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November 10, 2014

# A YANG model to manage the optical interface parameters of "G.698.2 single channel" in DWDM applications
draft-dharini-netmod-g-698-2-yang-02

## Abstract

This memo defines a yang model that translates the SNMP mib module defined in draft-galikunze-ccamp-g-698-2-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] 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 based on the Black Link approach.

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## Status of This Memo

time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

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## 1. Introduction

This memo defines a yang model that translates the SNMP mib module defined in draft-galikunze-ccamp-g-698-2-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] 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 the draft-kunze-g-698-2-management-control-framework

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.

The Yang Model, 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], which draft-galikunze-ccamp-g-698-2-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 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. 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 (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 Wavelength, 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).

Wavelength Value (see G.694.1 Table 1):
This parameter indicates the wavelength value that Ss and Rs will be set to work (in THz). See the details in Section 6/G.694.1 (G, S).

Number of Vendor Transceiver Class Supported
This parameter indicates the number of Vendor Transceiver codes supported by this interface (G).

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 |
|---|---|---|
| Wavelength Value | G,S | G.694.1 S.6 |
| Vendor Transceiver Class | G | N.A. |
| Number of Vendor Transceiver Class Supported | G | N.A. |
| 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:
This is the application code that is defined in G.698.2.

### 4.1.3. Table of Vendor Application Codes

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

Vendor Transceiver Class Identifier::
The Identifier for the vendor transceiver class.

Vendor Transceiver Class:
Other than specifying all the Transceiver parameter, it might be convenient for the vendors to summarize a set of parameters in a single proprietary parameter: the Class of transceiver. The Transceiver classification will be based on the Vendor Name and the main TX and RX parameters (i.e. Trunk Mode, Framing, Bit rate, Trunk Type, Channel Band, Channel Grid, Modulation Format, Channel Modulation Format, FEC Coding, Electrical Signal Framing at Tx, Minimum maximum Chromatic Dispersion (CD) at Rx, Maximum Polarization Mode Dispersion (PMD) at Rx, Maximum differential

group delay at Rx, Loopbacks, TDC, Pre-FEC BER, Q-factor, Q-margin,etc.). If this parameter is used, the vendor will be responsible to specify the Class contents and values. The Vendor can publish the parameters of its Classes or declare to be compatible with published Classes.(G) Optional for compliance. (not mentioned in G.698.2)

### 4.2. Optical Interface for G.698.2

The ietf-opt-if-g698-2 is an augment to the ietf-interface. It allows the user to set the application code/vendor transceiver class/ wavelength and the output power. The module can also be used to get the list of supported application codes/ transceiver class and also the wavelength/output power/input power of the interface.

```
      module: ietf-opt-if-g698-2
      augment /if:interfaces/if:interface:
          +--rw optIfOChRsSs
                +--rw ifCurrentApplicationCode
                |  +--rw applicationCodeId?   uint8
                |  +--rw applicationCode?     string
                +--rw ifCurrentVendorTransceiverClass
                |  +--rw vendorTransceiverClassId?   uint8
                |  +--rw vendorTransceiverClass?     string
                +--ro ifSupportedApplicationCodes
                |  +--ro numberApplicationCodesSupported?   uint32
                |  +--ro applicationCodesList* [applicationCodeId]
                |     +--ro applicationCodeId   uint8
                |     +--ro applicationCode?    string
                +--ro ifSupportedVendorTransceiverClass
                |  +--ro numberVendorTransceiverClassSupported?   uint32
                |  +--ro vendorTransceiverClassList*
                                          [vendorTransceiverClassId]
                |     +--ro vendorTransceiverClassId   uint8
                |     +--ro vendorTransceiverClass?    string
                +--rw outputPower?                     int32
                +--ro inputPower?                      int32
                +--rw wavelengthn?                     uint32


     notifications:
    +---n optIfOChWavelengthChange
    |  +--ro if-name?      leafref
    |  +--ro wavelength
    |     +--ro wavelength?   uint32
    +---n optIfOChApplicationCodeChange
    |  +--ro if-name?              leafref
    |  +--ro newApplicationCode
    |     +--ro applicationCodeId?   uint8
    |     +--ro applicationCode?     string
    +---n optIfOChVendorTransceiverCodeChange
       +--ro if-name?                     leafref
       +--ro newVendorTransceiverClass
          +--ro vendorTransceiverClassId?   uint8
          +--ro vendorTransceiverClass?     string
```

## 5. Structure of the Yang Module

ietf-opt-if-g698-2 is a top level model for the support of this feature.

