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A YANG model to manage the optical interface parameters for an external transponder in a WDM network
draft-dharini-netmod-dwdm-if-yang-00

Abstract

This memo defines a Yang model that translates the SNMP mib module defined in draft-galikunze-ccamp-dwdm-if-snmp-mib for managing single channel optical interface parameters of DWDM applications. This model is to support the optical parameters specified in ITU-T G.698.2 [ITU.G698.2] and application identifiers specified in ITU-T G.874.1 [ITU.G874.1] . Note that G.874.1 encompasses vendor-specific codes, which if used would make the interface a single vendor IaDI and could still be managed.

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

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Status of This Memo

Table of Contents

1. Introduction

This memo defines a Yang model that translates 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 is to support the optical parameters specified in ITU-T G.698.2 [ITU.G698.2], application identifiers specified in ITU-T G.874.1 [ITU.G874.1] and the Optical Power at Transmitter and Receiver side. Note that G.874.1 encompasses vendor-specific codes, which if used would make the interface a single vendor IaDI and could still be managed.'

[Editor's note: In G.698.2 this corresponds to the optical path from point S to R; network media channel is also used and explained in draft-ietf-ccamp-flexi-grid-fwk-02]

Management will be performed at the edges of the network media channel (i.e., at the transmitters and receivers attached to the S and R reference points respectively) for the relevant parameters specified in G.698.2 [ITU.G698.2], G.798 [ITU.G798], G.874 [ITU.G874], and the performance parameters specified in G.7710/Y.1701 [ITU-T G.7710] and G.874.1 [ITU.G874.1].

G.698.2 [ITU.G698.2] is primarily intended for metro applications that include optical amplifiers. 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 does not 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. The Recommendation currently includes unidirectional DWDM applications at 2.5 and 10 Gbit/s (with 100 GHz and 50 GHz channel frequency spacing). Work is still under way for 40 and 100 Gbit/s interfaces. There is possibility for extensions to a lower channel frequency spacing. This document specifically refers to the "application code" defined in the G.698.2 [ITU.G698.2] and included in the Application Identifier defined in G.874.1 [ITU.G874.1] and G.872 [ITU.G872], plus a few optical parameters not included in the G.698.2 application code specification.

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

The building of a yang model describing the optical parameters defined in G.698.2 [ITU.G698.2], and reflected in G.874.1 [ITU.G874.1], allows the different vendors and operator to retrieve, provision and exchange information across the G.698.2 multi-vendor IaDI in a standardized way. In addition to the parameters specified in ITU recommendations the Yang models support also the "vendor specifica application identifier", the Tx and Rx power at the Ss and Rs points and the channel frequency.

The Yang Model, reporting the Optical parameters and their values, characterizes the features and the performances of the optical components and allow a reliable link design in case of multi vendor optical networks.

Although RFC 3591 [RFC3591], which draft-galikunze-ccamp-DWDM-if-snmp-mib is extending, describes and defines the SNMP MIB of a number of key optical parameters, alarms and Performance Monitoring, as this RFC is over a decade old, it is primarily pre-OTN, and a more complete and up-to-date description of optical parameters and processes can be found in the relevant ITU-T Recommendations. The same considerations can be applied to the RFC 4054 [RFC4054].

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. 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.

4.1.1. Rs-Ss Configuration

The Rs-Ss configuration table allows configuration of Central Frequency, Power and Application codes as described in [ITU.G698.2] and G.694.1 [ITU.G694.1]
This parameter report the current Transceiver Output power, it can be either a setting and measured value (G, S).

Central frequency (see G.694.1 Table 1) (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 (G, S).

Single-channel application codes(see G.698.2):
   This parameter indicates the transceiver application code at Ss and Rs as defined in [ITU.G698.2] Chapter 5.4 - this parameter can be called Optical Interface Identifier OII as per [draft-martinelli-wson-interface-class](G).

Number of Single-channel application codes Supported
   This parameter indicates the number of Single-channel application codes supported by this interface (G).

Current Laser Output power:
   This parameter report the current Transceiver Output power, it can be either a setting and measured value (G, S).

Current Laser Input power:
   This parameter report the current Transceiver Input power (G).

PARAMETERS	Get/Set	Reference
Central frequency Value	G,S	G.694.1 S.6
Single-channel application codes	G	G.698.2 S.5.3
Number of Single-channel application codes Supported	G	N.A.
Current Output Power	G,S	N.A.
Current Input Power	G	N.A.

Table 1: Rs-Ss Configuration

4.1.2. Table of Application Codes

This table has a list of Application codes supported by this interface at point R are defined in G.698.2.

Application code Identifier:
The Identifier for the Application code.

Application code Type:
This parameter indicates the transceiver type of application code at Ss and Rs as defined in [ITU.G874.1], that is used by this interface Standard = 0, PROPRIETARY = 1
The first 6 octets of the printable string will be the OUI (organizationally unique identifier) assigned to the vendor whose implementation generated the Application Identifier Code.

Application code Length:
The number of octets in the Application Code.

Application code:
This is the application code that is defined in G.698.2 or the vendor generated code which has the OUI.

4.2. Use Cases

The use cases are described in draft-kdkgall-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 application code/vendor transceiver class/ Central frequency and the output power. The module can also be used to get the list of supported application codes/transceiver class and also the Central frequency/output power/input power of the interface.

```
module: ietf-ext-xponder-wdm-if
augment /if:interfaces/if:interface:
    +--rw optIfOChRsSs
          +--rw if-current-application-code
          |  +--rw application-code-id    uint8
          |  +--rw application-code-type  uint8
          |  +--rw application-code-length uint8
          |  +--rw application-code?     string
          +--ro if-supported-application-codes
          |  +--ro number-application-codes-supported?   uint32
          |  +--ro application-codes-list* [application-code-id]
          |     +--ro application-code-id   uint8
          |     +--rw application-code-type  uint8
          |     +--rw application-code-length uint8
          |     +--ro application-code?    string
          +--rw output-power?                      int32
          +--ro input-power?                       int32
          +--rw central-frequency?                 uint32


 notifications:
+---n opt-if-och-central-frequency-change
|  +--ro if-name?      leafref
|  +--ro new-central-frequency
|     +--ro central-frequency?   uint32
+---n opt-if-och-application-code-change
|  +--ro if-name?              leafref
|  +--ro new-application-code
|     +--ro application-code-id?   uint8
|     +--rw application-code-type  uint8
|     +--rw application-code-length uint8
|     +--ro application-code?     string
```

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 NETMOD (NETCONF Data Modelling Language)
          Working Group";

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

           WG Chair: Thomas Nadeau
                     <mailto:tnadeau@lucidvision.com>

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           Editor:   Dharini Hiremagalur
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        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.

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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 "2015-06-24" {
              description
                 "Revision 4.0";

              reference
                 " draft-dharini-netmod-dwdm-if-yang 3.0";
       }
       revision "2015-02-24" {
              description
```

```
                 "Revision 3.0";

              reference
                 " draft-dharini-netmod-dwdm-if-yang 3.0";
       }
       revision "2014-11-10" {
              description
                 "Revision 2.0";
              reference
                 " ";
       }
       revision "2014-10-14" {
              description
                 "Revision 1.0";
               reference
                 " ";
       }
       revision "2014-05-10" {
              description
                  "Initial revision.";
              reference
                  "RFC XXXX: A YANG Data Model for Optical
                   Management of an Interface for an external
                   transponder in a WDM netwrok";
       }




         grouping opt-if-och-application-code  {
                description "Application code entity.";
                leaf application-code-id {
                   type uint8 {
                         range "1..255";
                   }
                   description
                         "Id for the Application code";
                }
                leaf application-code-type {
                   type uint8 {
                         range "0..1";
                }
                  description
                         "Type for the Application code
                           0 - Standard, 1 - Proprietory
                           When the Type is Proprietory, then the
                           first 6 octets of the application-code
```

```
                       will be the OUI (organizationally unique
                       identifier)";

             }
             leaf application-code-length {
                type uint8 {
                      range "1..255";
                }
                description
                      "Number of octets in the Application code";

             }
             leaf application-code {
                type string {
                      length "1..255";
                }
                description "This parameter indicates the
                     transceiver application code at Ss and Rs as
                     defined in [ITU.G698.2] Chapter 5.3, that
                     is/should be used by this interface.
                     The optIfOChApplicationsCodeList has all the
                     application codes supported by this
                     interface.";

             }
      }


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


     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.";
          }

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

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

             }
       }

        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 opt-if-och-central-frequency {
                  description "The new Central Frequency of the
                               interface";
                  uses opt-if-och-central-frequency;
           }
        }

        notification opt-if-och-application-code-change {
           description "A change of Application code has been
                        detected.";
           leaf "if-name" {
               type leafref {
                   path "/if:interfaces/if:interface/if:name";
               }
               description "Interface name";
           }
```

```
            container new-application-code {
               description "The new application code for the
                   interface";
               uses opt-if-och-application-code;
            }
         }



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

               container if-supported-application-codes {
                   config false;
                   description "Supported Application codes of
                                the interface";
                   uses opt-if-och-application-code-list;
               }

               uses opt-if-och-power;

               uses opt-if-och-central-frequency;

            }
         }
      }

   <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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October 16, 2015

An SNMP MIB extension to RFC3591 to manage optical interface parameters of "G.698.2 single channel" in DWDM applications
draft-galikunze-ccamp-dwdm-if-snmp-mib-00

Abstract

This memo defines a module of the Management Information Base (MIB) used by Simple Network Management Protocol (SNMP) in TCP/IP- based internet. In particular, it defines objects for managing single channel optical interface parameters of DWDM applications, using the approach specified in G.698.2 [ITU.G698.2] . This interface, described in ITU-T G.872, G.709 and G.798, is one type of OTN multi-vendor Intra-Domain Interface (IaDI). This RFC is an extension of RFC3591 to support the optical parameters specified in ITU-T G.698.2 and application identifiers specified in ITU-T G.874.1 [ITU.G874.1]. Note that G.874.1 encompasses vendor-specific codes, which if used would make the interface a single vendor IaDI and could still be managed.

The MIB module defined in this memo can be used for Optical Parameters monitoring and/or configuration of the endpoints of the multi-vendor IaDI based on the Black Link approach.

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Status of This Memo

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

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1. Introduction

This memo defines a portion of the Management Information Base (MIB) used by Simple Network Management Protocol (SNMP)in TCP/IP-based internets. In particular, it defines objects for managing single channel optical interface parameters of DWDM applications, using the approach specified in G.698.2. This RFC is an extension of RFC3591 to support the optical parameters specified in ITU-T G.698.2 [ITU.G698.2] and application identifiers specified in ITU-T G.874.1 [ITU.G874.1] . Note that G.874.1 encompasses vendor-specific codes, which if used would make the interface a single vendor IaDI and could still be managed.

The Black Link approach allows supporting an optical transmitter/ receiver pair of one vendor to inject an optical tributary signal and run it over an optical network composed of amplifiers, filters, add-drop multiplexers from a different vendor. In the OTN architecture, the 'black-link' represents a pre-certified network media channel conforming to G.698.2 specifications at the S and R reference points.

[Editor's note: In G.698.2 this corresponds to the optical path from point S to R; network media channel is also used and explained in draft-ietf-ccamp-flexi-grid-fwk-02]

Management will be performed at the edges of the network media channel (i.e., at the transmitters and receivers attached to the S and R reference points respectively) for the relevant parameters specified in G.698.2 [ITU.G698.2], G.798 [ITU.G798], G.874 [ITU.G874], and the performance parameters specified in G.7710/Y.1701 [ITU-T G.7710] and G.874.1 [ITU.G874.1].

G.698.2 [ITU.G698.2] is primarily intended for metro applications that include optical amplifiers. 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 does not 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. The Recommendation currently includes unidirectional DWDM applications at 2.5 and 10 Gbit/s (with 100 GHz and 50 GHz channel frequency spacing). Work is still under way for 40 and 100 Gbit/s interfaces. There is possibility for extensions to a lower channel frequency spacing. This document specifically refers to the "application code" defined in the G.698.2 [ITU.G698.2] and included in the Application Identifier defined in G.874.1 [ITU.G874.1] and G.872 [ITU.G872], plus a few optical parameters not included in the G.698.2 application code specification.

This draft refers and supports also the draft-kunze-g-698-2-management-control-framework

The building of an SNMP MIB describing the optical parameters defined in G.698.2 [ITU.G698.2], and reflected in G.874.1 [ITU.G874], allows the different vendors and operator to retrieve, provision and exchange information across the G.698.2 multi-vendor IaDI in a standardized way.

