v5]. The following requirements should be considered:

- Support for carrying the link multiplexing capability: As discussed in Section 3.1.2, many different types of ODUk can be multiplexed into the ODUCn. For example, ODU4 may be multiplexed into ODUC1. An OTUCn link may support one or more types of ODUk signals. The routing protocol should be capable of carrying this multiplexing capability.

- Support for additional Tributary Slot Granularity advertisement: as new tributary slot granularity (5G TS) is introduced in [G.709 v5], there is a need to specify this parameter.

- Support for advertisement of OTUCn sub rates support information: Given the same n value, there is possible different OTUCn sub rates. Corresponding information should be defined in the routing mechanism to satisfy this feature.

6. Security Considerations

TBD.

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GMPLS Signaling Extension for Optical Transport Networks with Beyond 100G in G.709 Edition 5

draft-zheng-ccamp-gmpls-g709v5-signal-ext-00.txt

Abstract

The International Telecommunication Union Telecommunication Standardization Sector (ITU-T) has extended its Recommendations G.709 to edition 5 to support beyond 100G (B100G) features. Corresponding signaling extensions have been described in this document.

Status of this Memo

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Table of Contents

1. Introduction

[ITU-T G.709v5] defines the interfaces to Optical Transport Network. B100G features was included in the latest version v5. Corresponding OTN control plane techniques have been considered in [B100G-fwk].

[RFC4328] describes the control technology details that are specific to the 2001 revision of the G.709 specification. The previous signaling extension drafts include the [RFC7139] too support ODU4, ODU2e and ODUflex, and [RFC7963] to support additional ODU1e, ODU3e1 and ODU3e2. The signaling extension for B100G OTN network is described in this document.

2. Terminology

2.1. 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 RFC-2119 [RFC2119].

3. RSVP-TE Extensions to Support Optical Transport Network B100G

3.1. New Signal types in B100G OTN

New features has been defined for B100G OTN. The corresponding new signal types can be summarized as follow:

- Optical Data Unit - Cn (ODUCn)

  n can vary from 1 to 255;

- Optical Transport Unit - Cn (OTUCn)

  n can vary from 1 to 255;

[RFC7139] defines the format of Traffic Parameters in OTN-TDM SENDER_TSPEC and OTN-TDM FLOWSPEC objects. These traffic parameters have a Signal Type field. This document defines a new Signal Type for ODUCn, where n can vary from 1 to 255.

```
   Value    Type
   -----    ----
   TBD(31)  ODUCn (i.e., n * 100 Gbps)

  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
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |  Signal Type  |       n       |            Reserved           |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |              NVC              |        Multiplier (MT)        |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                            Bit_Rate                           |
```

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Signal Type: 8 bits

As defined in Section 3.2.1 of [RFC4328], with the following additional values:

```
Value    Type
-----    ----
4        ODU4 (i.e., 100 Gbps)
9        OCh at 100 Gbps
10       ODU0 (i.e., 1.25 Gbps)
11       ODU2e (i.e., 10 Gbps for FC1200 and GE LAN)
12-19    Reserved (for future use)
20       ODUflex(CBR) (i.e., 1.25*N Gbps)
21       ODUflex(GFP-F), resizable (i.e., 1.25*N Gbps)
22       ODUflex(GFP-F), non-resizable (i.e., 1.25*N Gbps)
23       ODU1e  (10Gbps Ethernet [G.Sup43])
26       ODU3e1 (40Gbps Ethernet [G.Sup43])
27       ODU3e2 (40Gbps Ethernet [G.Sup43])
31       ODUCn (B100G OTN [G.709-2016])
32-255   Reserved (for future use)
```

n : 8 bits

When the signal type is ODUCn, the n is used to specify the ODUCn granularity, the value of n varies from 1 to 255. When the signal type is not ODUCn, the n MUST be set to 0 and ignored.

3.2. New Tributary Slot Definition in B100G OTN

A new tributary slot granularity (i.e., 5Gbps) is defined in [G.709-2016]. This granularity is specially used to support ODUCn in B100G OTN networks. Legacy OTN interfaces will continue to use 2.5Gbps/1.25Gbps tributary slot granularity.

The OPUCn consists of n OPUC. Each OPUC is divided into 20 tributary slots (TS) and these tributary slots are 16-byte interleaved within the OPUC payload area. A tributary slot includes a part of the OPUC OH area and a part of the OPUC payload area. The bytes of the ODUk frame are mapped into the ODTUCn payload area and the ODTUCn bytes are mapped into the OPUCn tributary slot or slots. The bytes of the ODTUCn justification overhead are mapped into the OPUCn OH area.

There is only one type of tributary slot: Tributary slot with a bandwidth of approximately 5 Gbit/s; an OPUCn is divided into 20n tributary slots, numbered 1.1 to n.20.

To satisfy the new TS granularity, this document also updates the G-PID values defined in [RFC4328].

Value	G-PID Type
TBA(71)	OTN B100G control defined in [G.709-2016]

The update of payload types updated in [G709-2016] and their mapping to existing and new G-PID types are as follows:

G.709 Payload Type	G-PID	Type/Comment	LSP Encoding
0x22	TBA(71)	G.709 ODU-5G	G.709 ODUCn(n=1..255)

3.3. Generalized Label for B100G

[RFC7139] defined the GENERALIZED_LABEL object format that MUST be used with the OTN-TDM Switching Type, the format is re-drawn as follow:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         TPN           |   Reserved    |        Length         |
```

```
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      ~                   Bit Map          ......                 ~
      ~              ......                 |     Padding Bits     ~
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

This object was used to indicate how LO ODUj is multiplexed into HO ODUk. It can also be used to indicate how ODUk can be multiplexed into ODUCn.

In the extreme case for B100G, ODU0 need to be multiplexed to ODUC255. The maximum for TPN number is 20,400, which is beyond the 2^12. In this document this object need to be updated as follow:

```
       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
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |              TPN              |            Length             |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      ~                   Bit Map          ......                 ~
      ~              ......                 |     Padding Bits     ~
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

After the extension, the maximum values for TPN and Length are updated to 65,536, which can cover the extreme case in B100G multiplexing.

3.4. TPN allocation and MSI

TPN section has been used to indicates the tributary port number for the assigned tributary slot(s).

- In the case of an ODUk mapped into ODUCn, only the lower 15 bits of the TPN field are significant; the other bits of TPN field MUST be set to 0;

Per [G709-2016], the TPN is used to allow for correct demultiplexing in the data plane. When an LO ODUj is multiplexed into an HO ODUk occupying one or more TSs, a new TPN value is configured at the two ends of the HO ODUk link and is put into the related MSI byte(s) in the OPUk overhead at the (traffic) ingress end of the link, so that the other end of the link can learn which TS(s) is/are used by the LO ODUj in the data plane.

According to [G709-2016], the TPN field MUST be set according to the following tables:

```
+-------+-------+----+-----------------------------------------------+
| ODUk  | ODUC1 |TPN |          TPN Assignment Rules                 |
+-------+-------+----+-----------------------------------------------+
| ODU0  | ODUC1 |1-20|Flexible, != any other existing LO ODUs'TPNs |
+-------+-------+----+-----------------------------------------------+
| ODU1  | ODUC1 |1-20|Flexible, != any other existing LO ODUs' TPNs |
|-------+-------+----+-----------------------------------------------+
| ODU2  | ODUC1 |1-10|Flexible, != any other existing LO ODUs' TPNs |
+-------+-------+----+-----------------------------------------------+
| ODU3  | ODUC1 |1-2 |Flexible, != any other existing LO ODUs' TPNs |
|-------+-------+----+-----------------------------------------------+
| ODU4  | ODUC1 |1-1 |Flexible, != any other existing LO ODUs' TPNs |
+-------+-------+----+-----------------------------------------------+
```

Table X: TPN Assignment Rules from ODUk to ODUC1 (5 Gbps TS Granularity)

Editor's Note: The I-D stills need to consider how to multiplex ODU2e, ODU1e, and ODUFlex to ODUCn. This is a topic for further discussion.

For ODUCn where n>1, the only changes are the upper bound of TPN. As ODUCn is composed by n ODUC, the upper bound of TPN is multiplied by n.