## 6. Yang Module

The ietf-opt-if-g698-2 is defined as an extension to ietf interfaces.

```
<CODE BEGINS> file "ietf-opt-if-g698-2.yang"

module ietf-opt-if-g698-2 {
     namespace "urn:ietf:params:xml:ns:yang:ietf-opt-if";
     prefix ietf-opt-if-g698-2;

     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.

        Copyright (c) 2013 IETF Trust and the persons identified as
        authors of the code.  All rights reserved.

        Redistribution and use in source and binary forms, with or
        without modification, is permitted pursuant to, and subject
        to the license terms contained in, the Simplified BSD License
        set forth in Section 4.c of the IETF Trust’s Legal Provisions
        Relating to IETF Documents
        (http://trustee.ietf.org/license-info).";

        revision 2014-5-10 {
           description
               "Initial revision.";
```

```
             reference
                 "RFC XXXX: A YANG Data Model for Optical Management of
                   an Interface for g.698.2 support";
          }
          revision 2014-10-14 {
             description
                "Revision 1.0";
          }
          revision 2014-11-10{
             description
                "Revision 2.0";
          }
```

```
      grouping optIfOChVendorTransceiverClass {
          description "A unique Vendor transceiver class supported by
                       this interface";
          leaf vendorTransceiverClassId {
                   description
                       "Id for the Vendor transceiver class";
                   type uint8 {
                       range "1..255";
                   }
          }
          leaf vendorTransceiverClass {
              type string {
                   length "1..256";
              }
              description "This defines the transceiver class that
                      is/should be used by this interface.
                      Vendors can summarize a set of parameters in a
                      single proprietary parameter: the Class of
                      transceiver. The Transceiver classification will
                      be based on the Vendor Name and the main TX and RX
                      parameters i.e.  Trunk Mode, Framing, Bit rate,
                      Trunk Type etc).";
            }

      }

      grouping optIfOChVendorTransceiverClassList {
          description "List of vendor transceiver codes group.";
          leaf numberVendorTransceiverClassSupported {
              type uint32;
              description "Number of Vendor classes supported by this
                          interface";
          }
          list vendorTransceiverClassList {
              key "vendorTransceiverClassId";
              uses optIfOChVendorTransceiverClass;
          }
       }




      grouping optIfOChApplicationCode  {
             description "Application code entity.";
             leaf applicationCodeId {
                  description
                      "Id for the Application code";
```

```
                  type uint8 {
                      range "1..255";
                  }
              }
              leaf applicationCode {
                  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.";
                  type string {
                      length "1..256";
                  }
              }
      }


      grouping optIfOChApplicationCodeList {
          description "List of Application codes group.";
          leaf numberApplicationCodesSupported {
              type uint32;
              description "Number of Application codes supported by
                             this interface";
          }
          list applicationCodeList {
              key "applicationCodeId";
              uses optIfOChApplicationCode;
          }
      }


     grouping optIfOChPower {
         leaf outputPower {
            type int32;
            units ".01dbm";
            description "The output power for this interface in .01
                         dbm.";
         }

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

```
     grouping optIfOChWavelength {
          leaf wavelengthn {
              type uint32;
              description "This parameter indicate minimum wavelength
              spectrum - n, in a definite wavelength Band (L, C and S)
              as represented in[RFC6205] by the formula -
              Wavelength (nm ) = 1471nm + n* Channel Spacing
                                                  (converted to nm)
              Eg - Channel Spacing in nm
              'Wavelength (nm ) = 1471nm + n* 20nm  (20nm is the
               spacing for CWDM)' ";

            }
     }

      notification optIfOChWavelengthChange {
         description "A change of wavelength has been detected.";
         leaf "if-name" {
             type leafref {
                 path "/if:interfaces/if:interface/if:name";
             }
         }
         container wavelength {
             uses optIfOChWavelength;
         }
      }

      notification optIfOChApplicationCodeChange {
         description "A change of Application code has been detected.";
         leaf "if-name" {
             type leafref {
                 path "/if:interfaces/if:interface/if:name";
             }
         }
         container newApplicationCode {
             uses optIfOChApplicationCode;
         }
      }


      notification optIfOChVendorTransceiverCodeChange {
         description "A change of vendor transceiver code has been
                      detected.";
         leaf "if-name" {
             type leafref {
                 path "/if:interfaces/if:interface/if:name";
             }
         }
```