The MIB, reporting the Optical parameters and their values, characterizes the features and the performances of the optical components and allow a reliable black link design in case of multi vendor optical networks.

Although RFC 3591 [RFC3591] describes and defines the SNMP MIB of a number of key optical parameters, alarms and Performance Monitoring, as this RFC is over a decade old, it is primarily pre-OTN, and a more complete and up-to-date description of optical parameters and processes can be found in the relevant ITU-T Recommendations. The same considerations can be applied to the RFC 4054 [RFC4054]

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].

Managed objects are accessed via a virtual information store, termed the Management Information Base or MIB. MIB objects are generally accessed through the Simple Network Management Protocol (SNMP). Objects in the MIB are defined using the mechanisms defined in the Structure of Management Information (SMI). This memo specifies a MIB module that is compliant to the SMIv2, which is described in STD 58, RFC 2578 [RFC2578], STD 58, RFC 2579 [RFC2579] and STD 58, RFC 2580 [RFC2580].

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 the linear "black link" approach, for single-channel connection (Ss and Rs) 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: Linear Black Link approach

G.698.2 [ITU.G698.2] defines also Ring "Black Link" approach configurations [Fig. 5.2/G.698.2] and Linear "black link" approach for Bidirectional applications[Fig. 5.3/G.698.2]

4.1. Use Cases

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

4.2. Optical Parameters Description

The G.698.2 pre-certified 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 specified in G.698.2 [ITU.G698.2] section 5.3 referring 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 (G) the parameter can be retrieve with a GET, when (S) it can be provisioned by a SET, (G,S) can be either GET and SET.

To support the management of these parameters, the SNMP MIB in RFC 3591 [RFC3591] is extended with a new MIB module defined in section 6 of this document. This new MIB module includes the definition of new configuration table of the OCh Layer for the parameters at Tx (S) and Rx (R).

4.2.1. Rs-Ss Configuration

The Rs-Ss configuration table allows configuration of Central Frequency, Power and Application identifiers as described in [ITU.G698.2] and G.694.1 [ITU.G694.1]
This parameter report the current Transceiver Output power, it can be either a setting and measured value (G, S).

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), in particular Section 6/G.694.1 (G, S).

Single-channel application identifiers (see G.698.2):
   This parameter indicates the transceiver application identifier at Ss and Rs as defined in [ITU.G698.2] Chapter 5.4 - this parameter can be called Optical Interface Identifier OII as per [draft-martinelli-wson-interface-class] (G).

Number of Single-channel application identifiers Supported

This parameter indicates the number of Single-channel application codes supported by this interface (G).

Current Laser Output power:
This parameter report the current Transceiver Output power, see RFC3591.

Current Laser Input power:
This parameter report the current Transceiver Input power see RFC3591.

PARAMETERS	Get/Set	Reference
Central Frequency	G,S	G.694.1 S.6
Single-channel Application Identifier number in use	G	G.874.1
Single-channel Application Identifier Type in use	G	G.874.1
Single-channel Application Identifier in use	G	G.874.1
Number of Single-channel Application Identifiers Supported	G	N.A.
Current Output Power	G,S	RFC3591
Current Input Power	G	RFC3591

Table 1: Rs-Ss Configuration

4.2.2. Table of Application Identifiers

This table has a list of Application Identifiers supported by this interface at point R are defined in G.698.2.

Application Identifier Number:
The number that uniquely identifies the Application Identifier.

Application Identifier Type:
Type of application Identifier: STANDARD / PROPRIETARY in G.874.1

Note: if the A.I. type = PROPRIETARY, the first 6 Octets of the Application Identifier (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.

Application Identifier:
This is the application Identifier that is defined in G.874.1.

4.3. Use of ifTable

This section specifies how the MIB II interfaces group, as defined in RFC 2863 [RFC2863], is used for the link ends of a black link. Only the ifGeneralInformationGroup will be supported for the ifTable and the ifStackTable to maintain the relationship between the OCh and OPS layers. The OCh and OPS layers are managed in the ifTable using IfEntries that correlate to the layers depicted in Figure 1.

For example, a device with TX and/or RX will have an Optical Physical Section (OPS) layer, and an OCh layer. There is a one to n relationship between the OPS and OCh layers.

EDITOR NOTE: Reason for changing from OChr to OCh: Edition 3 of G.872 removed OChr from the architecture and G.709 was subsequently updated to account for this architectural change.

Figure 2 In the following figures, opticalPhysicalSection are abbreviated as OPS.

```
      _____________________
                           \
         Path Data Unit    |\
             (ODUk)        | \
      _____________________|  \ __________________
                           |   |                  |  >
        Tandem Data Unit   |   |                  |  |
             (ODUkT)       |   |    OCh  Layer    |   > n och IfEntries
      _____________________|   |                  |  |
                           |   |__________________|  >
              Optical      |  /|                  |  >
          Transport Unit   | / |                  |  |
              (OTUk)       |/  |    OPSn Layer    |   > m ops IfEntries
      _____________________/   |                  |  |
                               |__________________|  >
```

Figure 2: OTN Layers for OPS and OCh

Each opticalChannel IfEntry is mapped to one of the m opticalPhysicalSection IfEntries, where m is greater than or equal to 1. Conversely, each opticalTransPhysicalSection port entry is mapped to one of the n opticalChannel IfEntries, where n is greater than or equal to 1.

The design of the Optical Interface MIB provides the option to model an interface either as a single bidirectional object containing both sink and source functions or as a pair of unidirectional objects, one containing sink functions and the other containing source functions.

If the sink and source for a given protocol layer are to be modelled as separate objects, then there need to be two ifTable entries, one that corresponds to the sink and one that corresponds to the source, where the directionality information is provided in the configuration tables for that layer via the associated Directionality objects. The agent is expected to maintain consistent directionality values between ifStackTable layers (e.g., a sink must not be stacked in a 1:1 manner on top of a source, or vice-versa), and all protocol layers that are represented by a given ifTable entry are expected to have the same directionality.

When separate ifTable entries are used for the source and sink functions of a given physical interface, association between the two uni-directional ifTable entries (one for the source function and the other for the sink functions) should be provided. It is recommended that identical ifName values are used for the two ifTable entries to indicate such association. An implementation shall explicitly state what mechanism is used to indicate the association, if ifName is not used.

4.3.1. Use of ifTable for OPS Layer

Only the ifGeneralInformationGroup needs to be supported.

ifTable Object	Use for OTN OPS Layer
ifIndex	The interface index.
ifDescr	Optical Transport Network (OTN) Optical Physical Section (OPS)
ifType	opticalPhysicalSection (xxx)

<<<Editor Note: Need new IANA registration value for xxx. >>>

ifTable Object	Use for OTN OPS Layer
ifSpeed	Actual bandwidth of the interface in bits per second. If the bandwidth of the interface is greater than the maximum value of 4,294,967,295 then the maximum value is reported and ifHighSpeed must be used to report the interface’s speed.
ifPhysAddress	An octet string with zero length. (There is no specific address associated with the interface.)
ifAdminStatus	The desired administrative state of the interface. Supports read-only access.
ifOperStatus	The operational state of the interface. The value lowerLayerDown(7) is not used, since there is no lower layer interface. This object is set to notPresent(6) if a component is missing, otherwise it is set to down(2) if either of the objects optIfOPSnCurrentStatus indicates that any defect is present.

ifLastChange   The value of sysUpTime at the last change in ifOperStatus.

ifName   Enterprise-specific convention (e.g., TL-1 AID) to identify the physical or data entity associated with this interface or an OCTET STRING of zero length. The enterprise-specific convention is intended to provide the means to reference one or more enterprise-specific tables.

ifLinkUpDownTrapEnable Default value is enabled(1). Supports read-only access.

ifHighSpeed   Actual bandwidth of the interface in Mega-bits per second. A value of n represents a range of 'n-0.5' to 'n+0.499999'.

ifConnectorPresent Set to true(1).

ifAlias   The (non-volatile) alias name for this interface as assigned by the network manager.

4.3.2. Use of ifTable for OCh Layer

Use of ifTable for OCh Layer See RFC 3591 [RFC3591] section 2.4

4.3.3. Use of ifStackTable

Use of the ifStackTable and ifInvStackTable to associate the opticalPhysicalSection and opticalChannel interface entries is best illustrated by the example shown in Figure 3. The example assumes an ops interface with ifIndex i that carries two multiplexed OCh interfaces with ifIndex values of j and k, respectively. The example shows that j and k are stacked above (i.e., multiplexed into) i. Furthermore, it shows that there is no layer lower than i and no layer higher than j and/or k.

Figure 3

```
   HigherLayer   LowerLayer
 --------------------------
      0             j
      0             k
      j             i
      k             i
      i             0
```

Figure 3: Use of ifStackTable for an OTN port

For the inverse stack table, it provides the same information as the interface stack table, with the order of the Higher and Lower layer interfaces reversed.