```
+-------+-------+-----+-----------------------------------------------+
| ODUk  | ODUCn | TPN |          TPN Assignment Rules                 |
+-------+-------+-----+-----------------------------------------------+
| ODU0  | ODUCn |1-20n|Flexible, != any other existing LO ODUs'TPNs |
+-------+-------+----+-----------------------------------------------+
| ODU1  | ODUCn |1-20n|Flexible, != any other existing LO ODUs' TPNs |
|-------+-------+-----+-----------------------------------------------+
| ODU2  | ODUCn |1-10n|Flexible, != any other existing LO ODUs' TPNs |
+-------+-------+-----+-----------------------------------------------+
| ODU3  | ODUCn |1-2n |Flexible, != any other existing LO ODUs' TPNs |
```

```
      |-------+-------+-----+----------------------------------------------+
      | ODU4  | ODUCn | 1-n |Flexible, != any other existing LO ODUs' TPNs |
      +-------+-------+-----+----------------------------------------------+
```

Table X: TPN Assignment Rules from ODUk to ODUCn (5 Gbps TS Granularity)

3.5. Supporting of OTUCn sub rates (OTUCn-M)

The OTUCn-M frame is a type of OTUCn frame which contains n instances of OTUC, ODUC and OPUC overhead and M 5 Gbit/s OPUCn tributary slots. If a particular value of M is not indicated, the frame contains 20*n tributary slots.

For OTUCn-M, there is totally 20*n+M tributary slots. Accordingly, M need to be considered as in TPN numbers defined in section 3.4.

3.6. Examples:

Following examples are given to illustrate how to multiplexing ODUk into ODUCn format.

(1) ODU2 to ODUC1 Multiplexing

In this example, the n value in ODUCn is set to 1, with a signal type assigned as 31 which means ODUCn.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Signal Type=31|     n=1       |           Reserved            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The label format, defined in section 3.3 of this document, is illustrated as follow.

```
    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

   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

   |          TPN = 1                |         Length = 20          |
```

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|0 1 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 |     Padding Bits (0) |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The label above indicate that ODU2 (10G) is using the 2nd and 5th tributary slots of ODUC1. The tributary slot granularity in B100G MUST be set to 5Gbps.

(2) ODU4 to ODUC1 Multiplexing

This example is special, as both ODU4 and ODUC1 are assumed to be with a rate of 100Gbps. The signal type of ODUC1 is the same as previous example.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          TPN = 1              |         Length = 20           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 |     Padding Bits (0) |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

In this example, all the 20 tributary slots are occupied in the multiplexing.

4. Security Considerations

TBD.

5. IANA considerations

IANA maintains the "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Parameters" registry (see <http://www.iana.org/assignments/gmpls-sig-parameters>). The "Generalized PIDs (G-PID)" subregistry is included in this registry, which is extended and updated by this document as detailed below.

Value	Type	Technology	Reference
47	G.709 ODU-2.5G	G.709 ODUk	[RFC4328]
	(IANA updated the Type field)		[RFC7139]
56	SBCON/ESCON	G.709 ODUk,	[RFC4328]
	(IANA updated the Type field)	Lambda, Fiber	[RFC7139]
59	Framed GFP	G.709 ODUk	[RFC7139]
60	STM-1	G.709 ODUk	[RFC7139]
61	STM-4	G.709 ODUk	[RFC7139]
62	InfiniBand	G.709 ODUflex	[RFC7139]
63	SDI (Serial Digital Interface)	G.709 ODUk	[RFC7139]
64	SDI/1.001	G.709 ODUk	[RFC7139]
65	DVB_ASI	G.709 ODUk	[RFC7139]
66	G.709 ODU-1.25G	G.709 ODUk	[RFC7139]
67	G.709 ODU-any	G.709 ODUk	[RFC7139]
68	Null Test	G.709 ODUk	[RFC7139]
69	Random Test	G.709 ODUk	[RFC7139]
70	64B/66B GFP-F Ethernet	G.709 ODUk	[RFC7139]
TBD(71)	G.709 ODU-5G	G.709 ODUCn	[This draft]

This document also request IANA to add the following signal types in the subregistry via the Specification Required policy [RFC5226]:

Value	Signal Type	Reference
0	Not significant	[RFC4328]
1	ODU1 (i.e., 2.5 Gbps)	[RFC4328]
2	ODU2 (i.e., 10 Gbps)	[RFC4328]
3	ODU3 (i.e., 40 Gbps)	[RFC4328]
4	ODU4 (i.e., 100 Gbps)	[RFC7139]
5	Unassigned	[RFC4328]
6	Och at 2.5 Gbps	[RFC4328]
7	OCh at 10 Gbps	[RFC4328]
8	OCh at 40 Gbps	[RFC4328]
9	OCh at 100 Gbps	[RFC7139]
10	ODU0 (i.e., 1.25 Gbps)	[RFC7139]
11	ODU2e (i.e., 10 Gbps for FC1200 and GE LAN)	[RFC7139]
12-19	Unassigned	
20	ODUflex(CBR) (i.e., 1.25*N Gbps)	[RFC7139]
21	ODUflex(GFP-F), resizable (i.e., 1.25*N Gbps)	[RFC7139]
22	ODUflex(GFP-F), non-resizable (i.e., 1.25*N Gbps)	[RFC7139]
23	ODU1e (10Gbps Ethernet)	[RFC7963]
26	ODU3e1 (40Gbps Ethernet)	[RFC7963]
27	ODU3e2 (40Gbps Ethernet)	[RFC7963]

```
      31       ODUCn                               [This Draft]