```
         container newVendorTransceiverClass {
            uses optIfOChVendorTransceiverClass;
        }
      }

      augment "/if:interfaces/if:interface" {

         container optIfOChRsSs {
           description "RsSs path configuration for an interface";

            container ifCurrentApplicationCode {
               uses optIfOChApplicationCode;
            }

            container ifCurrentVendorTransceiverClass {
                uses optIfOChVendorTransceiverClass;
            }

            container ifSupportedApplicationCodes {
                config false;
                uses optIfOChApplicationCodeList;
            }

            container ifSupportedVendorTransceiverClass {
                config false;
                uses optIfOChVendorTransceiverClassList;
            }

            uses optIfOChPower;

            uses optIfOChWavelength;

         }
      }
}

<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-opt-if-g698-2

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-opt-if-g698-2 reference: RFC XXXX

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## Appendix A.  Change Log

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

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

## Appendix B.  Open Issues

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

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# Extension to the Link Management Protocol (LMP/DWDM -rfc4209) for Dense Wavelength Division Multiplexing (DWDM) Optical Line Systems to manage the application code of optical interface parameters in DWDM application

draft-dharinigert-ccamp-g-698-2-lmp-09

## Abstract

This memo defines extensions to LMP(rfc4209) for managing Optical parameters associated with Wavelength Division Multiplexing (WDM) systems or characterized by the Optical Transport Network (OTN) in accordance with the Interface Application Code approach defined in ITU-T Recommendation G.698.2.[ITU.G698.2], G.694.1.[ITU.G694.1] and its extensions.

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## Status of This Memo

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## 1. Introduction

This extension is based on "draft-galikunze-ccamp-g-698-2-snmp-mib-09", for the relevant interface optical parameters described in recommendations like ITU-T G.698.2 [ITU.G698.2] and G.694.1.[ITU.G694.1]. The LMP Model from RFC4902 provides link property correlation between a client and an OLS device. LMP link property correlation, exchanges the capabilities of either end of the link where the term 'link' refers to the attachment link between OXC and OLS (see Figure 1). By performing link property correlation, both ends of the link exchange link properties, such as application identifiers. This allows either end to operate within a commonly understood parameter window. Based on known parameter limits, each device can supervise the received signal for conformance using mechanisms defined in RFC3591. 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.

Figure 1 Extended LMP Model ( from [RFC4209] )

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

       OXC        : is an entity that contains transponders
       OLS        : generic optical system, it can be -
                    Optical Mux, Optical Demux, Optical Add
                    Drop Mux, etc.
       OLS to OLS : represents the black-Link itself
       Rs/Ss      : in between the OXC and the OLS
```

Figure 1: Extended LMP Model

## 2. Extensions to LMP-WDM Protocol

This document defines extensions to [RFC4209] to allow the Black Link (BL) parameters of G.698.2, to be exchanged between a router or optical switch and the optical line system to which it is attached. In particular, this document defines additional Data Link sub-objects to be carried in the LinkSummary message defined in [RFC4204] and [RFC6205]. The OXC and OLS systems may be managed by different Network management systems and hence may not know the capability and status of their peer. The intent of this draft is to enable the OXC and OLS systems to exchange this information. These messages and their usage are defined in subsequent sections of this document.

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