5. Structure of the MIB Module

EDITOR NOTE:text will be provided based on the MIB module in Section 6

6. Object Definitions

EDITOR NOTE: Once the scope in Section 1 and the parameters in Section 4 are finalized, a MIB module will be defined. It could be an extension to the OPT-IF-MIB module of RFC 3591. >>>

```
   OPT-IF-698-MIB DEFINITIONS ::= BEGIN

      IMPORTS
              MODULE-IDENTITY,
              OBJECT-TYPE,
              Gauge32,
              Integer32,
              Unsigned32,
              Counter64,
              transmission,
              NOTIFICATION-TYPE
                      FROM SNMPv2-SMI
              TEXTUAL-CONVENTION,
              RowPointer,
              RowStatus,
              TruthValue,
              DisplayString,
              DateAndTime
                      FROM SNMPv2-TC
              SnmpAdminString
                      FROM SNMP-FRAMEWORK-MIB
              MODULE-COMPLIANCE, OBJECT-GROUP
                      FROM SNMPv2-CONF
              ifIndex
                      FROM IF-MIB
              optIfMibModule
                     FROM OPT-IF-MIB;


   --  This is the MIB module for the optical parameters -
   --  Application codes associated with the black link end points.



   optIfXcvrMibModule MODULE-IDENTITY
       LAST-UPDATED "201401270000Z"
       ORGANIZATION "IETF Ops/Camp MIB Working Group"
       CONTACT-INFO
          "WG charter:
            http://www.ietf.org/html.charters/

           Mailing Lists:
           Editor: Gabriele Galimberti
           Email:  ggalimbe@cisco.com"
       DESCRIPTION
          "The MIB module to describe Black Link tranceiver
           characteristics to rfc3591.
```

```
           Copyright (C) The Internet Society (2014).  This version
           of this MIB module is an extension to rfc3591;  see the RFC
           itself for full legal notices."
       REVISION  "201305050000Z"
       DESCRIPTION
          "Draft version 1.0"
       REVISION  "201305050000Z"
       DESCRIPTION
          "Draft version 2.0"
       REVISION  "201302270000Z"
       DESCRIPTION
          "Draft version 3.0"
       REVISION  "201307020000Z"
       DESCRIPTION
          "Draft version 4.0
           Changed the draft to include only the G.698 parameters."
       REVISION  "201311020000Z"
       DESCRIPTION
          "Draft version 5.0
           Mib has a table of application code/vendor
           transcievercode G.698"
       REVISION  "201401270000Z"
       DESCRIPTION
          "Draft version 6.0"
       REVISION  "201407220000Z"
       DESCRIPTION
          "Draft version 8.0
          Removed Vendor transceiver code"
       REVISION  "201502220000Z"
       DESCRIPTION
          "Draft version 11.0
           Added reference to OUI in the first 6 Octets of a
           proprietary Application code
           Added a Length field for the Application code
           Changed some names"
       REVISION  "201507060000Z"
       DESCRIPTION
          "Draft version 12.0
          Added Power Measurement Use Cases
          and ITU description" "
          ::= { optIfMibModule 4 }


       ::= { optIfMibModule 4 }

   -- Addition to the RFC 3591 objects
   optIfOChSsRsGroup   OBJECT IDENTIFIER  ::= { optIfXcvrMibModule 1 }
```

```
   -- OCh Ss/Rs config table
   -- The application code/vendor tranceiver class for the Black Link
   -- Ss-Rs will be added to the OchConfigTable

   optIfOChSsRsConfigTable OBJECT-TYPE
       SYNTAX  SEQUENCE OF OptIfOChSsRsConfigEntry
       MAX-ACCESS  not-accessible
       STATUS  current
       DESCRIPTION
           "A table of Och General config extension parameters"
       ::= {  optIfOChSsRsGroup 1 }

   optIfOChSsRsConfigEntry OBJECT-TYPE
       SYNTAX      OptIfOChSsRsConfigEntry
       MAX-ACCESS  not-accessible
       STATUS  current
       DESCRIPTION
           "A conceptual row that contains G.698 parameters for an
           interface."
       INDEX   { ifIndex }
       ::= { optIfOChSsRsConfigTable 1 }

   OptIfOChSsRsConfigEntry ::=
       SEQUENCE {
           optIfOChCentralFrequency                    Unsigned32,
           optIfOChCfgApplicationIdentifierNumber      Unsigned32,
           optIfOChCfgApplicationIdentifierType        Unsigned32,
           optIfOChCfgApplicationIdentifierLength      Unsigned32,
           optIfOChCfgApplicationIdentifier            DisplayString,
           optIfOChNumberApplicationCodesSupported     Unsigned32
      }

   optIfOChCentralFrequency  OBJECT-TYPE
       SYNTAX  Unsigned32
       MAX-ACCESS  read-write
       UNITS "THz"
       STATUS  current
       DESCRIPTION
           " This parameter indicates the frequency of this interface.
           "
       ::= { optIfOChSsRsConfigEntry  1 }

   optIfOChCfgApplicationIdentifierNumber  OBJECT-TYPE
       SYNTAX Unsigned32
       MAX-ACCESS  read-write
       STATUS  current
       DESCRIPTION
           "This parameter uniquely indicates the transceiver
```

```
            application code at Ss and Rs as defined in [ITU.G874.1],
            that is used by this interface.
            The optIfOChSrcApplicationIdentifierTable has all the
            application codes supported by this interface. "
       ::= { optIfOChSsRsConfigEntry  2 }

   optIfOChCfgApplicationIdentifierType  OBJECT-TYPE
       SYNTAX Unsigned32
       MAX-ACCESS  read-write
       STATUS  current
       DESCRIPTION
           "This parameter indicates the transceiver type of
            application code at Ss and Rs as defined in [ITU.G874.1],
            that is used by this interface.
            The optIfOChSrcApplicationIdentifierTable has all the
            application codes supported by this interface
            Standard = 0, PROPRIETARY = 1. "
       ::= { optIfOChSsRsConfigEntry  3 }

   optIfOChCfgApplicationIdentifierLenght  OBJECT-TYPE
       SYNTAX Unsigned32
       MAX-ACCESS  read-write
       STATUS  current
       DESCRIPTION
           "This parameter indicates the number of octets in the
            Application Identifier.
            "
       ::= { optIfOChSsRsConfigEntry  4 }


   optIfOChCfgApplicationIdentifier  OBJECT-TYPE
       SYNTAX DisplayString
       MAX-ACCESS  read-write
       STATUS  current
       DESCRIPTION
           "This parameter indicates the transceiver application code
            at Ss and Rs as defined in [ITU.G698.2] Chapter 5.3, that
            is used by this interface. The
            optIfOChSrcApplicationCodeTable has all the application
            codes supported by this interface.
            If the optIfOChCfgApplicationIdentifierType is 1
            (Proprietary), then the first 6 octets of the printable
            string will be the OUI (organizationally unique identifier)
            assigned to the vendor whose implementation generated the
            Application Identifier."
       ::= { optIfOChSsRsConfigEntry  5 }

   optIfOChNumberApplicationIdentifiersSupported  OBJECT-TYPE
```

```
        SYNTAX Unsigned32
        MAX-ACCESS  read-only
        STATUS  current
        DESCRIPTION
           " Number of Application codes supported by this interface."
        ::= { optIfOChSsRsConfigEntry  6 }

   -- Table of Application codes supported by the interface
   --  OptIfOChSrcApplicationCodeEntry

   optIfOChSrcApplicationIdentifierTable  OBJECT-TYPE
        SYNTAX  SEQUENCE OF OptIfOChSrcApplicationIdentifierEntry
        MAX-ACCESS  not-accessible
        STATUS  current
        DESCRIPTION
            "A Table of Application codes supported by this interface."
        ::= { optIfOChSsRsGroup 2 }

   optIfOChSrcApplicationIdentifierEntry OBJECT-TYPE
        SYNTAX      OptIfOChSrcApplicationIdentifierEntry
        MAX-ACCESS  not-accessible
        STATUS  current
        DESCRIPTION
            "A conceptual row that contains the Application code for
             this interface."
        INDEX  { ifIndex, optIfOChApplicationIdentiferNumber  }
        ::= { optIfOChSrcApplicationIdentifierTable 1 }

   OptIfOChSrcApplicationIdentifierEntry ::=
        SEQUENCE {
            optIfOChApplicationIdentiferNumber            Integer32,
            optIfOChApplicationIdentiferType              Integer32,
            optIfOChApplicationIdentiferLength            Integer32,
            optIfOChApplicationIdentifier                 DisplayString
         }


   optIfOChApplicationIdentiferNumber  OBJECT-TYPE
        SYNTAX  Integer32 (1..255)
        MAX-ACCESS  not-accessible
        STATUS  current
        DESCRIPTION
          " The number/identifier of the application code supported at
            this interface. The interface can support more than one
            application codes.
          "
        ::= { optIfOChSrcApplicationIdentifierEntry  1}
```

```
   optIfOChApplicationIdentiferType  OBJECT-TYPE
       SYNTAX  Integer32 (1..255)
       MAX-ACCESS  read-only
       STATUS  current
       DESCRIPTION
         " The type of identifier of the application code supported at
           this interface. The interface can support more than one
           application codes.
           Standard = 0, PROPRIETARY = 1
         "
       ::= { optIfOChSrcApplicationIdentifierEntry  2}


   optIfOChApplicationIdentiferLength  OBJECT-TYPE
       SYNTAX  Integer32 (1..255)
       MAX-ACCESS  read-only
       STATUS  current
       DESCRIPTION
         " This parameter indicates the number of octets in the
           Application Identifier.
         "
       ::= { optIfOChSrcApplicationIdentifierEntry  3}

   optIfOChApplicationIdentifier  OBJECT-TYPE
       SYNTAX DisplayString
       MAX-ACCESS  read-only
       STATUS  current
       DESCRIPTION
           " The application code supported by this interface DWDM
             link.
             If the optIfOChApplicationIdentiferType is 1 (Proprietary),
             then the first 6 octets of the printable string will be
             the OUI (organizationally unique identifier) assigned to
             the vendor whose implementation generated the Application
             Identifier."
       ::= { optIfOChSrcApplicationIdentifierEntry  4}




   -- Notifications

   -- Central Frequency Change Notification
   optIfOChCentralFrequencyChange NOTIFICATION-TYPE
       OBJECTS { optIfOChCentralFrequency }
       STATUS  current
       DESCRIPTION
           "Notification of a change in the central frequency."
```

```
        ::= { optIfXcvrMibModule 1 }

   END
```

7. Relationship to Other MIB Modules

7.1. Relationship to the [TEMPLATE TODO] MIB

7.2. MIB modules required for IMPORTS

8. Definitions

[TEMPLATE TODO]: put your valid MIB module here.
A list of tools that can help automate the process of
checking MIB definitions can be found at
http://www.ops.ietf.org/mib-review-tools.html

9. Security Considerations

There are a number of management objects defined in this MIB module with a MAX-ACCESS clause of read-write and/or read-create. Such objects may be considered sensitive or vulnerable in some network environments. The support for SET operations in a non-secure environment without proper protection can have a negative effect on network operations. These are the tables and objects and their sensitivity/vulnerability:

o

Some of the readable objects in this MIB module (i.e., objects with a MAX-ACCESS other than not-accessible) may be considered sensitive or vulnerable in some network environments. It is thus important to control even GET and/or NOTIFY access to these objects and possibly to even encrypt the values of these objects when sending them over the network via SNMP.

SNMP versions prior to SNMPv3 did not include adequate security. Even if the network itself is secure (for example by using IPsec), even then, there is no control as to who on the secure network is allowed to access and GET/SET (read/change/create/delete) the objects in this MIB module.

It is RECOMMENDED that implementers consider the security features as provided by the SNMPv3 framework (see [RFC3410], section 8), including full support for the SNMPv3 cryptographic mechanisms (for authentication and privacy).

Further, deployment of SNMP versions prior to SNMPv3 is NOT RECOMMENDED. Instead, it is RECOMMENDED to deploy SNMPv3 and to enable cryptographic security. It is then a customer/operator responsibility to ensure that the SNMP entity giving access to an instance of this MIB module is properly configured to give access to the objects only to those principals (users) that have legitimate rights to indeed GET or SET (change/create/delete) them.

10. IANA Considerations

Option #1:

The MIB module in this document uses the following IANA-assigned OBJECT IDENTIFIER values recorded in the SMI Numbers registry:

```
Descriptor        OBJECT IDENTIFIER value
----------        -----------------------

sampleMIB  { mib-2 XXX }
```

Option #2:

Editor’s Note (to be removed prior to publication): the IANA is requested to assign a value for "XXX" under the ’mib-2’ subtree and to record the assignment in the SMI Numbers registry. When the assignment has been made, the RFC Editor is asked to replace "XXX" (here and in the MIB module) with the assigned value and to remove this note.

Note well: prior to official assignment by the IANA, an internet draft MUST use place holders (such as "XXX" above) rather than actual numbers. See RFC4181 Section 4.5 for an example of how this is done in an internet draft MIB module.

Option #3:

This memo includes no request to IANA.

11. Contributors

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12. References

12.1. Normative References

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Appendix A. Change Log

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

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

Appendix B. Open Issues

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GMPLS OSPF-TE Extensions in support of Flexi-grid DWDM networks

draft-ietf-ccamp-flexible-grid-ospf-ext-03.txt

Abstract

This memo describes the OSPF-TE extensions in support of GMPLS control of networks that include devices that use the new flexible optical grid.

Status of this Memo

Copyright Notice

Table of Contents

1. Introduction

[G.694.1] defines the Dense Wavelength Division Multiplexing (DWDM) frequency grids for Wavelength Division Multiplexing (WDM) applications. A frequency grid is a reference set of frequencies used to denote allowed nominal central frequencies that may be used for defining applications. The channel spacing is the frequency spacing between two allowed nominal central frequencies. All of the wavelengths on a fiber should use different central frequencies and occupy a fixed bandwidth of frequency.

Fixed grid channel spacing is selected from 12.5 GHz, 25 GHz, 50 GHz, 100 GHz and integer multiples of 100 GHz. But [G.694.1] also defines "flexible grids", also known as "flexi-grid". The terms "frequency slot" (i.e., the frequency range allocated to a specific channel and unavailable to other channels within a flexible grid) and "slot width" (i.e., the full width of a frequency slot in a flexible grid) are used to define a flexible grid.

[FLEX-FWK] defines a framework and the associated control plane requirements for the GMPLS based control of flexi-grid DWDM networks.

[RFC6163] provides a framework for GMPLS and Path Computation Element (PCE) control of Wavelength Switched Optical Networks (WSONs), and [WSON-OSPF] defines the requirements and OSPF-TE extensions in support of GMPLS control of a WSON.

[FLEX-SIG] describes requirements and protocol extensions for signaling to set up LSPs in networks that support the flexi-grid, and this document complements [FLEX-SIG] by describing the requirement and extensions for OSPF-TE routing in a flexi-grid network.

This draft compliments the efforts to provide extensions to Open Short Path First (OSPF) Traffic-Engineering (TE) protocol so as to support GMPLS control of flexi-grid networks.

2. Terminology

For terminology related to flexi-grid, please consult [FLEX-FWK] and [G.694.1].

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. Requirements for Flexi-grid Routing

The architecture for establishing LSPs in a Spectrum Switched optical Network (SSON) is described in [FLEX-FWK].

A flexi-grid LSP occupies a specific frequency slot, i.e. a range of frequencies. The process of computing a route and the allocation of a frequency slot is referred to as RSA (Routing and Spectrum Assignment). [FLEX-FWK] describes three types of architectural approaches to RSA: combined RSA; separated RSA; and distributed SA. The first two approaches among them could be called "centralized SA" because the spectrum (frequency slot) assignment is performed by a single entity before the signaling procedure.