     23-255   Unassigned
```

These Signal Types are carried in the Traffic Parameters in OTN-TDM SENDER_TSPEC and OTN-TDM FLOWSPEC objects.

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GMPLS Routing and Signaling Framework for B100G
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Abstract

The latest revision of G.709 introduces support for OTU links with rates larger than 100G. This document provides a framework to address the GMPLS routing and signalling extensions that enable GMPLS to setup paths through network that contain these newly introduced OTUCn links.

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1. Introduction

The current GMPLS routing [RFC7138] and signaling extensions [RFC7139] includes coverage for all the OTN capabilities that were defined in the 2012 version of G.709 [ITU-T_G709_2012]. The 2012 version of the G.709 included support for the following capabilities:

a. Introduction of ODU0

b. Mapping of 100BASE-X client (1GE) and other sub-1.25G client signals into ODU0

c. Mapping of FC-1200 into ODU2e

d. Mappings for 100GBASE-R and 40GBASE-R Ethernet client signals.

e. OTU4 layer with a rate of 100G.

f. Support for 1.25G tributary slots in OPU2, OPU3, OPU4 -- to fully support the newly introduced ODU0 signal.

g. Support for multi-lane interfaces for OTU3, and OTU4 signals

The 2016 version of G.709 [ITU-T_G709_2012] introduces support for higher rate OTU signals, termed OTUCn (which have a nominal rate of 100n Gbps). The newly introduced OTUCn represent a very powerful extension to the OTN capabilities, and one which naturally scales to transport any newer clients with bit rates in excess of 100G, as they are introduced.

This document presents an overview of the changes introduced in [ITU-T_G709_2016] and analyzes them to identify the extensions that would be required in GMPLS routing and signaling to enable the new OTN capabilities. In an OTN network as defined by [ITU-T_G709_2016] and [ITU-T_G798], two layers can be switched at the intermediate nodes: (a) ODU (digital switching), (b) OCh/Optical Tributary Signal (OTSi) (optical switching). This document focuses on the GMPLS extensions that are necessary to support ODU switching in networks that include the beyond 100G OTU links.

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. Terminology

a. OPUCn: Optical Payload Unit -Cn. This signal can be seen as the interleaving of n OPUC "slices".

b. ODUCn: Optical Data Unit - Cn. Like the OPUCn, this signal can be seen as the interleaving of n slices of ODUC signals.

c. OTUCn: Fully standardized Optical Transport Unit - Cn. This signal can be viewed as being formed as a result of multiplexing n OTUC "slices". An OTUCn has a bandwidth of (approximately) nx100G. An OTUCn signal has n OTUC/ODUC/OPUC overhead instances.

d. OTUCn-M: This signal is an extension of the OTUCn signal introduced above. This signal contains the same amount of overhead as the OTUCn signal, but contains a reduced amount of payload area. Specifically the payload area consists of M 5G tributary slots (where M is strictly less than 20*n).

e. GMP: Generic Mapping Procedure. This procedure allows a uniform asynchronous mapping procedure for a adapting a client signal to a server layer. This generic mapping procedure computes the population of stuff bytes for all client/server signal rates. Specifically this procedure is used to map client signals into ODU(s), and Low-Order ODUs into High-Order ODUs.

f. PSI: OPU Payload structure Indicator. This is a multi-frame message and describes the composition of the OPU signal. This structure includes a field called Payload Type (PT) whose values indicates whether the OPU payload area has been formed by (a) mapping a single non-OTN client (b) multiplexing LO-ODUs. The MSI field is a substructure of the PSI structure, and contains information about the ODU mix contained in a HO-ODU. For mappings of type (b), the following PT codepoints are defined:

   A. 0x20: indicates 2.5G time slots (with AMP)

   B. 0x21: indicates 1.25G tributary slots (with GMP).

   C. 0x22: (introduced in [ITU-T_G709_2016] is used for ODUCn entities, and implies a tributary slot granularity of 5G (with GMP).

g. MSI: Multiplex Structure Indicator. This structure indicates the grouping of the tributary slots in an OPU payload area to realize a client signal that is multiplexed into an OPU. The individual clients multiplexed into the OPU payload area are distinguished by the Tributary Port number (TPN).

h. FlexO lane: Refers to an electrical/optical lane of a FlexO interface, used to carry OTUC transport signals.

i. FlexO group: Refers to the group of m * FlexO interfaces.

j. AMP: Asynchronous Mapping Procedure

k. BMP: Bitsynchronous Mapping Procedure

l. GMP: Generic Mapping Procedure

3. Overview of B100G links in G.709

3.1. The OTUCn signal

In G.709 [ITU-T_G709_2012], the standard mechanism for transporting a client signal is to first map it into an ODU signal (of the appropriate rate), and then switch the resulting ODU signal through the OTN network. In the course of its traversal through the OTN network, the ODU signal generated by the mapper is either (a) multiplexed into higher-order ODU, and then encapsulated to form an OTU or (b) directly encapsulated into an OTU signal that defines the section layer. The option (b), i.e. direct encapsulation into an OTU was possible only for ODU1/ODU2/ODU3/ODU4; ODU signals with other rates (e.g. ODUflex) would first have to be processed per option (a) above. The term "client signal" is generic in the sense that it encompasses both Constant Bit rate (CBR) clients (e.g. 10GBASE-R, SONET OC-768), or packet traffic -- where the goal is to transfer the payload from end-to-end (without regard for bit transparency at the PCS layer). Given that OTU4 was the highest rate section layer signal supported in [ITU-T_G709_2012], the client signal rates were limited to be less than 100G (if ODU-VCAT was not used).

With the emergence of client signals with rates greater than 100Gbps (e.g. 200GBASE-R, 400GBASE-R Ethernet), aggregate signals such as FlexE ([OIF_FLEXE_1.0], and the availability of NPUs which can source packet traffic of n*100G, it becomes necessary for the OTN to transport these signals. This means that the OTN must be capable of creating, and switching ODU entities with rates in excess of n*100G. Traditionally, the ITU-T has introduced OTUx/ODUx signals in G.709 as and when new client signals with higher rates are defined by other standards bodies (e.g. IEEE). Rather than follow the traditional trajectory, [ITU-T_G709_2016] takes a general and scalable approach to decoupling the rates of OTU signals from the client rate evolution. The new OTU signal is called OTUCn; this signal is defined to have a rate of (approximately) n*100G. The following are the key characteristics of the OTUCn signal:

a. Unlike the signals OTU1..OTU4, the OTUCn signals are not realized by keeping the frame format intact and increasing the frame rate.

b. The OTUCn signal contains one ODUCn, which in turn contains one OPUCn signal. The OTUCn and ODUCn signals serve as section layer entities.

c. The OTUCn signals can be viewed as formed by interleaving n OTUC signals (where are labeled 1, 2, ..., n), each of which has the format of a standard OTUk signal without the FEC columns (per [ITU-T_G709_2016]:Figure 7-1). The ODUCn, and OPUCn have a similar structure, i.e. they can be seen as being formed by interleaving n instances of ODUC, OPUC signals (respectively) The OTUC signal contains the ODUC, and OPUC signals, just as in the case of fixed rate OTUs defined in G.709 [ITU-T_G709_2016].

d. Each of the OTUC "slices" have the same overhead (OH) as the standard OTUk signal in G.709 [ITU-T_G709_2016]. The combined signal OTUCn has n instances of OTUC OH, ODUC OH, and OPUC OH.

e. The OTUC signal has a slightly highly rate compared to the OTU4 signal (without FEC); this is to ensure that the OPUC payload area can carry an ODU4 signal.

3.1.1. Carrying OTUCn signal between 3R points

As explained above, within G.709 [ITU-T_G709_2016], the OTUCn, ODUCn and OPUCn signal structures are presented in an interface independent manner, by means of n OTUC, ODUC and OPUC instances that are marked #1 to #n. Specifically, the definition of the OTUCn signal does not cover aspects such as FEC, modulation formats, etc. These details are defined as part of the adaptation of the OTUCn layer to the optical layer(s). The specific interleaving of OTUC/ODUC/OPUC signals onto the optical signals is interface specific and specified for OTN interfaces with standardized application codes in the interface specific recommendations (G.709.x).

The original working assumption was that the first B100G inter-domain interface for an OTUC4 would use the optical modules developed for the 400GbE signal. This assumption has been revised as a result of new insights into how the notions developed for FlexE can be applied to the OTN domain. The new developments make it possible to support OTUC4 signals without having to wait for the 400GbE optical modules. The main motivation for developing the interoperable FlexO interfaces is to (a) reuse already existing optical modules developed for carrying Ethernet signals and (b) realize higher rate OTUCn interfaces by bonding the required number of available PHY(s) -- thereby decoupling the rates of OTUCn interfaces from the rates of the available Ethernet PHY(s) . The FlexO layer can be viewed as an encapsulation layer for the OTUCn signal.

Recommendation [ITU-T_G709.1] specifies a flexible interoperable short-reach OTN interface over which an OTUCn (n >=1) is transferred, using bonded FlexO interfaces which belong to a FlexO group. Conceptually, the FlexO can be seen as the adaptation of the idea of

FlexE [OIF_FLEXE_1.0] to OTN signals. Like the FlexE group, the FlexO group supports physical interface bonding, the management of the group members, overhead for communication between FlexO peers etc. (these overheads are separate from the GCC0 channel defined over OTUCn). In its current form, Recommendation [ITU-T_G709.1] is limited to the case of transporting OTUCn signals using n 100G Ethernet PHY(s). When the PHY(s) for the emerging set of Ethernet signals, e.g. 200GbE and 400GbE, become available, new recommendations can define the required adaptations.

The (high-level) sequence of steps performed at the FlexO/OTUCn adaptation source are the following:

a. one OTUCn is split into n instances of OTUC at the FlexO source node.

b. One or more OTUC instances are associated with one FlexO interface (which could have a rate of p*100G. As of this document’s writing, Ethernet PHY(s) exist for transporting 100GBASE-R signals (i.e. p=1). This is the basis for the FlexO interface specified in [ITU-T_G709.1]. For this specific instance, the mapping between OTUC, and the FlexO interface is 1:1, and the mapping is illustrated in Figure 1. Figure 2 illustrates the scenario in which OTUCn transport makes use of 200GbE PHY(s).

c. The contents of the selected subset of OTUC signals are mapped to FlexO frames directed at one of the FlexO interfaces in the FlexO group.

d. Alignment markers are added to these FlexO frames so that the resulting stream can be transported across multiple physical/ electrical lanes. The standard IEEE FEC used in conjuction with the appropriate Ethernet signal(e.g. 100GbE, or 200GbE) is also added to the frames.

The sink performs the reverse sequence of operations and reconstructs the OTUCn signal. As a result of the direct encapsulation of the OTUCn signal into the FlexO layer, full transparency for the OTUCn layer is guaranteed. Once the OTUCn signal is transported between 3R regeneration points, all B100G capabilities -- such as the support for ODUs with rates higher than 100G, and client signals larger than 100G are enabled.