```
 - OCh_General                  (sub-object Type = TBA)
 - OCh_ApplicationIdentier      (sub-object Type = TBA)
 - OCh_Ss                       (sub-object Type = TBA)
 - OCh_Rs                       (sub-object Type = TBA)
```

## 3. General Parameters - OCh_General

These are the general parameters as described in [G698.2] and [G.694.1]. Please refer to the "draft-galikunze-ccamp-g-698-2-snmp-mib-09" for more details about these parameters and the [RFC6205] for the wavelength definition.

The general parameters are

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

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

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type       |    Length     |         (Reserved)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Central Frequency                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Number of Application                 |                     |
|   Identifiers Supported                 |     (Reserved)      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Single-channel|  A.I. Type    |         A.I. length           |
| Application   |   in use      |                               |
| Identifier    |               |                               |
| Number in use |               |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Single-channel Application Identifier in use        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Single-channel Application Identifier in use        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Single-channel Application Identifier in use        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

A.I. Type in use: STANDARD, PROPRIETARY

A.I. Type in use: STANDARD

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

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

A.I. Type in use: PROPRIETARY

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

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

Figure 2: OCh_General

## 4. ApplicationIdentifier - OCh_ApplicationIdentifier

This message is to exchange the application identifiers supported as described in [G698.2]. Please refer to the "draft-galikunze-ccamp-g-698-2-snmp-mib-09". For more details about these parameters. There can be more than one Application Identifier supported by the OXC/OLS. The number of application identifiers supported is exchanged in the "OCh_General" message. (from [G698.1]/[G698.2]/[G959.1] and G.874.1 )

The parameters are

1. Number of Application Identifiers (A.I.) Supported

2. Single-channel application identifier Number uniquely identifiers this entry - 8 bits

3. Application Indentifier Type (A.I.) (STANDARD/PROPRIETARY)

4. Single-channel application identifier -- 96 bits (from [G698.1]/[G698.2]/[G959.1]

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

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

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type       |    Length     |         (Reserved)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Number of Application                 |                     |
|   Identifiers Supported                 |     (Reserved)      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Single-channel|  A.I. Type    |         A.I. length           |
| Application   |               |                               |
| Identifier    |               |                               |
| Number        |               |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Single-channel Application Identifier           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Single-channel Application Identifier           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Single-channel Application Identifier           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
//              ....                                            //
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Single-channel|               |         A.I. length           |
| Application   |   A.I. Type   |                               |
| Identifier    |               |                               |
```

```
   | Number         |               |                              |
   |                |               |                              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |               Single-channel Application Identifier           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |               Single-channel Application Identifier           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |               Single-channel Application Identifier           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

A.I. Type in use: STANDARD, PROPRIETARY

A.I. Type in use: STANDARD
Refer to G.698.2 recommendation :  B-DScW-ytz(v)

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

A.I. Type in use: PROPRIETARY

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

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

Figure 3: OCh_ApplicationIdentifier

## 5. OCh_Ss - OCh transmit parameters

These are the G.698.2 parameters at the Source(Ss reference points). Please refer to "draft-galikunze-ccamp-g-698-2-snmp-mib-09" for more details about these parameters.

1. Output power

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

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type       |    Length     |         (Reserved)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Output Power                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4: OCh_Ss transmit parameters

## 6. OCh_Rs - receive parameters

These are the G.698.2 parameters at the Sink (Rs reference points). Please refer to the "draft-galikunze-ccamp-g-698-2-snmp-mib-09" for more details about these parameters.

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

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

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

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type       |    Length     |                   (Reserved)  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Current Input Power                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5: OCh_Rs receive parameters

## 7.  Security Considerations

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

## 8.  IANA Considerations

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

- LMP Message Type
- LMP Object Class
- LMP Object Class type (C-Type) unique within the Object Class
- LMP Sub-object Class type (Type) unique within the Object Class

This memo introduces the following new assignments:

LMP Sub-Object Class names:

```
 under DATA_LINK Class name (as defined in <xref target="RFC4204"/>)
    - OCh_General                  (sub-object Type = TBA)
        - OCh_ApplicationIdentifier    (sub-object Type = TBA)
        - OCh_Ss                       (sub-object Type = TBA)
        - OCh_Rs                       (sub-object Type = TBA)
```

# 9. References

## 9.1. Normative References

[RFC4204] Lang, J., "Link Management Protocol (LMP)", RFC 4204, October 2005.

[RFC4209] Fredette, A. and J. Lang, "Link Management Protocol (LMP) for Dense Wavelength Division Multiplexing (DWDM) Optical Line Systems", RFC 4209, October 2005.

[RFC6205] Otani, T. and D. Li, "Generalized Labels for Lambda-Switch-Capable (LSC) Label Switching Routers", RFC 6205, March 2011.

[RFC4054] Strand, J. and A. Chiu, "Impairments and Other Constraints on Optical Layer Routing", RFC 4054, May 2005.

[ITU.G698.2] International Telecommunications Union, "Amplified multichannel dense wavelength division multiplexing applications with single channel optical interfaces", ITU-T Recommendation G.698.2, November 2009.

[ITU.G694.1] International Telecommunications Union, ""Spectral grids for WDM applications: DWDM frequency grid"", ITU-T Recommendation G.698.2, February 2012.

[ITU.G709] International Telecommunications Union, "Interface for the Optical Transport Network (OTN)", ITU-T Recommendation G.709, February 2012.

[ITU.G872] International Telecommunications Union, "Architecture of optical transport networks", ITU-T Recommendation G.872, October 2012.

[ITU.G874.1] International Telecommunications Union, "Optical transport network (OTN): Protocol-neutral management information model for the network element view", ITU-T Recommendation G.874.1, October 2012.

## 9.2. Informative References

[I-D.galimbe-kunze-g-698-2-snmp-mib]
Kunze, R. and D. Hiremagalur, "A SNMP MIB to manage black-link optical interface parameters of DWDM applications", draft-galimbe-kunze-g-698-2-snmp-mib-02 (work in progress), March 2012.

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# An SNMP MIB extension to RFC3591 to manage optical interface parameters of "G.698.2 single channel" in DWDM applications
draft-galikunze-ccamp-g-698-2-snmp-mib-09

## 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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# 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. 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).

### 4.1.1. 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

### 4.1.2. 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

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

## 4.2. 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.

#### 4.2.1. 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. >>>

| | |
|---|---|
| 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.

#### 4.2.2. Use of ifTable for OCh Layer

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

#### 4.2.3. 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"
       ::= { 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,
        optIfOChInterfaceApplicationIdentifierNumber Unsigned32,
        optIfOChInterfaceApplicationIdentifierType   Unsigned32,
        optIfOChInterfaceApplicationIdentifier       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 }

optIfOChInterfaceApplicationIdentifierNumber  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 }

   optIfOChInterfaceApplicationIdentifierType  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 }

   optIfOChInterfaceApplicationIdentifier  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. "
       ::= { optIfOChSsRsConfigEntry  4 }

   optIfOChNumberApplicationIdentifiersSupported  OBJECT-TYPE
       SYNTAX Unsigned32
       MAX-ACCESS  read-only
       STATUS  current
       DESCRIPTION
          " Number of Application codes supported by this interface."
       ::= { optIfOChSsRsConfigEntry  5 }

   -- 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,
          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.
        "
      ::= { optIfOChSrcApplicationIdentifierEntry  2}

  optIfOChApplicationIdentifier  OBJECT-TYPE
      SYNTAX DisplayString
      MAX-ACCESS  read-only
      STATUS  current
      DESCRIPTION
          " The application code supported by this interface DWDM
            link."
      ::= { optIfOChSrcApplicationIdentifierEntry  3}
```

```
-- 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.

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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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# An SNMP MIB extension to RFC3591 to manage optical interface parameters of DWDM applications

draft-galikunze-ccamp-g-698-2-snmp-mib-10

## 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 Optical parameters associated with Dense Wavelength Division Multiplexing (DWDM) interfaces. This is an extension of the RFC3591 to support the optical parameters described in ITU-T G.698.2. [ITU.G698.2] and used in ITU-T G.872. [ITU.G872] and ITU-T G.874.1. [ITU.G874.1]

The MIB module defined in this memo can be used for Optical Parameters monitoring and/or configuration of the endpoints of Black Links.

## Copyright Notice



## Status of This Memo

Table of Contents

## 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 Optical parameters associated with Wavelength Division Multiplexing (WDM) systems in accordance with the optical interface defined in G.698.2 [ITU.G698.2] and ITU-T G.874.1. [ITU.G874.1]

Black Link approach allows supporting an optical transmitter/receiver pair of one vendor to inject a DWDM channel and run it over an optical network composed of amplifiers, filters, add-drop multiplexers from a different vendor. From architectural point of view, the "Black Link" is a set of pre-configured/qualified network connections between the G.698.2 reference points S and R. The black links will be managed at the edges (i.e. 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 G.7710/Y.1701 [ITU-T G.7710] and and G.874.1 [ITU.G874.1].

The G.698.2 [ITU.G698.2] provides optical parameter values for physical layer interfaces of Dense Wavelength Division Multiplexing (DWDM) systems primarily intended for metro applications which 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 specify the details of the optical link, e.g. the maximum fibre length, explicitly. 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 few optical parameter not included in the application code definition.

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] G.798 [ITU.G798], G.874 [ITU.G874], parameters specified G.7710/Y.1701 [ITU-T G.7710] allows the different vendors and operator to retrieve, provision and exchange information related to Optical blak links in a standardized way. This facilitates interworking in case of using optical interfaces from different vendors at the end of the link.

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, a more complete description of optical parameters and processes can be found in the ITU-T Recommendations.  Appendix A of this document provides an overview about the extensive ITU-T documentation in this area.  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

G.698.2 [ITU.G698.2] defines also Ring Black Link configurations [Fig. 5.2/G.698.2] and Bidirectional Black Link configurations [Fig. 5.3/G.698.2]

### 4.1. Optical Parameters Description

The black links are managed at the edges, i.e. at the transmitters (Tx) and receivers (Rx) attached to the S and R reference points respectively. The parameters that could be managed at the black link edges 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).

#### 4.1.1. 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

#### 4.1.2. 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.

### 4.2. 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 Optical Channel (OCh) layer. There is a one to n relationship between the OPS and OCh layers.

EDITOR NOTE: Reason for changing from OChr to OCh: Work on revised G.872 in the SG15 December 2011 meeting agreed to remove OChr from the architecture and to update G.709 to account for this architectural change. The meeting also agreed to consent the revised text of G.872 and G.709 at the September 2012 SG15 meeting.

Figure 2 In the following figures, opticalChannel and opticalPhysicalSection are abbreviated as OCh and ops respectively.

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

         Sub-layers in
         the OCh Layer
```