In the case of centralized SA, the assigned frequency slot is specified in the RSVP-TE Path message during the signaling process. In the case of distributed SA, only the requested slot width of the flexi-grid LSP is specified in the Path message, allowing the involved network elements to select the frequency slot to be used.

If the capability of switching or converting the whole optical spectrum allocated to an optical spectrum LSP is not available at nodes along the path of the LSP, the LSP is subject to the Optical "Spectrum Continuity Constraint", as described in [FLEX-FWK].

The remainder of this section states the additional extensions on the routing protocols in a flexi-grid network. That is, the additional information that must be collected and passed between nodes in the network by the routing protocols in order to enable correct path computation and signaling in support of LSPs within the network.

3.1. Available Frequency Ranges

In the case of flexi-grids, the central frequency steps from 193.1 THz with 6.25 GHz granularity. The calculation method of central frequency and the frequency slot width of a frequency slot are defined in [G.694.1], i.e., by using nominal central frequency n and the slot width m.

On a DWDM link, the allocated or in-use frequency slots must not overlap with each other. However, the border frequencies of two frequency slots may be the same frequency, i.e., the highest frequency of a frequency slot may be the lowest frequency of the next frequency slot.

```
                         Frequency Slot 1   Frequency Slot 2
                           +-----------+-----------------------+
                           |           |                       |
     -9 -8 -7 -6 -5 -4 -3 -2 -1 0  1  2  3  4  5  6  7  8  9 10  11
  ...+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--...
                           ------------ ------------------------
                                 ^                  ^
                    Central F = 193.1THz    Central F = 193.1375 THz
                     Slot width = 25 GHz    Slot width = 50 GHz
```

Figure 1 - Two Frequency Slots on a Link

Figure 1 shows two adjacent frequency slots on a link. The highest frequency of frequency slot 1 denoted by n=2 is the lowest frequency of slot 2. In this example, it means that the frequency range from n=-2 to n=10 is occupied and is unavailable to other flexi-grid LSPs.

Hence, in order to clearly show which LSPs can be supported and what frequency slots are unavailable, the available frequency ranges MUST be advertised by the routing protocol for the flexi-grid DWDM links. A set of non-overlapping available frequency ranges MUST be disseminated in order to allow efficient resource management of flexi-grid DWDM links and RSA procedures which are described in Section 4.8 of [FLEX-FWK].

3.2. Application Compliance Considerations

As described in [G.694.1], devices or applications that make use of the flexi-grid may not be capable of supporting every possible slot width or position (i.e., central frequency). In other words, applications or implementations may be defined where only a subset of the possible slot widths and positions are required to be supported.

For example, an application could be defined where the nominal central frequency granularity is 12.5 GHz (by only requiring values of n that are even) and that only requires slot widths as a multiple of 25 GHz (by only requiring values of m that are even).

Hence, in order to support all possible applications and implementations the following information should be advertised for a flexi-grid DWDM link:

o Chanel Spacing (C.S.): as defined in [FLEX-LBL] and for flexi-grid, is set to 5 to denote 6.25GHz.

o Central frequency granularity: a multiplier of C.S..

o Slot width granularity: a multiplier of 2*C.S..

o Slot width range: two multipliers of the slot width granularity, each indicate the minimal and maximal slot width supported by a port respectively.

The combination of slot width range and slot width granularity can be used to determine the slot widths set supported by a port.

3.3. Comparison with Fixed-grid DWDM Links

In the case of fixed-grid DWDM links, each wavelength has a pre-defined central frequency and each wavelength maps to a pre-defined central frequency and the usable frequency range is implicit by the channel spacing. All the wavelengths on a DWDM link can be identified with an identifier that mainly convey its central frequency as the label defined in [RFC6205], and the status of the wavelengths (available or not) can be advertised through a routing protocol.

Figure 2 shows a link that supports a fixed-grid with 50 GHz channel spacing. The central frequencies of the wavelengths are pre-defined by values of "n" and each wavelength occupies a fixed 50 GHz frequency range as described in [G.694.1].

```
     W(-2)  |    W(-1)  |    W(0)   |    W(1)   |     W(2)  |
...---------+-----------+-----------+-----------+-----------+----...
      |   50 GHz  |  50 GHz   |  50 GHz   |   50 GHz  |

    n=-2        n=-1        n=0         n=1         n=2
...---+-----------+-----------+-----------+-----------+----------...
                              ^
                Central F = 193.1THz
```

Figure 2 - A Link Supports Fixed Wavelengths with 50 GHz Channel Spacing

Unlike the fixed-grid DWDM links, on a flexi-grid DWDM link the slot width of the frequency slot is flexible as described in section 3.1. That is, the value of m in the following formula [G.694.1] is uncertain before a frequency slot is actually allocated for a flexi-grid LSP.

Slot Width (GHz) = 12.5GHz * m

For this reason, the available frequency slot/ranges need to be advertised for a flexi-grid DWDM link instead of the specific "wavelengths" points that are sufficient for a fixed-grid link. Moreover, thus advertisement is represented by the combination of Central Frequency Granularity and Slot Width Granularity.

4. Extensions

As described in [FLEX-FWK], the network connectivity topology constructed by the links/nodes and node capabilities are the same as for WSON, and can be advertised by the GMPLS routing protocols (refer to section 6.2 of [RFC6163]). In the flexi-grid case, the available frequency ranges instead of the specific "wavelengths" are advertised for the link. This section defines the GMPLS OSPF-TE extensions in support of advertising the available frequency ranges for flexi-grid DWDM links.

4.1. ISCD Extensions for Flexi-grid

Value	Type
152 (TBA by IANA)	Flexi-Grid-LSC capable

Switching Capability and Encoding values MUST be used as follows:

Switching Capability = Flexi-Grid-LSC

Encoding Type = lambda [as defined in RFC3471]

When Switching Capability and Encoding fields are set to values as stated above, the Interface Switching Capability Descriptor MUST be interpreted as in [RFC4203] with the optional inclusion of one or more Switching Capability Specific Information sub-TLVs.

4.1.1. Switching Capability Specific Information (SCSI)

The technology specific part of the Flexi-grid ISCD should include the available frequency spectrum resource as well as the max slot widths per priority information. The format of this flex-grid SCSI, the frequency available bitmap TLV, 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  = 1            |           Length              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Priority    |                   Reserved                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Max Slot Width at Priority 0  |           ...                 ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~ Max Slot Width at Priority 7  |   Unreserved padding          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| C.S.  |       Starting n            | No. of Effective. Bits|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       Bit Map                 ...                             ~
~      ...                            |  padding bits           ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type (16 bits): The type of this sub-TLV and is set to 1.

Length (16 bits): The length of the value field of this sub-TLV.

Priority (8 bits): A bitmap used to indicate which priorities are being advertised. The bitmap is in ascending order, with the leftmost bit representing priority level 0 (i.e., the highest) and the rightmost bit representing priority level 7 (i.e., the lowest). A bit MUST be set (1) corresponding to each priority represented in the sub-TLV, and MUST NOT be set (0) when the corresponding priority is not represented. At least one priority level MUST be advertised that, unless overridden by local policy, SHALL be at priority level 0.

Max Slot Width (16 bits): This field indicates maximal frequency slot width supported at a particular priority level. This field MUST be set to max frequency slot width supported in the unit of 2.C.S., for a particular priority level. One field MUST be present for each bit set in the Priority field, and is ordered to match the Priority field. Fields MUST NOT be present for priority levels that are not indicated in the Priority field.

Unreserved Padding (16 bits): The Padding field is used to ensure the 32 bit alignment of Max Slot Width fields. When present the Unreserved Padding field is 16 bits (2 byte) long. When the number of priorities is odd, the Unreserved Padding field MUST be included. When the number of priorities is even, the Unreserved Padding MUST be omitted.

C.S. (4 bits): As defined in [FLEX-LBL] and it is currently set to 5.

Starting n (16 bits): as defined in [FLEX-LBL] and this value denotes the starting nominal central frequency point of the frequency availability bitmap sub-TLV.

Number of Effective Bits (12 bits): Indicates the number of effective bits in the Bit Map field.

Bit Map (variable): Indicates whether a basic frequency slot, characterized by a nominal central frequency and a fixed m value of 1, is available or not for flexi-grid LSP setup. The first nominal central frequency is the value of starting n and with the subsequent ones implied by the position in the bitmap. Note that when setting to 1, it means that the corresponding central frequency is available for a flexi-grid LSP with m=1. Note that a centralized SA process will need to extend this to high values of m by checking a sufficient large number of consecutive basic frequency slots that are available.

Padding Bits (variable): Added after the Bit Map to make it a multiple of four bytes if necessary. Padding bits MUST be set to 0 and MUST be ignored on receipt.

The Reserved field MUST be set to zero on transmission and SHOULD be ignored on receipt.

The starting n MAY be set to the lowest possible nominal central frequency supported by the link. An example is provided in the next section.

4.1.2. An SCSI Example

Figure 3 shows an example of the available frequency spectrum resource of a flexi-grid DWDM link.

```
   -9 -8 -7 -6 -5 -4 -3 -2 -1 0  1  2  3  4  5  6  7  8  9 10  11
...+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--...
                             |--Available Frequency Range--|
```

Figure 3 - Flexi-grid DWDM Link Example

The symbol "+" represents the allowed nominal central frequency. The symbol "--" represents a central frequency granularity of 6.25 GHz, as currently be standardized in [G.694.1]. The number on the top of the line represents the "n" in the frequency calculation formula

(193.1 + n * 0.00625). The nominal central frequency is 193.1 THz when n equals zero.

In this example, it is assumed that the lowest nominal central frequency supported is n= -9 and the highest is n=11. Note they cannot be used as a nominal central frequency for setting up a LSP, but merely as the way to express the supported frequency range. Using the encoding defined in Section 4.1.1, the relevant fields to express the frequency resource availability can be filled as below:

```
 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  = 1            |           Length              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Priority    |                   Reserved                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Max Slot Width at Priority 0  |         ...                   ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~ Max Slot Width at Priority 7  |   Unreserved padding          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   5   |       Starting n (-9)        | No. of Effec. Bits(21)|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|0|0|0|0|0|0|0|0|1|1|1|1|1|1|1|1|1|0|0|0|0|  padding bits (0s)  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

In the above example, the starting n is selected to be the lowest nominal central frequency, i.e. -9. Note other starting n values can be chosen and for example, the first available nominal central frequency (a.k.a., the first available basic frequency slot) can be chosen and the SCSI will be expressed as the following:

```
     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  = 1            |           Length              |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |   Priority    |                   Reserved                    |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    | Max Slot Width at Priority 0  |           ...                 ~
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    ~ Max Slot Width at Priority 7  |   Unreserved padding          |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |   5   |       Starting n (-1)         | No. of Effec. Bits(9)|
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |1|1|1|1|1|1|1|1|1|            padding bits (0s)                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

This denotes that other than the advertised available nominal central frequencies, the other nominal central frequencies within the whole frequency range supported by the link are not available for path computation use.