```
    ==================================================================


         +-----------------------------------+
         |          OTUCn                    |    OTUCn signal
         +-----------------------------------+
             |           |              |
             |           |     ....     |
         +-------+   +-------+      +-------+    n X OTUC instances
         | OTUC  |   | OTUC  |      | OTUC  |
         +-------+   +-------+      +-------+
             |           |              |
             |           |              |
         +-------+   +-------+      +-------+    n FlexO interfaces
         | FlexO |   | FlexO |      | FlexO |
         | Frame |   | Frame |      | Frame |
         +-------+   +-------+      +-------+
             |           |              |
      +----------------------------------------->  Electrical lanes
             |           |              |
             |           |              |
         +-------+   +-------+      +-------+    n 100GbE Eth PHY(s)
         | 100GE |   | 100GE |      | 100GE |
         | PHY   |   | PHY   |      | PHY   |
         +-------+   +-------+      +-------+

    ==================================================================
```

Figure 1: OTUCn transport using 100GbE PHY(s)

```
   ==================================================================


      +-----------------------------------+
      |          OTUCn                    |    OTUCn signal
      +---+-----------+--------------+---+
          |           |              |
          |           |     ....     |
      +---+---+   +---+---+      +---+---+    n X OTUC instances
      | OTUCx2|   | OTUCx2|      | OTUCx2|    n/2 groups, 2 OTUC/group
      +---+---+   +---+---+      +---+---+
          |           |              |
          |           |              |
      +---+---+   +---+---+      +---+---+    n/2  FlexO interfaces
      | FlexO |   | FlexO |      | FlexO |
      | Frame |   | Frame |      | Frame |
      +---+---+   +---+---+      +---+---+
          |           |              |
   +----------------------------------------->  Electrical lanes
          |           |              |
          |           |              |
      +---+---+   +---+---+      +---+---+    n/2 200GbE Eth PHY(s)
      | 200GE |   | 200GE |      | 200GE |
      | PHY   |   | PHY   |      | PHY   |
      +-------+   +-------+      +-------+

   ==================================================================
```

Figure 2: OTUCn transport with 200G PHY(s)

3.2. The OTUCn-M signal

The standard OTUCn signal has the same rate as that of the ODUCn signal as captured in Table 1. This implies that the OTUCn signal can only be transported over wavelengths which have a capacity of multiples of (approximately) 100G. Modern DSPs support a variety of bit rates per wavelength, depending on the reach requirements for the optical link. With this in mind, ITU-T supports the notion of a reduced rate OTUCn signal, termed the OTUCn-M. The OTUCn-M signal is derived from the OTUCn signal by retaining all the n slices of overhead (one per OTUC slice) and trimming the OPUC tributary slots marked as "unavailable". This operation is equivalent to that referred to as "crunching" in the context of FlexE PHY(s).

3.3. The ODUCn signal

The ODUCn signal [ITU-T_G709_2016] can be viewed as being formed by the appropriate interleaving of content from n ODUC frames. The ODUC frames have the same structure as a standard ODU -- in the sense that it has the same Overhead (OH), and the payload area -- but has a higher rate since its payload area can embed an ODU4 signal. The ODUCn is meant to be used as a high-order signal only -- implying that only other lower-rate (i.e. low-order) ODUs can be multiplexed into an ODUCn signal; in other words, no client signals can be directly mapped to an ODUCn signal. The ODUCn signals have a rate that is captured in Table 1.

ODU Type	ODU Bit Rate
ODUCn	n x 239/226 x 99,532,800 kbit/s

Not all values of 'n' may be standardized by ITU-T-T.

Table 1: ODUCn rates

The ODUCn is a higher-order ODU signal, and is encapsulated into an OTUCn signal which occupies the section layer. In most common scenarios, the ODUCn, and OTUCn signals will be co-terminous, i.e. they will have identical source/sink locations. [ITU-T_G709_2016] and [ITU-T_G872] allow for the ODUCn signal to pass through a digital regenerator node which will terminate the OTUCn layer, but will pass the regenerated (but otherwise untouched) ODUCn towards a different OTUCn interface where a fresh OTUCn layer will be initiated. Specifically, the OPUCn signal flows through these regenerators unchanged. That is, the set of client signals, their TPNs, trib-slot allocation remains unchanged. Note however that the ODUCn Overhead (OH) might be modified if TCM sub-layers are instantiated in order to monitor the performance of the repeater hops. In this sense, the ODUCn should not be seen as a general, switchable ODU.

3.4. OPUCn Time Slot Granularity

[ITU-T_G709_2012] introduced the support for 1.25G granular tributary slots in OPU2, OPU3, and OPU4 signals. With the introduction of higher rate signals such as the OPUCn (which are formed by interleaving n OPUC signals), it is no longer practical for the optical networks (and the datapath hardware) to support a very large number of flows at such a fine granularity. ITU-T has defined the OPUC with a tributary slot granularity of 5G. This choice is motivated by the following reasons:

a. Low bitrate flows will usually be aggregated into higher-order ODUs before they are transported over the core of the transport network, and as a consequence, the network is not expected to see a large number of small bitrate flows such as ODU0.

b. The IEEE is planning to define new MAC rates such as 25Gbps. The choice of 5G TS for OPUC nicely accomodates 25GE clients, without wasting a large amount of bandwidth

c. The OIF FlexE Implementation agreement also defines the FlexE PHY calendar slots to have a bandwidth of 5G; the OPUC granularity perfectly matches the capacity of the finest FlexE client.

3.5. Structure of OPUCn MSI

An OPUCn signal can be viewed as being formed from an interleaving of n OPUC signals. Each of the OPUC "slices" has a format that is very similar to that OPU4 -- albeit with a slightly higher rate (since an ODU4 can be fully embedded in the payload area of the OPUC signal). As mentioned above, the OPUC signal has 20 tributary slots, each with a bandwidth of 5G. The PSI structure for an OPUCn signal can be viewed as the concatenation of n PSI structures (one per OPUC). The PSI structure of an OPUC includes the following fields:

a. the Payload Type (PT) - 1byte - with a value of 0x22. This indicates that ODUC has been formed by multiplexing zero or more low-order ODUs into OPUC.

b. Reserved Field - 1 byte. In ODUs other than ODUC (e.g. ODU0/1/2/3/4/flex), this byte carries the "Client Signal Failure Indication". This field is unused in the case of ODUC entities since no non-OTN client signal is directly mapped to these server layers.

c. The MSI field (of size 40 bytes) which contains the information about 20 tributary slots; each such information structure occupies 2 bytes and has the following format (G.709:Section 20.4.1 [ITU-T_G709_2016]):

Bit Position # (Bit 1= MSB; Bit 16 = LSB)	Description
1	The TS availability bit 1 indicates if the tributary slot is available or unavailable
9	The TS occupation bit 9 indicates if the tributary slot is allocated or unallocated
2-8, 10-16	The tributary port number (TPN) of the client signal that is being transported in this TS. A given client uses the same TPN value in all the TS(s) that are being used to transport the client signal. ODTUCn.ts tributary ports are numbered 1 to 10n. The current 14-bit field for the TPN will allow the index ’n’ to grow as large as 1638 -- which is sufficient for all conceivable OTUCn links.

Table 2: OPUC MSI information (for each tributary slot

3.6. Client Signal Mappings

Note that [ITU-T_G709_2016] introduces support for OTUCn signals with rates of n*100G and also introduces support for client signals with rates larger than 100G (e.g. the future 400GBASE-R client being standardized by IEEE, higher packet streams from NPUs). The approach taken by the ITU-T to map non-OTN client signals to the appropriate ODU containers is as follows:

a. All client signals with rates less than 100G are mapped as specified in [ITU-T_G709_2016]:Clause 17. These mappings are identical to those specified in the earlier revision of G.709 [ITU-T_G709_2012]. Thus, for example, the 1000BASE-X/10GBASE-R signals are mapped to ODU0/ODU2e respectively (see Table 3 -- based on Table 7-2 in [ITU-T_G709_2016])

b. Always map the new and emerging client signals to ODUflex signals of the appropriate rates (see Table 3 -- based on Table 7-2 in [ITU-T_G709_2016])

c. Drop support for ODU Virtual Concatenation. This simplifies the network, and the supporting hardware since multiple different mappings for the same client are no longer necessary.

d. ODUflex signals are low-order signals only. If the ODUflex entities have rates of 100G or less, they can be transported using either an ODUk (k=1..4) or an ODUCn server layer. On the other hand, ODUflex connections with rates greater than 100G will require the server layer to be ODUCn. The ODUCn signals must be adapted to an OTUCn signal. Figure 3 illstrates the hierarchy of the digital signals defined in G.709; this figure does not illustrate the handed off to the optical layers.

ODU Type	ODU Bit Rate
ODU0	1,244,160 Kbps
ODU1	239/238 x 2,488,320 Kbps
ODU2	239/237 x 9,953,280 Kbps
ODU2e	239/237 x 10,312,500 Kbps
ODU3	239/236 x 39,813,120 Kbps
ODU4	239/227 x 99,532,800 Kbps
ODUflex for CBR client signals	239/238 x Client signal Bit rate
ODUflex for GFP-F mapped packet traffic	Configured bit rate
ODUflex for IMP mapped packet traffic	s x 239/238 x 5 156 250 kbit/s: s=2,8,5*n, n >= 1
ODUflex for FlexE aware transport	103 125 000 x 240/238 x n/20 kbit/s, where n is total number of available tributary slots among all PHYs which have been crunched and combined.

Note that this table doesn't include ODUCn -- since it cannot be generated by mapping a non-OTN signal. An ODUCn is always formed by multiplexing multiple LO-ODUs.

Table 3: Types and rates of ODUs usable for client mappings