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.

#### 4.2.1.  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.
```

### 4.2.2.  Use of ifTable for OCh Layer

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

### 4.2.3.  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 9.0
           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"
       ::= { 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 }

 optIfOChCfgApplicationIdentifierLength  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
          (Proprietory), 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.
                 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 (Proprietory),
           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.

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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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# Framework and Requirements for GMPLS-based control of Flexi-grid DWDM networks
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## Abstract

To allow efficient allocation of optical spectral bandwidth for high bit-rate systems, the International Telecommunication Union Telecommunication Standardization Sector (ITU-T) has extended its Recommendations G.694.1 and G.872 to include a new dense wavelength division multiplexing (DWDM) grid by defining a set of nominal central frequencies, channel spacings and the concept of "frequency slot". In such an environment, a data plane connection is switched based on allocated, variable-sized frequency ranges within the optical spectrum creating what is known as a flexible grid (flexi-grid).

Given the specific characteristics of flexi-grid optical networks and their associated technology, this document defines a framework and the associated control plane requirements for the application of the existing GMPLS architecture and control plane protocols to the control of flexi-grid DWDM networks. The actual extensions to the GMPLS protocols will be defined in companion documents.

## Status of This Memo

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# 1. Introduction

The term "Flexible grid" (flexi-grid for short) as defined by the International Telecommunication Union Telecommunication Standardization Sector (ITU-T) Study Group 15 in the latest version of [G.694.1], refers to the updated set of nominal central frequencies (a frequency grid), channel spacing and optical spectrum management/allocation considerations that have been defined in order to allow an efficient and flexible allocation and configuration of optical spectral bandwidth for high bit-rate systems.

A key concept of flexi-grid is the "frequency slot"; a variable-sized optical frequency range that can be allocated to a data connection. As detailed later in the document, a frequency slot is characterized by its nominal central frequency and its slot width which, as per [G.694.1], is constrained to be a multiple of a given slot width granularity.

Compared to a traditional fixed grid network, which uses fixed size optical spectrum frequency ranges or frequency slots with typical channel separations of 50 GHz, a flexible grid network can select its media channels with a more flexible choice of slot widths, allocating as much optical spectrum as required.

From a networking perspective, a flexible grid network is assumed to be a layered network [G.872][G.800] in which the media layer is the server layer and the optical signal layer is the client layer. In the media layer, switching is based on a frequency slot, and the size of a media channel is given by the properties of the associated frequency slot. In this layered network, a media channel can transport more than one Optical Tributary Signals (OTSi), as defined later in this document.

A Wavelength Switched Optical Network (WSON), addressed in [RFC6163], is a term commonly used to refer to the application/deployment of a GMPLS-based control plane for the control (provisioning/recovery, etc.) of a fixed grid wavelength division multiplexing (WDM) network in which media (spectrum) and signal are jointly considered.

This document defines the framework for a GMPLS-based control of flexi-grid enabled dense wavelength division multiplexing (DWDM) networks (in the scope defined by ITU-T layered Optical Transport Networks [G.872]), as well as a set of associated control plane requirements. An important design consideration relates to the decoupling of the management of the optical spectrum resource and the client signals to be transported.

## 2. Terminology

Further terminology specific to flexi-grid networks can be found in Section 3.2.

### 2.1. 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 [RFC2119].

While [RFC2119] describes interpretations of these key words in terms of protocol specifications and implementations, they are used in this document to describe design requirements for protocol extensions.

### 2.2. Abbreviations

FS: Frequency Slot

FSC: Fiber-Switch Capable

LSR: Label Switching Router

NCF: Nominal Central Frequency

OCh: Optical Channel

OCh-P: Optical Channel Payload

OTN: Optical Transport Network

OTSi: Optical Tributary Signal

OTSiG: OTSi Group is a set of OTSi

OCC: Optical Channel Carrier

PCE: Path Computation Element

ROADM: Reconfigurable Optical Add-Drop Multiplexer

SSON: Spectrum-Switched Optical Network

SWG: Slot Width Granularity

# 3. Overview of Flexi-grid Networks

## 3.1. Flexi-grid in the Context of OTN

[G.872] describes, from a network level, the functional architecture of an OTN. It is decomposed into independent layer networks with client/layer relationships among them. A simplified view of the OTN layers is shown in Figure 1.