If a LSP with slot width (m) equal to 1 is set up using this link, say using n= -1, then the SCSI information is updated to be the following:

```
     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  = 1            |           Length              |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |   Priority    |                   Reserved                    |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    | Max Slot Width at Priority 0  |           ...                 ~
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    ~ Max Slot Width at Priority 7  |   Unreserved padding          |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |   5   |       Starting n (-1)         | No. of Effec. Bits(9)|
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |0|0|1|1|1|1|1|1|1|            padding bits (0s)                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

4.2. Extensions to Port Label Restriction sub-TLV

As described in Section 3.2, a port that supports flexi-grid may support only a restricted subset of the full flexible grid. The Port Label Restriction sub-TLV is defined in [RFC7579]. It can be used to describe the label restrictions on a port and is carried in the top-level Link TLV as specified in [RFC7580]. A new restriction type, the flexi-grid Restriction Type, is defined here to specify the restrictions on a port to support flexi-grid.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| MatrixID      | RstType = 5 | Switching Cap |   Encoding    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  C.S. |     C.F.G     |    S.W.G      |     Reserved          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Min Slot Width           |        Reserved               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

MatrixID (8 bits): As defined in [RFC7579].

RstType (Restriction Type, 8 bits): Takes the value of 5 to indicate the restrictions on a port to support flexi-grid.

Switching Cap (Switching Capability, 8 bits): As defined in [RFC7579], MUST be consistent with the one specified in ISCD as described in Section 4.1.

Encoding (8 bits): As defined in [RFC7579], must be consistent with the one specified in ISCD as described in Section 4.1.

C.S. (4 bits): As defined in [FLEX-LBL] and for flexi-grid is 5 to denote 6.25GHz.

C.F.G (Central Frequency Granularity, 8 bits): A positive integer. Its value indicates the multiple of C.S., in terms of central frequency granularity.

S.W.G (Slot Width Granularity, 8 bits): A positive integer. Its value indicates the multiple of 2*C.S., in terms of slot width granularity.

Min Slot Width (16 bits): A positive integer. Its value indicates the multiple of 2*C.S. (GHz), in terms of the supported minimal slot width.

The Reserved field MUST be set to zero on transmission and SHOULD be ignored on receipt.

5. IANA Considerations

5.1. New Switching Type

Upon approval of this document, IANA will make the assignment in the "Switching Types" section of the "GMPLS Signaling Parameters" registry located at http://www.iana.org/assignments/gmpls-sig-parameters:

Value	Name	Reference
152 (*)	Flexi-Grid-LSC capable	[This.I-D]

(*) Suggested value

5.2. New Sub-TLV

This document defines one new sub-TLV that are carried in the Interface Switching Capability Descriptors [RFC4203] with Signal Type Flexi-Grid-LSC capable.

Upon approval of this document, IANA will create and maintain a new sub-registry, the "Types for sub-TLVs of Flexi-Grid-LSC capable SCSI (Switch Capability-Specific Information)" registry under the "Open Shortest Path First (OSPF) Traffic Engineering TLVs" registry, see http://www.iana.org/assignments/ospf-traffic-eng-tlvs/ospf-traffic-eng-tlvs.xml, with the sub-TLV types as follows:

This document defines new sub-TLV types as follows:

Value	Sub-TLV	Reference
0	Reserved	[This.I-D]
1	Frequency availability bitmap	[This.I-D]

6. Implementation Status

[RFC Editor Note: Please remove this entire section prior to publication as an RFC.]

This section records the status of known implementations of the protocol defined by this specification at the time of posting of this Internet-Draft, and is based on a proposal described in RFC 6982[RFC6982]. The description of implementations in this section is intended to assist the IETF in its decision processes in progressing drafts to RFCs. Please note that the listing of any individual implementation here does not imply endorsement by the IETF. Furthermore, no effort has been spent to verify the information presented here that was supplied by IETF contributors. This is not intended as, and must not be construed to be, a catalog of available implementations or their features. Readers are advised to note that other implementations may exist.

According to RFC 6982, "this will allow reviewers and working groups to assign due consideration to documents that have the benefit of running code, which may serve as evidence of valuable experimentation and feedback that have made the implemented protocols more mature. It is up to the individual working groups to use this information as they see fit.

6.1. Centre Tecnologic de Telecomunicacions de Catalunya (CTTC)

Organization Responsible for the Implementation: CTTC - Centre Tecnologic de Telecomunicacions de Catalunya (CTTC), Optical Networks and Systems Department, http://wikiona.cttc.es.

Implementation Name and Details: ADRENALINE testbed, http://networks.cttc.es/experimental-testbeds/

Brief Description: Experimental testbed implementation of GMPLS/PCE control plane.

Level of Maturity: Implemented as extensions to a mature GMLPS/PCE control plane. It is limited to research / prototyping stages but it has been used successfully for more than the last five years.

Coverage: Support for the 64 bit label [FLEC-LBL] for flexi-grid as described in this document, with available label set encoded as bitmap.

It is expected that this implementation will evolve to follow the evolution of this document.

Licensing: Proprietary

Implementation Experience: Implementation of this document reports no issues. General implementation experience has been reported in a number of journal papers. Contact Ramon Casellas for more information or see http://networks.cttc.es/publications/?search=GMPLS&research_area=optical-networks-systems

Contact Information: Ramon Casellas: ramon.casellas@cttc.es

Interoperability: No report.

7. Acknowledgments

This work was supported in part by the FP-7 IDEALIST project under grant agreement number 317999.

This work was supported in part by NSFC Project 61201260.

8. Security Considerations

This document extends [RFC4203] and [RFC7580] to carry flex-grid specific information in OSPF Opaque LSAs. This document does not introduce any further security issues other than those discussed in [RFC3630], [RFC4203]. To be more specific, the security mechanisms described in [RFC2328] which apply to Opaque LSAs carried in OSPF still apply. An analysis of the OSPF security is provided in [RFC6863] and applies to the extensions to OSPF in this document as well.

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Link Management Protocol Extensions for Grid Property Negotiation
draft-ietf-ccamp-grid-property-lmp-02

Abstract

ITU-T [G.694.1] introduces the flexible-grid DWDM technique, which provides a new tool that operators can implement to provide a higher degree of network optimization than is possible with fixed-grid systems. This document describes the extensions to the Link Management Protocol (LMP) to negotiate link grid property between the adjacent DWDM nodes before the link is brought up.

Status of This Memo

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1. Introduction

ITU-T [G.694.1] introduces the flexible-grid DWDM technique, which provides a new tool that operators can implement to provide a higher degree of network optimization than is possible with fixed-grid systems. A flexible-grid network supports allocating a variable-sized spectral slot to a channel. Flexible-grid DWDM transmission systems can allocate their channels with different spectral bandwidths/slot widths so that they can be optimized for the bandwidth requirements of the particular bit rate and modulation scheme of the individual channels. This technique is regarded to be a promising way to improve the spectrum utilization efficiency and can be used in the beyond 100Gbit/s transport systems.

Fixed-grid DWDM system is regarded as a special case of Flexi-grid DWDM. It is expected that fixed-grid optical nodes will be gradually replaced by flexible nodes and interworking between fixed-grid DWDM and flexible-grid DWDM nodes will be needed as the network evolves. Additionally, even two flexible-grid optical nodes may have different grid properties based on the filtering component characteristics, thus need to negotiate on the specific parameters to be used during neighbor discovery process [FLEX-FWK]. This document describes the extensions to the Link Management Protocol (LMP) to negotiate a link grid property between two adjacent nodes before the link is brought up.

1.1. 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 [RFC2119].

2. Terminology

For the flexible-grid DWDM, the spectral resource is called frequency slot which is represented by the central frequency and the slot width. The definition of nominal central frequency, nominal central frequency granularity, slot width and slot width granularity can be referred to [FLEX-FWK].

In this contribution, some other definitions are listed below:

Tuning range: It describes the supported spectrum slot range of the switching nodes or interfaces. It is represented by the supported minimal slot width and the maximum slot width.

Channel spacing: It is used in traditional fixed-grid network to identify spectrum spacing between two adjacent channels.

3. Requirements for Grid Property Negotiation

3.1. Flexi-fixed Grid Nodes Interworking

Figure 1 shows an example of interworking between flexible and fixed-grid nodes. Node A, B, D and E support flexible-grid. All these nodes can support frequency slots with a central frequency granularity of 6.25 GHz and slot width granularity of 12.5 GHz. Given the flexibility in flexible-grid nodes, it is possible to configure the nodes in such a way that the central frequencies and slot width parameters are backwards compatible with the fixed DWDM grids (adjacent flexible frequency slots with channel spacing of

8*6.25 and slot width of 4*12.5 GHz is equivalent to fixed DWDM grids with channel spacing of 50 GHz).

As node C can only support the fixed-grid DWDM property with channel spacing of 50 GHz, to establish a LSP through node B, C, D, the links between B to C and C to D must set to align with the fixed-grid values. This link grid property must be negotiated before establishing the LSP.

```
     +---+         +---+         +---+         +---+        +---+
     | A |---------| B |=========| C |=========| D +--------+ E |
     +---+         +---+         +---+         +---+        +---+
```

Figure 1: An example of interworking between flexible and fixed-grid nodes

```
          ^               ^               ^               ^
   ------->|<----50GHz---->|<----50GHz---->|<----50GHz---->|<------
     ..... |               |               |               | .....
   +-------+-------+-------+-------+-------+--------+------+-------+-
 n=-2              -1              0                1              2
                     Fixed channel spacing of 50 GHz (Node C)
          ^               ^               ^               ^
          |               |               |               |
   --------+---------------+---------------+---------------+---------
     ..... |  n=-8, m=4    |   n=0, m=4    |   n=8, m=4    | .....
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
 n=-16 -14 -12 -10 -8  -6  -4  -2   0   2   4   6   8   10  12  14  16
                                                                   |_|
                         Flexi-grid (Nodes B,D)               6.25 GHz
                  Central frequency granularity=6.25 GHz
                      Slot width granularity=12.5 GHz
```

Figure 2: Representation of fixed channel spacing and flexi-grid spectrum slot

3.2. Flexible-Grid Capability Negotiation

The updated version of ITU-T [G.694.1] has defined the flexible-grid with a central frequency granularity of 6.25 GHz and a slot width granularity of 12.5 GHz. However, devices or applications that make use of the flexible-grid may not be able to support every possible slot width or position. In other words, applications may be defined where only a subset of the possible slot widths and positions are required to be supported. Taking node G in figure 3 as an example, an application could be defined where the nominal central frequency granularity is 12.5 GHz (by only requiring values of n that are even) requiring slot widths being multiple of 25 GHz (by only requiring values of m that are even). Therefore the link between two optical node F and G with different grid granularity must be configured to align with the larger of both granularities. Besides, different nodes may have different slot width tuning ranges. For example, in figure 3, node F can only support slot width with tuning change from 12.5 to 100 GHz, while node G supports tuning range from 25 GHz to 200 GHz. The link property of slot width tuning range for the link between F and G should be chosen as the range intersection, resulting in a range from 25 GHz to 100 GHz.