```
    ==================================================================


                   Clients (e.g. SONET/SDH, Ethernet)
                        +       +      +
                        |       |      |
       +-------------------+-------+------+-----------------------+
       |                    OPUk                                  |
       +----------------------------------------------------------+
       |                    ODUk                                  |
       +-----------------------+----------------------------+-------+
       | OTUk, OTUk.V, OTUkV   |          OPUk              |       |
       +----------+--------------------------------------------+       |
       | OTLk.n   |            |          ODUk              |       |
       +----------+            +---------------------+-----+       |
                               | OTUk, OTUk.V, OTUkV |   OPUCn    |
                               +----------+----------------------+
                               | OTLk.n   |          |   ODUCn    |
                               +----------+          +------------+
                                                     |   OTUCn    |
                                                     +------------+


    ==================================================================
```

Figure 3: Digital Structure of OTN interfaces (from G.709:Figure 6-1)

4. Usecases

This section introduces various usecases, in increasing order of complexity. This material serves as background information that provides the rationale for the requirements that any solution must satisfy. At a later point in time, it is possible to consolidate these usecases so that all the multiplexing (and demultiplexing) variants are encountered along the path of an end-to-end ODU circuit.

Note: These usecases present scenarios in which OTUCn links are depicted. These illustrations do not highlight how the OTUCn is transported between the 3R points. That is, these usecases cover cases in which a standard FlexO interface (e.g. as defined in [ITU-T_G709.1]) is used, or whether a vendor specific mapping of OTUCn to OTSiG (as defined in [ITU-T_G872]) is used. In other words, multiple variants of these usecases based on FlexO usage (or not) are not included in this document.

4.1. 100GE Client Service with a homogeneous chain of OTUC1 links

In the scenario illustrated in Figure 4 a 100GBASE-R client is mapped into an ODU4 at NE1. The resulting ODU4 signal is multiplexed into the ODUC1 server layer (using GMP) and further encapsulated to form the OTUC1 signal. The links NE1-NE2, and NE2-NE3 are both OTUC1 links -- and they can carry one 100GE client mapped into an ODU4 server layer. Actions performed at NE2 are: (a) terminate OTUC1, and ODUC1 towards NE1 (b) demultiplex the ODU4 signal from ODUC1 (c) map the ODU4 signal onto a different ODUC1/OTUC1 towards NE3. NE3 performs the inverse sequence of steps performed at NE1, and recovers the 100GBASE-R client from the ODU4 signal. Note that the ODU4 and ODUC1 signals are not "interoperable" and that the ODUC1 is a server layer to the ODU4 signal.

This illustration is also applicable to the usecase in which members of a FlexE group are transported in a flexe-unaware mode in the transport network. Although this illustration included only OTUC1 signals, any higher rate OTUCn signal can be substituted for these signals. In this particular scenario, there are two adjacent ODUC1 hops, and the NE2 demultiplexs (and multiplexes) the ODU4 onto the ODUC1. It is possible to construct an alternative scenario in the case when NE2 acts as a regenerator, and doesn’t terminate the ODUC1 signals in the two hops, and instead repeats the ODUC1 signal; this scenario is specifically discussed in Section 4.6.

```
 ==================================================================


       +----------+                                +----------+
       |  100GE   |                                |  100GE   |
       +----------+       +---------------+        +----------+
       |  ODU4    |       |      ODU4     |        |  ODU4    |
       +----------+       +---------------+        +----------+
       |  ODUC1   |       | ODUC1 | ODUC1 |        |  ODUC1   |
       +----------+       +---------------+        +----------+
       |  OTUC1   +-------+ OTUC1 | OTUC1 +--------+  OTUC1   |
       +----------+       +---------------+        +----------+
          NE1                   NE2                   NE3

                +------------->          +------------->
                   Scope of                 Scope of
                   OTUC1, ODUC1             OTUC1, ODUC1


 ==================================================================
```

Figure 4: 100GE Client service

4.2. 100GE Client Service with a mix of OTU4, and OTUC1 links

In the scenario illustrated in Figure 5 a 100GBASE-R client is mapped into an ODU4 at NE1. The resulting ODU4 signal is encapsulated with an OTU layer to form the OTU4 signal. Actions performed at NE2 are: (a) terminate OTU4 layer, and extract the ODU4 signal (b) map the ODU4 signal onto a different ODUC1/OTUC1 towards NE3. NE3 performs the same set of actions that were performed by NE3 in Figure 4.

```
=================================================================


    +----------+                                +----------+
    |  100GE   |                                |  100GE   |
    +----------+        +---------------+       +----------+
    |  ODU4    |        |      ODU4     |       |  ODU4    |
    +----------+        +-------+-------+       +----------+
    |  OTU4    +--------+ OTU4  | ODUC1 |       |  ODUC1   |
    +----------+        +---------------+       +----------+
                                | OTUC1 +---------+  OTUC1   |
                                --------+       +----------+
         NE1                 NE2                     NE3

            +--------------->        +----------------->
                Scope of                 Scope of
                OTU4 layer               OTUC1, ODUC1


=================================================================
```

Figure 5: 100GE Client Service with a mix of OTU4, and OTUC1 links

4.3. 400GE Client Service with a mix of OTUCn links

In the scenario illustrated in Figure 6 a 400GBASE-R client is mapped into an ODUflex at NE1. The resulting ODUflex signal is multiplexed into an ODUC4 (using GMP), and then transformed into an OTUC4 signal. The links between NE1-NE2, and NE2-NE3 are OTUC4 and OTUC6 (respectively). Actions performed at NE2 are: (a) terminate OTUC4, and ODUC4 towards NE1 (b) demultiplex the ODUflex signal from ODUC4 (c) map the ODU4 signal onto ODUC6/OTUC6 towards NE3. NE3 performs the inverse sequence of steps performed at NE1, and recovers the 400GBASE-R client from the ODUflex signal.

Although not specifically illustrated in this figure, the 200G of spare capacity in the NE2-NE3 links can be used to carry other client signals.. Although the scenario illustrated in Figure 6 is specific to 400GE, the treatment for packet clients at other rates (e.g. 25G, 50G, 200G) follows a very similar processing sequence. In the case of 25GBASE-R clients , the 25GE client signal will be mapped to an ODUflex, and can be multiplexed into an ODU4 signal, or an ODUCn signal as illustrated here.

```
 ===================================================================


     +----------+                                +----------+
     |  400GE   |                                |  400GE   |
     +----------+       +---------------+        +----------+
     |  ODUflex |       |    ODUflex    |        |  ODUflex |
     +----------+       +-------+-------+        +----------+
     |  ODUC4   |       | ODUC4 | ODUC6 |        |  ODUC6   |
     +----------+       +---------------+        +----------+
     |  OTUC4   +-------+ OTUC4 | OTUC6 +--------+  OTUC6   |
     +----------+       +-------+-------+        +----------+
        NE1                  NE2                      NE3

              <------------->            <------------->
                 Scope of                   Scope of
                 OTUC4, ODUC4               OTUC6, ODUC6


 ===================================================================
```

Figure 6: 400GE transport over OTUCn links

4.4. FlexE aware transport over OTUCn links

In the scenario illustrated in Figure 7 NE1 interfaces to a client equipment which includes the FlexE SHIM functions which originate/ terminate a FlexE group. The transport network edge node NE2 is FlexE aware -- but doesn't terminate the FlexE group. NE1 may (as defined in the FlexE draft [I-D.izh-ccamp-flexe-fwk]), crunch the unavailable tributary slots in the FlexE PHY signals, and map the resultant stream to one or more ODUflex signals. The links between NE1-NE2, and NE2-NE3 are OTUC4 and OTUC6 (respectively). Actions performed at NE2 are: (a) terminate OTUC4, and ODUC4 towards NE1 (b) demultiplex the ODUflex signal from ODUC4 (c) map the ODUflex signal onto ODUC6/OTUC6 towards NE3. NE3 recovers the Crunched and combined PHY(s) from the ODUflex signal, re-adds the unavailable calendar slots, and outputs the resulting stream towards the FlexE PHY(s).

In the scenario illustrated in Figure 7 the lowest rate OTUCn link is the OTUC4 link between NE1-NE2. This means that the size of the FlexE group is at most 4. FlexE groups with greater sizes can be handled by utilizing appropriate OTUCn links. Note that at most 400G of the capacity of OTUC6 (or 600G) NE2-NE3 link is occupied by the ODUflex signal; the remaining bandwidth can be allocated to other client signals.

```
 ===================================================================


FlexE    +-----------+                      +-----------+       FlexE
group    | Crunched  |                      | Crunche   |       Group
  +------> and       |                      | and       +-------->
         | Combined  |                      | Combined  | Add
         | PHY(s)    |                      | PHY(s)    | unavailable
         +-----------+  +---------------+   +-----------+ Calendar
         |  ODUflex  |  |    ODUflex    |   |  ODUflex  | slots
         +-----------+  +-------+-------+   +-----------+
         |  ODUC4    |  | ODUC4 | ODUC6 |   |  ODUC6    |
         +-----------+  +---------------+   +-----------+
         |  OTUC4    +---+ OTUC4 | OTUC6 +---+  OTUC6    |
         +-----------+  +-------+-------+   +-----------+
            NE1             NE2                NE3

                  <--------->        <------------>
                  Scope of            Scope of
                  OTUC4, ODUC4        OTUC6, ODUC6


 ===================================================================
```

Figure 7: FlexE aware transport over OTUCn links

4.5. FlexE Client transport over OTUCn links

This use case (see Figure 8) concerns the scenario in which a FlexE group is terminated at the transport network edge node (via the FlexE SHIM function), and the FlexE clients are demultiplexed, and independently transported through the OTN network. In the scenario illustrated in Figure 8 the lowest rate OTUCn link is the OTUC4 link between NE1-NE2. This means that the maximum bit rate of the FlexE client is at most 400G. FlexE clients with greater sizes can be handled by utilizing appropriate OTUCn links. This figure illustrates the case in which one FlexE client is transported between NE1 and NE3. Other FlexE clients recovered at NE1 can routed independently to NE3, or to other network elements.

```
    ==================================================================


       +------------------+                          +----------------+
       |     FlexE        |                          |    FlexE       |
       |     Client       |                          |    Client      |
       +------------------+                          +----------------+
       | FlexE |          |   +----------------+     |       | Flex   |
       | SHIM  | ODUflex  |   |     ODUflex    |     |ODUflex| SHIM   |
       +------------------+   +----------------+     +----------------+
       | FlexE | ODUC4    |   | ODUC4 | ODUC6  |     | ODUC6 | FlexE  |
  +----+ PHY(s +----------+   +----------------+     +-------+ PHY(s)+---->
 FlexE |       | OTUC4    +---+ OTUC4 | OTUC6  +---+ OTUC6 |        | FlexE
 Group +------------------+   +----------------+     +----------------+ Group
                  NE1           NE2                   NE3

                    <------------->       <------------>
                       Scope of              Scope of
                       OTUC4, ODUC4          OTUC6, ODUC6

    ==================================================================
```

Figure 8: FlexE client transport over OTUCn links

4.6. Multihop ODUCn link

As mentioned in the introductory section, the ODUCn is not a switchable entity. The ODUCn layer is a server layer, which more-or-less occupies the position of a section layer in OTN networks. As such, the ODUCn signal must be terminated and the contained low-order ODU flows can be switched independently to other OTN interfaces. G.709 and G.872 however allow for digital regenerators to terminate the OTUCn layer, and reinject the ODUCn layer towards another interface (where a new OTUCn section layer is started). This scenario is illustrated in Figure 9. In this figure, NE3 is the regenerator. The ODUC2 signal is terminated at NE2, and NE4. At the regeneration points, all the clients embedded inside the ODUCn signal are not touched (i.e. no TS changes can occur). More specifically, the OPUC2 signal is not modified in any way. However, the ODUC2 OH may be modified if intrusive TCM monitoring points are applied to the ODUC2 signal at NE3. It is for this reason that the ODUC2 entity must be visible at NE3.

In scenarios involving multi-hop ODUCn links, GMPLS signalling will be required to first establish the ODUCn LSP, and then use it as an FA-LSP to switch any contained Low-order ODUs.