```
                  +---+            +---+
                  | F +------------| G |
                  +---+            +---+
       +------------------+-------------+-----------+
       |    Unit (GHz)    |    Node F   |   Node G  |
       +------------------+-------------+-----------+
       | Grid granularity | 6.25 (12.5) | 12.5 (25) |
       +------------------+-------------+-----------+
       |   Tuning range   | [12.5, 100] | [25, 200] |
       +------------------+-------------+-----------+
```

Figure 3: An example of flexible-grid capability negotiation

3.3. Summary

In summary, in a DWDM Link between two nodes, the following properties should be negotiated:

o Grid capability: flexible grid or fixed grid DWDM.

o Nominal central frequency granularity: a multiplier of 6.25 GHz.

o Slot width granularity: a multiplier of 12.5 GHz.

o Slot width tuning range: two multipliers of 12.5GHz, each indicate the minimal and maximal slot width supported by a port respectively.

4. LMP extensions

4.1. Grid Property Subobject

According to [RFC4204], the LinkSummary message is used to verify the consistency of the link property on both sides of the link before it is brought up. The LinkSummary message contains negotiable and non-negotiable DATA_LINK objects, carrying a series of variable-length data items called subobjects, which illustrate the detailed link properties. The subobjects are defined in Section 12.12.1 in [RFC4204].

To meet the requirements stated in section 3, this draft extends the LMP protocol by introducing a new DATA_LINK subobject called "Grid property", allowing the grid property correlation between adjacent nodes. The encoding format of this new subobject 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    | Grid  | C.F.G |     S.W.G     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Min Width   |    Reserved   |           Max Width           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4

Type=TBD, Grid property type.

Grid: 4 bits

The value is used to represent which grid the node/interface supports. Values defined in [RFC6205] identify DWDM [G.694.1] and CWDM [G.694.2]. The value defined in [draft-ietf-ccamp-flexigrid-lambda-label] identifies flexible DWDM.

Grid	Value
Reserved	0
ITU-T DWDM	1
ITU-T CWDM	2
ITU-T Flex	3
Future use	4-16

C.F.G (central frequency granularity):

It is a positive integer. Its value indicates the multiple of 6.25 GHz in terms of central frequency granularity.

S.W.G (Slot Width Granularity):

It is a positive integer value which indicates the slot width granularity which is the multiple of 12.5 GHz.

Min Width and Max Width:

Min Width and Max Width are positive integers. Their value indicate the multiple of 12.5 GHz in terms of the slot width tuning range the interface supports. For example, for slot width tuning range from 25 GHz to 100 GHz (with regard to a node with slot width granularity of 12.5 GHz), the values of Min Width and Max Width should be 2 and 8 respectively. For fixed-grid nodes, these two fields are meaningless and should be set to zero.

5. Messages Exchange Procedure

5.1. Flexi-fixed Grid Nodes Messages Exchange

To demonstrate the procedure of grid property correlation, the model shown in Figure 1 is reused. Node B starts sending messages.

o After inspecting its own node/interface property, node B sends node C a LinkSummary message including the MESSAGE ID, TE_LINK ID and DATA_LINK objects. The setting and negotiating of MESSAGE ID and TE_link ID can be referenced to [RFC4204]. As node B supports flexible-grid property, the Grid and C.F.G values in the grid property subobject are set to be 3 (i.e., ITU-T Flex) and 1 (i.e.,1*6.25GHz) respectively. The slot width tuning range is from 12.5 GHz to 200 GHz (i.e., Min Width=1, Max Width=16). Meanwhile, the N bit of the DATA_LINK object is set to 1, indicating that the property is negotiable.

o When node C receives the LinkSummary message from B, it checks the Grid, C.F.G, Min and Max values in the grid property subobject. Node C can only support fixed-grid DWDM and realizes that the flexible-grid property is not acceptable for the link. Since the receiving N bit in the DATA_LINK object is set, indicating that the Grid property of B is negotiable, node C responds to B with a LinkSummaryNack containing a new Error_code object and state that the property of the interface connected to node B needs further negotiation. Meanwhile, an accepted grid property subobject (Grid=2, C.F.G=4, fixed DWDM with channel spacing of 50 GHz) is carried in LinkSummaryNack message. At this moment, the N bit in the DATA_LINK object is set to 0, indicating that the grid property subobject is non-negotiable.

o As the channel spacing and slot width of the corresponding interface of node B can be configured to be any integral multiples of 6.25 GHz and 12.5 GHz respectively, node B supports the fixed DWDM values announced by node C. Consequently, node B will resend the LinkSummary message carrying the grid property subobject with values of Grid=2 and C.F.G=4.

o Once received the LinkSummary message from node B, node C replies with a LinkSummaryACK message. After the message exchange, the link between node B and C is brought up with a fixed channel spacing of 50 GHz.

In the above mentioned grid property correlation scenario, the node supporting a flexible-grid is the one that starts sending LMP messages. The procedure where the initiator is the fixed-grid node is as follows:

o After inspecting its own interface property, Node C sends B a LinkSummary message containing a grid property subobject with Grid=2, C.F.G=4. The N bit in the DATA_LINK object is set to 0, indicating that it is non-negotiable.

o As the channel spacing and slot width of node B can be configured to be any integral multiples of 6.25 GHz and 12.5 GHz respectively, node B is able to support the fixed DWDM parameters. Then, node B will make appropriate configuration and reply node C the LinkSummaryACK message

o After the message exchange, the link between node B and C is brought up with a fixed channel spacing of 50 GHz.

5.2. Flexible Nodes Messages Exchange

To demonstrate the procedure of grid property correlation between to flexi-grid capable nodes, the model shown in figure 3 is reused. The procedure of grid property correlation (negotiating the grid granularity and slot width tuning range) is similar to the scenarios mentioned above.

o The Grid, C.F.G, Min and Max values in the grid property subobject sent from node F to G are set to be 3,1,1,8 respectively. Meanwhile, the N bit of the DATA_LINK object is set to 1, indicating that the grid property is negotiable.

o When node G has received the LinkSummary message from F, it will analyze the Grid, C.F.G, Min and Max values in the Grid property subobject. But the corresponding interface of node G can only support grid granularity of 12.5 GHz and a slotwdith tuning range from 25 GHz to 200 GHz. Considering the interface property of node F, node G will first match these property with its corresponding interface, and then judge the mismatch of the property of the link between node F and G, then respond F a LinkSummaryNack containing a new Error_code object and state that the property need further negotiation. Meanwhile, an accepted grid property subobject (Grid=3, C.F.G=2, Min=2, Max=8, the slot width tuning range is set to the intersection of Node F and G) is carried in LinkSummaryNack message. Meanwhile, the N bit in the DATA_LINK object is set to 1, indicating that the grid property subobject is non-negotiable.

o As the channel spacing and slot width of the corresponding interface of node F can be configured to be any integral multiples of 6.25 GHz and 12.5 GHz respectively, node F can support the lager granularity. The suggested slot width tuning range is acceptable for node F. In consequence, node F will resend the LinkSummary message carrying the grid subobject with values of Grid=3, C.F.G=2, Min=2 and Max=8.

o Once received the LinkSummary message from node F, node G replies with a LinkSummaryACK message. After the message exchange, the link between node F and G is brought up supporting central frequency granularity of 12.5 GHz and slot width tuning range from 25 GHz to 100 GHz.

From the perspective of the control plane, once the links have been brought up, wavelength constraint information can be advertised and the wavelength label can be assigned hop-by-hop when establishing a LSP based on the link grid property.

6. IANA Considerations

This draft introduces the following new assignments:

LMP Sub-Object Class names:

o under DATA_LINK Class name (as defined in [RFC4204])

- Grid property type (sub-object Type = TBD.)

7. Acknowledgments

This work was supported in part by the China NSFC Project 61201260.

8. 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. As such, this document introduces no other new security considerations not covered in [RFC4204].

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OSPF Routing Extension for Links with Variable Discrete Bandwidth
draft-ietf-ccamp-ospf-availability-extension-03.txt

Abstract

A network MAY contain links with variable discrete bandwidth, e.g., copper, radio, etc. The bandwidth of such links may change discretely in reaction to changing external environment. Availability is typically used for describing such links during network planning. This document introduces an optional ISCD Availability sub-TLV in OSPF routing protocol. This extension can be used for route computation in a network that contains links with variable discrete bandwidth.

Status of this Memo

This Internet-Draft will expire on April 13, 2016.

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Table of Contents

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].

The following acronyms are used in this draft:

OSPF   Open Shortest Path First

PSN   Packet Switched Network

SNR   Signal-to-noise Ratio

LSP   Label Switched Path

ISCD   Interface Switching Capacity Descriptor

LSA   Link State Advertisement

1. Introduction

Some data communication technologies, e.g., microwave, and copper, allow seamless change of maximum physical bandwidth through a set of known discrete values. The parameter availability [G.827, F.1703, P.530] is often used to describe the link capacity during network planning. The availability is a time scale that the requested bandwidth is ensured. Assigning different availability classes to different types of service over such kind of links provides more efficient planning of link capacity. To set up an LSP across these links, availability information is required for the nodes to verify bandwidth satisfaction and make bandwidth reservation. The availability information should be inherited from the availability requirements of the services expected to be carried on the LSP. For example, voice service usually needs "five nines" availability, while non-real time services may adequately perform at four or three nines availability. Since different service types may need different availabilities guarantees, multiple <availability, bandwidth> pairs may be required when signaling. The signaling extension for links with discrete bandwidth is defined in [ASTE].

For the route computation, the availability information should be provided along with bandwidth resource information. In this document, an extension on Interface Switching Capacity Descriptor (ISCD) [RFC4202] for availability information is defined to support in routing signaling. The extension reuses the reserved field in the ISCD and also introduces an optional Availability sub-TLV.

If there is a hop that cannot support the Availability sub-TLV, the Availability sub-TLV should be ignored.

2. Overview

A node which has link(s) with variable bandwidth attached should contain a <bandwidth, availability> information list in its OSPF TE LSA messages. The list provides the information that how much bandwidth a link can support for a specified availability. This information is used for path calculation by the node(s).

To setup a label switching path (LSP), a node may collect link information which is spread in OSPF TE LSA messages by network nodes to get know about the network topology, calculate out an LSP route based on the network topology and send the calculated LSP route to signaling to initiate a PATH/RESV message for setting up the LSP.

Availability information is required to carry in the signaling message to better utilize the link bandwidth. The signaling extension for availability can be found in [ASTE].

3. Extension to OSPF Routing Protocol

3.1. Interface Switching Capacity Descriptor

The Interface Switching Capacity Descriptor (ISCD) sub-TLV is defined in Section 1.4 of [RFC 4203].

3.2. ISCD Availability sub-TLV

The Switching Capability field MAY be PSC-1, LSC. The Switching Capability specific information field MAY include one or more ISCD Availability sub-TLV(s). The ISCD Availability sub-TLV has the following format:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              Type             |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Availability level                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   LSP Bandwidth at Availability level n       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type: 0x01, 16 bits;

Length: 16 bits;

Availability level: 32 bits

This field is a 32-bit IEEE floating point number which describes the decimal value of availability guarantee of the switching capacity in the ISCD object which has the AI value equal to Index of this sub-TLV. The value MUST be less than 1.

LSP Bandwidth at Availability level n: 32 bits

This field is a 32-bit IEEE floating point number which describes the LSP Bandwidth at a certain Availability level which was described in the Availability field.

3.3. Signaling Process

A node which has link(s) with variable bandwidth attached SHOULD contain one or more ISCD Availability sub-TLVs in its OSPF TE LSA messages. Each ISCD Availability sub-TLV provides the information about how much bandwidth a link can support for a specified availability. This information SHOULD be used for path calculation by the node(s).

A node that doesn’t support ISCD Availability sub-TLV SHOULD ignore ISCD Availability sub-TLV.

4. Security Considerations

This document does not introduce new security considerations to the existing OSPF protocol.

5. IANA Considerations

This document introduces an Availability sub-TLV of the ISCD sub-TLV of the TE Link TLV in the TE Opaque LSA for OSPF v2. This document proposes a suggested value for the Availability sub-TLV; it is recommended that the suggested value be granted by IANA. Initial values are as follows:

Type	Length	Format	Description
0	-	Reserved	Reserved value
0x01	8	see Section 3.2	Availability

6. References

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7. Acknowledgments

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Ethernet Traffic Parameters with Availability Information
draft-ietf-ccamp-rsvp-te-bandwidth-availability-03.txt

Abstract

A Packet switching network may contain links with variable bandwidth, e.g., copper, radio, etc. The bandwidth of such links is sensitive to external environment. Availability is typically used for describing the link during network planning. This document introduces an Extended Ethernet Bandwidth Profile TLV and an optional Availability sub-TLV in Resource ReSerVation Protocol - Traffic Engineer (RSVP-TE) signaling. This extension can be used to set up a label switching path (LSP) in a Packet Switched Network (PSN) that contains links with discretely variable bandwidth.

Status of this Memo

This Internet-Draft will expire on April 13, 2016.

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Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC-2119 [RFC2119].

The following acronyms are used in this draft:

RSVP-TE Resource Reservation Protocol-Traffic Engineering

LSP   Label Switched Path

PSN   Packet Switched Network

SNR   Signal-to-noise Ratio

TLV   Type Length Value

LSA   Link State Advertisement

1. Introduction

The RSVP-TE specification [RFC3209] and GMPLS extensions [RFC3473] specify the signaling message including the bandwidth request for setting up a label switching path in a PSN network.

Some data communication technologies allow seamless change of maximum physical bandwidth through a set of known discrete values. The parameter availability [G.827, F.1703, P.530] is often used to describe the link capacity during network planning. The availability is a time scale that the requested bandwidth is ensured. A more detailed example on the bandwidth availability can be found in Appendix A. Assigning different availability classes to different types of service over such kind of links provides more efficient planning of link capacity. To set up an LSP across these links, availability information is required for the nodes to verify bandwidth satisfaction and make bandwidth reservation. The availability information should be inherited from the availability requirements of the services expected to be carried on the LSP. For example, voice service usually needs "five nines" availability, while non-real time services may adequately perform at four or three nines availability. Since different service types may need different availabilities guarantees, multiple <availability, bandwidth> pairs may be required when signaling.

If the availability requirement is not specified in the signaling message, the bandwidth will be reserved as the highest availability. For example, the bandwidth with 99.999% availability of a link is 100 Mbps; the bandwidth with 99.99% availability is 200 Mbps. When a video application requests for 120 Mbps without availability requirement, the system will consider the request as 120 Mbps with 99.999% availability, while the available bandwidth with 99.999% availability is only 100 Mbps, therefore the LSP path cannot be set up. But in fact, video application doesn’t need 99.999% availability; 99.99% availability is enough. In this case, the LSP could be set up if availability is specified in the signaling message.

To fulfill LSP setup by signaling in these scenarios, this document specifies an Extended Ethernet Bandwidth Profile and an Availability sub-TLV. The Availability sub-TLV can be applicable to any kind of physical links with variable discrete bandwidth, such as microwave or DSL. Multiple Extended Ethernet Bandwidth Profiles with different availability can be carried in the Ethernet SENDER_TSPEC object.

2. Overview

A PSN tunnel may span one or more links in a network. To setup a label switching path (LSP), a node may collect link information which is spread in routing message, e.g., OSPF TE LSA message, by network nodes to get to know about the network topology, and calculate out an LSP route based on the network topology, and send the calculated LSP route to signaling to initiate a PATH/RESV message for setting up the LSP.

In case that there is(are) link(s) with variable discrete bandwidth in a network, a <bandwidth, availability> requirement list should be specified for an LSP. Each <bandwidth, availability> pair in the list means that listed bandwidth with specified availability is required. The list could be inherited from the results of service planning for the LSP.

A node which has link(s) with variable discrete bandwidth attached should contain a <bandwidth, availability> information list in its OSPF TE LSA messages. The list provides the information that how much bandwidth a link can support for a specified availability. This information is used for path calculation by the node(s). The routing extension for availability can be found in [ARTE].

When a node initiates a PATH/RESV signaling to set up an LSP, the PATH message should carry the <bandwidth, availability> requirement list as bandwidth request. Intermediate node(s) will allocate the bandwidth resource for each availability requirement from the remaining bandwidth with corresponding availability. An error message may be returned if any <bandwidth, availability> request cannot be satisfied.

3. Extension to RSVP-TE Signaling

The initial idea is to define an Availability sub-TLV under Ethernet Bandwidth Profile TLV [RFC6003]. However the Ethernet Bandwidth Profile TLV doesn’t have the ability to carry a sub-TLV according to RFC6003. Therefore, an Extend Ethernet Bandwidth Profile TLV is defined in this document to avoid the backward compatibility issue. The Extended Ethernet Bandwidth Profile TLV includes Ethernet BW TLV and has variable length. It MAY include Availability sub-TLV which is also defined in this document.

3.1.1. Extended Ethernet Bandwidth Profile TLV

The Extended Ethernet Bandwidth Profile TLV is included in the Ethernet SENDER_TSPEC, and MAY be included for more than one time. The Extended Ethernet Bandwidth Profile TLV has the following format.