```
    ==================================================================

 +----------+                                              +----------+
 |  100GE   |                                              |  100GE   |
 +----------+     +---------------+                        +----------+
 |  ODU4    |     |      ODU4     |                        |  ODU4    |
 +----------+     +-------+-------+      +---------+       +----------+
 |  ODUC1   |     | ODUC1 | ODUC2 |      |  ODUC2  |       |  ODUC2   |
 +----------+     +---------------+      +---------+       +----------+
 |  OTUC1   +-----+ OTUC1 | OTUC2 +-------+  OTUC2  +-------+  OTUC2   |
 +----------+     +-------+-------+      +---------+       +----------+
    NE1              NE2                     NE3              NE4

          <------------->     <------------->    <------------->
             Scope of              OTUC2               OTUC2
             OTUC1, ODUC1

                              <--------------------------------->
                                       ODUC2


    ==================================================================
```

Figure 9: Multihop ODUCn link

4.7. Use of OTUCn-M links

The scenario illustrated in Figure 10 is a variant of the basic usecase presented in Figure 4. The only difference is that the second hop of the ODU4 connection makes use of a OTUC2-30 link which has a capacity of 150G.

```
    =================================================================

          +----------+                                +-----------+
          |  100GE   |                                |  100GE    |
          +----------+          +------------------+  +-----------+
          |  ODU4    |          |      ODU4        |  |  ODU4     |
          +----------+          +-------+----------+  +-----------+
          |  ODUC1   |          | ODUC1 | ODUC2    |  |  ODUC2    |
          +----------+          +------------------+  +-----------+
          |  OTUC1   +--------+ OTUC1 | OTUC2-30 +------+  OTUC2-30 |
          +----------+          +-------+----------+  +-----------+
             NE1                    NE2                    NE3

                   +------------->            +------------->
                      Scope of                   Scope of
                      OTUC1, ODUC1               OTUC2-30
                                                 ODUC2


    =================================================================
```

Figure 10: 100GE Client service over OTUCn-M links

4.8. Intermediate State of ODU mux

The ODUCn links have a tributary slot granularity of 5G -- and this makes it a bit inefficient if a small number of ODU0 flows have to be switched across an ODUCn links. In these cases, it is conceivable that the intermediate nodes may offer the convenience of a intermediate-stage multiplexing, whereby multiple ODU0 flows are first multiplexed into a higher rate container (e.g. ODU2), and then multiplexed into an ODUCn signal. This however assumes that all these ODU0 flows are co-routed in the network. If this assumption cannot be made, the only solution is to multiplex these ODU0 flows into higher rate flows, from the source of the traffic. This usecase isn't elaborated in this document. We can add details if required.

5. GMPLS Implications

5.1. OTN ODUCn layer network

As described in the overview section, ODUCn can not be used to support non-OTN client signal, so the mapping hierarchy would be the OTN client signals (e.g. ODU0, ODU1, ODU2, ODU2e, ODU3, ODU4, ODUflex) are first multiplexed into an ODUCn container, then the ODUCn container is then mapped into OTUCn (see Figure 3). The signal hierarchy supported by the ODUCn and OTUCn layers needs to be taken into consideration in control plane Routing and Signaling.

5.2. Implications for GMPLS Signaling

As described in Section 3 [ITU-T_G709_2016] introduced some new containers, such as OPUCn, ODUCn, and OTUCn. The GMPLS signaling mechanisms defined in [RFC4328] and [RFC7139] do not support these new OTN features. Therefore, GMPLS signaling protocol extensions will be necessary to support this new functionality. The following summarizes key aspects that should be considered for GMPLS signaling extensions:

a. The GMPLS signalling protocol SHALL be able to specify the new ODUCn/OTUCn signal types and related traffic information. The traffic parameters should be extended in a signalling message to support the new ODUCn/OTUCn signal types

b. The GMPLS signalling protocol SHALL be able to set up ODUCn/OTUCn LSP with related mapping and multiplexing capabilities, and allocate slot resources for ODU clients signal. [Note: Under Discussion]

c. The GMPLS signalling protocol SHALL be able to set up LSP using 5G TS granularity

d. The GMPLS signalling protocol SHALL support the TPN allocation and negotiation

e. The GMPLS signalling protocol SHALL support the setup of OTUCn sub rates (OTUCn-M) LSP, which includes the negotiation of unavaliable slots number, slots postion and allocation of slot resources. [Note: Under Discussion]

f. The GMPLS signalling protocol SHALL be able to set up ODUCn/OTUCn/OTUCn-M LSP over FlexO group. [Note: Under Discussion]

g. The GMPLS signalling protocol SHALL be able to set up ODUCn/OTUCn/OTUCn-M LSP over different kinds of FlexO interfaces (e.g., 100G/200G FlexO interfaces) [Note: Under Discussion]

5.3. Implications for GMPLS Routing

The path computation process needs to select a suitable route and capabilities for an ODUCn/OTUCn/OTUCn-M connection request. In order to perform the path computation, it needs to evaluate the available bandwidth/slots available on one or more candidate links. The routing protocol should be extended to convey sufficient information to represent ODU Traffic Engineering (TE) topology. Following GMPLS Routing Implications should be considered:

a. The GMPLS Routing protocol should be able to indicate the ODUCn/OTUCn/OTUCn subrates (OTUCn-M) support information

b. The GMPLS Routing protocol SHALL support the advertisement of 5G Tributary Slot Granularity

c. The GMPLS Routing protocol SHALL support the advertisement of unused ODUCn tributary slot resource information.

d. The GMPLS Routing protocol SHALL support the advertisement of available/unavailable tributary slot information in OTUCn-M scenario

e. The GMPLS Routing protocol SHALL support the advertisement of OTUCn implementation (FlexO) specific information, including the specific Flexible OTN interface support information [Note: Under Discussion]

6. Acknowledgements

7. IANA Considerations

This memo includes no request to IANA.

8. Security Considerations

None.

9. References

9.1. Normative References

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GMPLS Signalling Extensions for control of B100G OTUCn/ODUCn Network
draft-zihc-ccamp-otn-b100g-signalling-00

Abstract

This document provides extensions to GMPLS signalling to control the B100G OTUCn/ODUCn Network, as a result of the introduction of new beyond 100G OTUCn/ODUCn signals in ITU-T Recommendation G.709 [G.709-2016].

Status of This Memo

Copyright Notice

Table of Contents

1. Introduction

The 2016 version of G.709 [G.709-2016] introduces support for higher rate OTU and ODU signals, termed OTUCn and ODUCn (which have a nominal rate of 100n Gbps). The newly introduced OTUCn and ODUCn represent a very powerful extension to the OTN capabilities, and one which naturally scales to transport any newer clients with bit rates in excess of 100G, as they are introduced.

B100G framework document [I-D.zih-ccamp-otn-b100g-fwk] provides a framework to allow the development of protocol extensions to support GMPLS control of OTN as specified in [G.709-2016]. Based on this framework, this document provide Resource Reservation Protocol - Traffic Engineering (RSVP-TE) extensions to support control of OTUCn/ODUCn introduced in [G.709-2016].

Note: the RSVP-TE signalling extensions in this document will try to reuse the extensions defined in RFC4328 [RFC4328] and RFC7139 [RFC7139].

2. 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].

3. Terminology

OPUCn Optical Payload Unit-Cn

ODUCn Optical Data Unit-Cn

OTUCn completely standardized Optical Transport Unit-Cn

OTUCn-M Optical Transport Unit-Cn with n OxUC overhead instances and M 5G tributary slots

OTUCn completely standardized Optical Transport Unit-Cn

4. Overview of the GMPLS Extensions for Support of OTUCn/ODUCn

New OTUCn/ODUCn are specified in [G.709-2016]. The corresponding new Signal Types are defined below:

completely standardized Optical Transport Unit-Cn (OTUCn)

Optical Transport Unit-Cn with n OxUC overhead instances and M 5G tributary slots (OTUCn-M)

Optical Data Unit-Cn (ODUCn)

A new tributary slot granularity (i.e., 5 Gbps) is described in [G.709-2016]. But this kind of tributary slot (TS) can only be used at ODUCn capable interfaces.

Virtual Concatenation (VCAT) of Optical channel Payload Unit-k (OPUk) and ODUCn is not supported by [G.709-2016] any more.

The implementation of the OTUCn/ODUCn Signal which has been briefly described in [I-D.zih-ccamp-otn-b100g-fwk] is achieved through the bonding of FlexO interfaces, which can also be referred to as PHYs. Higher rate OTUCn is split into n instances of OTUC at the FlexO source nodes. One or more OTUC instances are associated with one FlexO interface. Several end-to-end FlexO connections (PHYs) are bonded together as one FlexO group to carry the OTUCn. The FlexO layer are used as the server layer of the OTUCn signal.

5. Generalized Label Request

As desfined in RFC3471 [RFC3471], the Generalized Label Request includes a common part (i.e., used for any switching technology) and a technology dependent part (i.e., the traffic parameters). Both of these two parts are extended in RFC4328 [RFC4328] and RFC7139 [RFC7139] to accommodate GMPLS Signalling to the G.709 transport plane recommendation.

In this document, the LSP Encoding Type in the common part and the traffic parameter in the technology dependent part are extended/ refined to accommodate the G.709 Recommendation [G.709-2016]. The other parts are not changed.

5.1. LSP Encoding Type

In [G.709-2016], the ODUCn is used as a high-order signal only. Only other lower-rate (i.e. low-order) ODUs can be multiplexed into an ODUCn signal; in other words, no non-OTN client signals can be directly mapped to an ODUCn signal.

A new code-points for the LSP LSP Encoding Type is defined:

```
          =================================================

   Value           Type
   -----           ----
    XX             G.709 ODUCn (Digital Path)

          =================================================
```

Figure 1

5.2. Refination of Traffic Parameters for OTUCn/ODUCn in G.709

Section 3.2 of RFC4328 [RFC4328] defines the initial traffic parameters, and RFC7139 [RFC7139] extend the format by adding the Bit_Rate field and deleting the NMC (Number of Multiplexed Components).

This document refine the Traffic Parameter format defined in section 5 RFC7139 [RFC7139].

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Signal Type  |       n       |        Multiplier (MT)        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            Bit_Rate                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2

Signal Type: three new signal types (i.e., OTUCn, OTUCn-M, ODUCn) are defined in this document.

n (8 bits): "n" is an positive integer and contained in "OTUCn/OTUCn-M/ODUCn", and it can used to represent the bandwidth resource being requested. Also "n" is equal to the number of the OTUC/ODUC/OPUC instances.

NVC (Number of Virtual Components) defined in RFC7139 [RFC7139] is not used any more, because virtual concatenation is not support in the [G.709-2016].

MT (Multiplexer): defined in section 3.2.4 of RFC4328 [RFC4328].

Bit_Rate: defined in section 5 of RFC7139 [RFC7139].

This Traffic Parameters for the OTN-TDM-capable Switching Type are carried in the OTN-TDM SENDER_TSPEC object in the Path message and the OTN-TDM FLOWSPEC object in the Resv message.

6. Generalized Label

This section defines the format of the OTUCn/OTUCn-M/ODUCn Generalized Label.

6.1. Label Format

Following is the GENERALIZED_LABEL object format for OTUCn/OTUCn-M/ODUCn.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         TPN           |    IF Type    |        Length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Bit Map of Available/Unavailable Slots | Resvd |      NUS      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         ......                                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Bit Map of Available/Unavailable Slots | Resvd |      NUS      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3

This GENERALIZED_LABEL object is used to indicate how the ODU client signal is multiplexed into the ODUCn link. Note that the LO OUDj Signal Type is indicated by Traffic Parameters, while the type of ODUCn link is identified by the bonding FlexO capable interfaces carried in the IF_ID RSVP_HOP object.

TPN: defined in section 6.1 of RFC7139 [RFC7139].

IF (Interface) Type (8 bits): indicate the interface type of the port that provide support for OTUCn/OTUCn-M/ODUCn, which can be 100G/200G/400G Ethernet PHY interfaces.

Length (12 bits): indicates the number of bits of the Bit Map field. This field can also be used to indicate the number of the OTUC/ODUC instances being requested. For example, the number of OTUC/ODUC instances can be derived through the length number divided by 4.

Bit Map of Available/Unavailable Slots: when the label is used to set up OTUCn-M path, this field is used to represent the position of unavailable slots, when the label is used to set up ODUCn path, this field is used to represent the slots resource allocated for client.

NUS (Number of Unavailable Slots): indicate the number of unavailable slots.

This GENERALIZED_LABEL object contains several label blocks, with each block correspond to one OTUC instance.

Compatibility: actually, there will be different FlexO interfaces used for carrying OTUCn signal, and the length of the bit map may be different. The label format defined in this document can only support the 100G interface. If the label format is used in the case of 200G/400G interfaces, the bit map field can be extended to accommodate the slots number. Besides this, byte alignment also needs to be taken into consideration.

6.2. Procedures

This section does not change the procedure of RSVP-TE protocol described in section 6.2 of RFC7139 [RFC7139], like birdirectional LSP, LABEL_SET object, except the process procedure at the node.

When a downstream node or egress node receives a Path message containing a GENERALIZED_LABEL_REQUEST object for setting up an ODUflex LSP over an ODUCn connection from its upstream neighbor node. The node need to check if there are n Ethernet PHYs (FlexO capable) available for transport ODUflex LSP.

When an upstream node receives a Resv message containing a GENERALIZED_LABEL object, it MUST first identify which ODU Signal Type is multiplexed or mapped into which ODU Signal Type according to the Traffic Parameters and the IF_ID RSVP_HOP object in the received message. The IF_ID RSVP_HOP object contains several TLVs, and each of them has an one-to-one relationship with one label block. In another word, which component FlexO interface is used to carry a specific OTUC instance needs to be explicitly specified.

> In the case of ODUCn-to-OTUCn mapping, the TPN field MUST be set to 0. Bit Map information is not required and MUST NOT be included, so the Length field MUST be set to 0 as well. The NUS field should be set to 0.
>
> In the case of ODUCn-to-OTUCn-M mapping, the NUS field is set to indicate the number of unavailable in this connection, and the postions of these slots are indicated by the Bit map field. Unavailable slots can not be assigned to ODUCn. This information is required when provide resource for ODUCn client signal.
>
> In the case of ODU Client-to-ODUCn multiplexing, the node MUST retrieve the reserved tributary slots in the ODUCn by its downstream neighbor node according to the position of the bits that are set to 1 in the Bit Map field. The TS granularity is 5G, so that the node can multiplex the ODU Client into the ODUCn based on the TS granularity. The node MUST also retrieve the TPN value assigned by its downstream neighbor node from the label and fill the TPN into the related MSI byte(s) in the OPUCn overhead in the data plane.

A new LSP_ATTRIBUTE object needs to be extended to collect the number and position of the unavailable slots at each link in the connection, so the destination node can compute a proper label.

When PCE is involved, an ERO can be used to indicate the nodes and ports passed according to the resouce information at each nodes and ports. Thus the LSP_ATTRIBUTE object used to collect unavailable slots information are not needed any more.

7. Security Considerations

TBD

8. IANA Considerations

The signal types documented in this draft needs to be allocate by IANA.

9. References

9.1. Normative References

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