```
   0                   1                   2                   3
       0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |              Type             |           Length              |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |Pro|A|         |     Index     |            Reserved           |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                              CIR                              |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                              CBS                              |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                              EIR                              |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                              EBS                              |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                       sub-TLV(OPTIONAL)                       |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 1: A new "AF" filed in Extended Ethernet Bandwidth Profile TLV

The difference between the Extended Ethernet Bandwidth Profile TLV and Ethernet Bandwidth Profile TLV is that a new AF field to indicate the sub-TLV is defined in the Extended Ethernet Bandwidth Profile TLV. The rest definitions are the same.

A new filed is defined in this document:

AF filed (bit 2): Availability Field (AF)

If the AF filed is set to 1, Availability sub-TLV MUST be included in the Extended Ethernet Bandwidth Profile TLV. If the AF field is set to value 0, then an Availability sub-TLV SHOULD NOT be included.

3.1.2. Availability sub-TLV

The Availability sub-TLV has the following format:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Type            |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Availability                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2: Availability sub-TLV

Type (2 octets): TBD

Length (2 octets): 4

Availability (4 octets): a 32-bit floating number describes the decimal value of availability requirement for this bandwidth request. The value MUST be less than 1.

As the Extended Ethernet Bandwidth Profile TLV can be carried for one or more times in the Ethernet SENDER_TSPEC object, the Availability sub-TLV can also be present for one or more times.

3.2. FLOWSPEC Object

The FLOWSPEC object (Class-Num = 9, Class-Type = TBD) has the same format as the Ethernet SENDER_TSPEC object.

3.3. Signaling Process

The source node initiates PATH messages including one or more Extended Bandwidth Profile TLVs with different availability values in the SENDER_TSPEC object. Each Extended Bandwidth Profile TLV specifies the bandwidth request with referred availability requirement.

The intermediate and destination nodes check whether they can satisfy the bandwidth requirements by comparing each bandwidth requirement inside the SENDER_TSPEC objects with the remaining link sub-bandwidth resource with respective availability guarantee when received the PATH message.

- o If all <bandwidth, availability> requirements can be satisfied (the requested bandwidth under each availability parameter is smaller than or equal to the remaining bandwidth under the corresponding availability parameter on its local link), it SHOULD reserve the bandwidth resource from each remaining sub-bandwidth portion on its local link to set up this LSP. Optionally, the higher availability bandwidth can be allocated to lower availability request when the lower availability bandwidth cannot satisfy the request.

- o If at least one <bandwidth, availability> requirement cannot be satisfied, it SHOULD generate PathErr message with the error code "Admission Control Error" and the error value "Requested Bandwidth Unavailable" (see [RFC2205]).

If two LSPs request for the bandwidth with the same availability requirement, a way to resolve the contention is comparing the node ID, the node with the higher node ID will win the contention. More details can be found in [RFC3473].

If a node does not support the Extended Bandwidth Profile TLV and Availability sub-TLV, it SHOULD generate PathErr message with the error code "Extended Class-Type Error" and the error value "Class-Type mismatch" (see [RFC2205]).

4. Security Considerations

This document does not introduce new security considerations to the existing RSVP-TE signaling protocol.

5. IANA Considerations

IANA maintains registries and sub-registries for RSVP-TE used by GMPLS. IANA is requested to make allocations from these registries as set out in the following sections.

5.1 Ethernet Sender TSpec TLVs

IANA maintains a registry of GMPLS parameters called "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Parameters".

IANA has created a new sub-registry called "Ethernet Sender TSpec TLVs / Ethernet Flowspec TLVs" to contain the TLV type values for TLVs carried in the Ethernet SENDER_TSPEC object. A new value is as follow:

Type	Description	Reference
TBD	Extended Ethernet Bandwidth Profile	[This ID]

5.2 Extended Ethernet Bandwidth Profile TLV

IANA has created a new sub-registry called "Extended Ethernet Bandwidth Profiles" to contain bit flags carried in the Extended Ethernet Bandwidth Profile TLV of the Ethernet SENDER_TSPEC object.

Bits are to be allocated by Standards Action. Bits are numbered from bit 0 as the low order bit. A new bit field is as follow:

Bit	Hex	Description	Reference
0	0x01	Coupling Flag (CF)	[RFC6003]
1	0x02	Color Mode (CM)	[RFC6003]
2	0x04	Availability Field (AF)	[This ID]

Sub-TLV types for Extended Ethernet Bandwidth Profiles are to be allocated by Standards Action. Initial values are as follows:

Type	Length	Format	Description
0	-	Reserved	Reserved value
0x01	4	see Section 3.1.2 of this ID	Availability

6. References

6.1. Normative References

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7. Appendix: Bandwidth Availability Example

In mobile backhaul network, microwave links are very popular for providing connection of last hops. In case of heavy rain, to maintain the link connectivity, the microwave link MAY lower the modulation level since demodulating the lower modulation level needs a lower Signal-to-Noise Ratio (SNR). This is called adaptive modulation technology [EN 302 217]. However, a lower modulation level also means lower link bandwidth. When link bandwidth is reduced because of modulation down-shifting, high-priority traffic can be maintained, while lower-priority traffic is dropped. Similarly, the copper links MAY change their link bandwidth due to external interference.

Presuming that a link has three discrete bandwidth levels:

The link bandwidth under modulation level 1, e.g., QPSK, is 100 Mbps;

The link bandwidth under modulation level 2, e.g., 16QAM, is 200 Mbps;

The link bandwidth under modulation level 3, e.g., 256QAM, is 400 Mbps.

In sunny day, the modulation level 3 can be used to achieve 400 Mbps link bandwidth.

A light rain with X mm/h rate triggers the system to change the modulation level from level 3 to level 2, with bandwidth changing from 400 Mbps to 200 Mbps. The probability of X mm/h rain in the local area is 52 minutes in a year. Then the dropped 200 Mbps bandwidth has 99.99% availability.

A heavy rain with Y(Y>X) mm/h rate triggers the system to change the modulation level from level 2 to level 1, with bandwidth changing from 200 Mbps to 100 Mbps. The probability of Y mm/h rain in the local area is 26 minutes in a year. Then the dropped 100 Mbps bandwidth has 99.995% availability.

For the 100M bandwidth of the modulation level 1, only the extreme weather condition can cause the whole system unavailable, which only happens for 5 minutes in a year. So the 100 Mbps bandwidth of the modulation level 1 owns the availability of 99.999%.

In a word, the maximum bandwidth is 400 Mbps. According to the weather condition, the sub-bandwidth and its availability are shown as follows:

Sub-bandwidth(Mbps)	Availability
200	99.99%
100	99.995%
100	99.999%

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A framework for Management and Control of DWDM optical interface parameters

draft-kdkgall-ccamp-dwdm-if-mng-ctrl-fwk-01

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 DMDM 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 a single channel DWDM interface The purpose is to identify the necessary information elements and processes to be used by control or management systems for further processing.

Status of This Memo

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1. Introduction

The usage of the Colored interfaces in the Client Nodes connected to a DWDM Network (which include ROADMs and optical amplifiers) adds further networking option for operators opening to 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 a black link deployment, 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 give use cases on how to manage the solutions. In particular, it examines topological elements and related network management measures. From an architectural point of view, the network can be consideres as a black link, that is a set of pre-configured/qualified unidirectional, single-fiber, network connections between the G.698.2 reference points S and R. The optical transport network is managed and controlled in order to provide Oprical 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 in ITU-T Recommendations G.698.2 and G.798. The Management or Control planes of the Client and DWDM network must know the parameters of the Interfaces to properly set the optical link.

Furthermore, support for Fast Fault Detection can benefit from the solution proposed.

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

Current generation 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 Client interfaces changes this scenario, by introducing a standardized interface at the level of OCh between the Client 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 Client DWDM interface

The management of optical interfaces using the Black Link approach deals with 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.

The solution allows the direct connection of a wide variety of equipments 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. Multiple optical client devices, each from a different vendor, supplying one channel each

3. A combination of the above

Table 1 provides a list of management regarding the configuration of optical parameters.

Task	Domain	a	b	c	d
determination of centre frequency	optical	R	R	R	R
configuration of centre frequency at optical IF	client	NR	NR	R	R
path computation of wavelength	optical	NR	NR	R	R
routing of wavelength	optical	NR	NR	R	R
wavelength setup across optical network	optical	?	?	R	R
detection of wavelength fault	client	R	R	R	R
fault isolation, identification of root failure	optical	NR	R	R	R
repair actions within optical network	optical	R	R	R	R
protection switching of wavelength	optical	NR	NR	R	R
restoration of wavelength	optical	NR	NR	R	R

Note: R = relevant, NR = not relevant

Table 1: List of tasks related to Client - Network interconnection management

Furthermore the following deployment cases will be considered:

a. Passive WDM

b. P2P WDM systems

c. WDM systems with OADMs

d. Transparent optical networks supporting specific IPoWDM functions, nterfaces, protocols etc.

Case a) is added for illustration only, since passive WDM is specified in ITU-T Recommendations G.695 and G.698.1.

Case b) and case c)are motivated by the usage of legacy equipment using the traditional connection as described in Figure 1 combined with the BL approach.

3.1. Comparison of approaches for transverse compatibility

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 labelled "single channel non-DWDM interfaces from other vendor(s)" and "Single channel non DWDM interfaces to/from other vendor(s)" 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 Client DWDM interface deployment this interface moves into the client devices and extends the optical and administrative domain towards the client node. ITU-T G.698.2 specifies the parameter set for a certain set of applications.

This document elaborates only the IaDI Interface as specified in ITU-T G.698.2 as transversely compatible and multi-vendor interface within one administrative domain controlled by the network operator. This administrative domain can contain several vendor domains (vendor A for the DWDM sub-network, and vendors B1 and B2 at the transmitter and receiver terminal side).

3.1.2. Black Link Deployments

In case of a Black Link deployment as shown in Figure 2, through the use of the single channel DWDM interfaces defined in [ITU.G698.2], multi-vendor interconnection can also be achieved while removing the need for one s hort reach transmitter and receiver pair per channel (eliminating the transponders).

Figure 2 shows a set of reference points, for the linear "black-link" approach, 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

In Figure 2, if the administrative domain consists of several domains (e.g. A for a DWDM network, B1 for the DWDM Tx, and B2 for the DWDM Rx), it is typical that there will be a separate Element Management Systems (EMS) will be used for each vendor domain (e.g. EMS-a for domain A, EMS-b1 for domain B1, and EMS-b2 for domain B2). Each EMS may have a common standard north bound management interface to a

Network Management System (NMS), allowing consistent end-to-end management of the connection.

To facilitate consistent end-to-end network management, the north bound management interface from the EMS to the NMS should be consistent (frome a management information point of view) with the standard protocol-neutral (or protocol-specific) information model used in the EMS south bound management interface to its subtending NEs (TX and/or RX). The [Interface-MIB] defines such a protocol-specific information using SNMP/SMI, Yang models and LMP TLV to support the direct exchange of information between the Client and the Network control planes.

4. Solutions for managing and controlling the 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 there are the following approaches will be considered to manage and operate optical interfaces.

<vspace>:

1. Separate operation and management of client device and the transport network

   a.Direct link between the client device and the management system of the optical network (e.g. EMS, NMS)

   b.Indirect link to the management system of the optical network using a protocol 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 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 to higher layers (e.g. IP), this may lead to more 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 [Black-Link-MIB]. In that case SNMP is used to exchange data between the client device and the management system of the WDM domain. Yang models are as well needed to enable and SDN controller to easily read/provision the interfaces parameters.

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

The 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] can (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 has to 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 signaling communication channel (SCC or IPCC).

4.2. Control Plane Considerations

The concept of black link 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 BL implementation. Since the implementation of the BL itself is unknown a priori, different sequences to light up wavelength need to be considered:

1. Transponders first, transponder tuning: The transmitter is switched on and the BL 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. Transponder 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, Transponder 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 transponders 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 signalling information but covers:

1. Control channel manangement

2. Link property correlation

3. Link verification

4. Fault Manangement

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 G.698.2 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 a black link 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. Operational aspects using IUT-T G.698.2 specified single channel DWDM interfaces

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

5.1. Bringing into service

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 Cleint 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-T Recommendation M.xxxx. When needed further Black Link 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. LMP 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

Pure Access Link (AL) Monitoring Use Case

Figure 4 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 llustrated 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.

AL 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 power 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

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: Extended LMP Model

- 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. Acknowledgements

The author would like to thank Ulrich Drafz for the very good teamwork during the last years and the initial thoughts related to the packet optical integration. Furthermore the author would like to thank all people involved within Deutsche Telekom for the support and fruitful discussions.

7. IANA Considerations

This memo includes no request to IANA.

8. 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 authentification 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 Yang Data Model for WSON Optical Networks

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Abstract

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

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This Internet-Draft will expire on January 1, 2016.

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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 drafts [WSON-Encode] and [Gen-Encode] that developed protocol independent encodings based on [RFC7446]. This document augments the generic TE topology draft [TE-TOPO].

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

2. Routing and Wavelength Assignment Informational Model

The relevant information model in this document comprises

- Connectivity Matrix Model (Section 2.1)
- Resource Pool Model (Section 2.2)
- Port Wavelength Restriction (Section 2.3)
- Wavelength Availability on Links (Section 2.4)

[Editor’s Note: This version covers the corresponding YANG data model for the first two sections (Sections 2.1 and 2.2) and leaves the YANG model for Sections 2.3 and 2.4 in the later version.]

Sections 2.1 - 2.4 rehashes key information models from [RWA-Info] to facilitate the development of the YANG model (Section 3).

2.1. Connectivity Matrix Model

The connectivity matrix (ConnectivityMatrix) represents either the potential connectivity matrix for asymmetric switches (e.g. ROADMs and such) or fixed connectivity for an asymmetric device such as a multiplexer.

Note that multiple connectivity matrices are allowed and the Node_ID would be an appropriate identifier for the node to point the Connectivity matrix within the WSON RWA context.

```
<Node_Information> ::= <Node_ID> [<ConnectivityMatrix>...]

<ConnectivityMatrix> ::= <MatrixID>

                         <ConnType>
```

<Matrix>

Where

<MatrixID> is a unique identifier for the matrix.

<ConnType> can be either 0 or 1 depending upon whether the connectivity is either fixed or switched.

<Matrix> represents the fixed or switched connectivity in that Matrix(i, j) = 0 or 1 depending on whether input port i can connect to output port j for one or more wavelengths.

2.2. Resource Pool Model

A WSON node may include regenerators or wavelength converters arranged in a shared pool. As discussed in [RFC6163] this can include Optical-Electronic-Optical (OEO) based Wavelength Division Multiplexing (WDM) switches as well. There are a number of different approaches used in the design of WDM switches containing regenerator or converter pools. However, from the point of view of path computation the following need to be known:

1. The nodes that support regeneration or wavelength conversion.

2. The accessibility and availability of a wavelength converter to convert from a given input wavelength on a particular input port to a desired output wavelength on a particular output port.

3. Limitations on the types of signals that can be converted and the conversions that can be performed.

The following Figures show resource pool architecture of WSON.

```
     I1   +-------------+                        +-------------+ O1
    ----->|             |      +--------+        |             |----->
     I2   |             +------+ Rb #1  +--------+             | O2
    ----->|             |      +--------+        |             |----->
          |             |                        |             |
          | Resource    |      +--------+        |  Resource   |
          | Pool        +------+        +--------+  Pool       |
          |             |      + Rb #2  +        |             |
          | Input       +------+        +--------|  Output     |
          | Connection  |      +--------+        |  Connection |
          | Matrix      |          .             |  Matrix     |
          |             |          .             |             |
          |             |          .             |             |
     IN   |             |      +--------+        |             | OM
    ----->|             +------+ Rb #P  +--------+             |----->
          |             |      +--------+        |             |
          +-------------+   ^               ^    +-------------+
                            |               |
                            |               |
                            |               |
                            |               |

                   Input wavelength      Output wavelength
                   constraints for       constraints for
                   each resource         each resource
```

Note: Rb is a Resource Block.

Figure 1 Schematic diagram of resource pool model.

Since resources tend to be packaged together in blocks of similar devices, e.g., on line cards or other types of modules, the fundamental unit of identifiable resource in this document is the "resource block". A resource block may contain one or more resources. A resource is the smallest identifiable unit of processing allocation. One can group together resources into blocks if they have similar characteristics relevant to the optical system being modeled, e.g., processing properties, accessibility, etc.

This leads to the following formal high level model:

<Node_Information> ::= <Node_ID>

```
                           [<ConnectivityMatrix>...]
                           [<ResourcePool>]
   Where
   <ResourcePool> ::= <ResourceBlockInfo>...
                      [<ResourceAccessibility>...]
                      [<ResourceWaveConstraints>...]
                      [<RBPoolState>]


   <ResourceAccessibility> ::= <PoolInputMatrix>
                               <PoolOutputMatrix>


   <ResourceWaveConstraints> ::= <InputWaveConstraints>
                                 <OutputOutputWaveConstraints>


   <RBSharedAccessWaveAvailability> ::= [<InAvailableWavelengths>]
                                        [<OutAvailableWavelengths>]


   <RBPoolState> ::=    <ResourceBlockID>
                        <NumResourcesInUse>
                        [<RBSharedAccessWaveAvailability>]
                        [<RBPoolState>]


   <ResourceBlockInfo> ::= <ResourceBlockSet>
```

```
                          [<InputConstraints>]

                          [<ProcessingCapabilities>]

                          [<OutputConstraints>]
```

Where <ResourceBlockSet> is a list of resource block identifiers with the same characteristics. If this set is missing the constraints are applied to the entire network element.

```
<InputConstraints> ::= <SharedInput>

                       [<OpticalInterfaceClassList>]

                       [<ClientSignalList>]

<ProcessingCapabilities> ::= [<NumResources>]

                             [<RegenerationCapabilities>]

                             [<FaultPerfMon>]

                             [<VendorSpecific>]

<OutputConstraints> := <SharedOutput>

                       [<OpticalInterfaceClassList>]

                       [<ClientSignalList>]

<OpticalInterfaceClassList> ::= <OpticalInterfaceClass> ...


<ClientSignalList>::=[<G-PID>]...
```

1. Number of Resources within the block

2. Regeneration capability

3. Fault and performance monitoring

4. Vendor Specific capability

Note that the code points for Fault and performance monitoring and vendor specific capability are subject to further study.

2.3. Port Label Restriction Model

```
<LinkInfo> ::=  <LinkID>

                [<AdministrativeGroup>]

                [<InterfaceCapDesc>]

                [<Protection>]

                [<SRLG>...]

                [<TrafficEngineeringMetric>]

                [<PortLabelRestriction>...]
```

Note that these additional link characteristics only applies to line side ports of WDM system or add/drop ports pertaining to Resource Pool (e.g., Regenerator or Wavelength Converter Pool). The advertisement of input/output tributary ports is not intended here.

```
<PortLabelRestriction> ::= <MatrixID>

                           <Restriction parameters list>


<Restriction parameters list> ::=

                           <LabelSet> ...
```

Where

MatrixID is the ID of the corresponding connectivity matrix.

LabelSet is a conceptual set of labels (wavelengths).

MaxNumChannels is the maximum number of channels that can be simultaneously used (relative to either a port or a matrix).

LinkSet is a conceptual set of ports.

2.4. Wavelength Availability on Links

In the previously presented information model there are a limited number of information elements that are dynamic, i.e., subject to change with subsequent establishment and teardown of connections. Depending on the protocol used to convey this overall information model it may be possible to send this dynamic information separate from the relatively larger amount of static information needed to characterize WSON's and their network elements.

```
<DynamicLinkInfo> ::=  <LinkID>

                       <AvailableLabels>

                       [<SharedBackupLabels>]
```

AvailableLabels is a set of labels (wavelengths) currently available on the link. Given this information and the port wavelength restrictions one can also determine which wavelengths are currently in use. This parameter could potential be used with other technologies that GMPLS currently covers or may cover in the future.

SharedBackupLabels is a set of labels (wavelengths) currently used for shared backup protection on the link. An example usage of this information in a WSON setting is given in [Shared]. This parameter could potential be used with other technologies that GMPLS currently covers or may cover in the future.

3. YANG Model (Tree Structure)

(Editor's Note: This version is based on the augmentation of draft-ietf-teas-yang-te-topo [TE-TOPO].)

```
module: ietf-wson-topology
augment /tet:te-topologies/tet:topology/tet:topology-types/tet:te-
topology:
    +--rw wson-topology
augment /tet:te-topologies/tet:topology/tet:node/tet:te-node-
attributes/tet:connectivity-matrix:
    +--rw wson-matrix
       +--rw device-type?        devicetype
       +--rw dir?                directionality
       +--rw matrix-interface* [in-port-id]
          +--rw in-port-id     wson-interface-ref
          +--rw out-port-id?   wson-interface-ref
augment /tet:te-topologies/tet:topology/tet:node/tet:te-node-
attributes/tet:te-link:
    +--rw wavelength-available-bitmap*   boolean
augment /tet:te-topologies/tet:topology/tet:node:
    +--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
```

4. WSON-RWA YANG Model

```
<CODE BEGINS>

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

   prefix wson;

   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.

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      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 2015-07-01 {
         description
            "version 2.";

      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 "/tet:te-topologies/tet:topology/tet:node"
            + "/tet:te-node-attributes/tet:te-link"
            + "/tet:te-link-id";
         }
         description
            "This type is used by data models that need to
            reference WSON interface.";
      }

      augment "/tet:te-topologies/tet:topology/tet:topology-types"
            + "/tet:te-topology" {
         description "WSON augmentation.";
         container wson-topology{
            description
               "An empty WSON container to identify
```

```
             the topology type.";
         }
      }

      augment "/tet:te-topologies/tet:topology/tet:node"
            +"/tet:te-node-attributes"
            +"/tet:connectivity-matrix" {
         when "/tet:te-topologies/tet:topology/tet:topology-types"
            +"/tet:te-topology/wson-topology" {
            description
               "This augment is only valid for WSON.";
         }
         description "WSON Connectivity Matrix augmentation.";
         container wson-matrix{
            description "WSON specific Matrix.";
            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 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";
               }
            }
         }
      }

      augment "/tet:te-topologies/tet:topology/tet:node"
            + "/tet:te-node-attributes/tet:te-link"   {

         when "/tet:te-topologies/tet:topology/tet:topology-types"
            +"/tet:te-topology/wson-topology" {
            description
               "This augment is only valid for WSON.";
            }
         description "WSON Link augmentation.";

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

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

         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";
            }

            list matrix-interface {
               key "in-port-id";

               description
                  "pool is described as matrix-interface
                  with input-ports and output-ports
                  around the pool";

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

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

   <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

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