```
+----------------+
| Digital Layer  |
+----------------+
| Signal Layer   |
+----------------+
|  Media Layer   |
+----------------+
```

Figure 1: Generic OTN Overview

In the OTN layering context, the media layer is the server layer of the optical signal layer. The optical signal is guided to its destination by the media layer by means of a network media channel. In the media layer, switching is based on a frequency slot.

In this scope, this document uses the term flexi-grid enabled DWDM network to refer to a network in which switching is based on frequency slots defined using the flexible grid, and covers mainly the Media Layer as well as the required adaptations from the Signal layer. The present document is thus focused on the control and management of the media layer.

### 3.2. Flexi-grid Terminology

This section presents the definition of the terms used in flexi-grid networks. More detail about these terms can be found in the ITU-T Recommendations [G.694.1], [G.872]), [G.870], [G.8080], and [G.959.1-2013].

Where appropriate, this documents also uses terminology and lexicography from [RFC4397].

#### 3.2.1. Frequency Slots

This subsection is focused on the frequency slot and related terms.

- o Frequency Slot [G.694.1]: The frequency range allocated to a slot within the flexible grid and unavailable to other slots. A frequency slot is defined by its nominal central frequency and its slot width.

- o Nominal Central Frequency: Each of the allowed frequencies as per the definition of flexible DWDM grid in [G.694.1]. The set of nominal central frequencies can be built using the following expression

f = 193.1 THz + n x 0.00625 THz

where 193.1 THz is ITU-T "anchor frequency" for transmission over the C band, and n is a positive or negative integer including 0.

```
  -5 -4 -3 -2 -1  0  1  2  3  4  5     <- values of n
...+--+--+--+--+--+--+--+--+--+--+-
                  ^
                  193.1 THz <- anchor frequency
```

Figure 2: Anchor Frequency and Set of Nominal Central Frequencies

- o Nominal Central Frequency Granularity: This is the spacing between allowed nominal central frequencies and it is set to 6.25 GHz [G.694.1].

- o Slot Width Granularity (SWG): 12.5 GHz, as defined in [G.694.1].

- o Slot Width: The slot width determines the "amount" of optical spectrum regardless of its actual "position" in the frequency axis. A slot width is constrained to be m x SWG (that is, m x 12.5 GHz), where m is an integer greater than or equal to 1.

```
           Frequency Slot 1     Frequency Slot 2
            -------------     -------------------
            |           |     |                 |
         -3 -2 -1  0  1  2  3  4  5  6  7  8  9 10 11
     ...--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--...
            -------------     -------------------
                  ^                     ^
         Slot NCF = 193.1THz     Slot NCF = 193.14375 THz
         Slot width = 25 GHz     Slot width = 37.5 GHz
           n=0, m=2                n=7, m=3
```

Figure 3: Example Frequency Slots

* The symbol '+' represents the allowed nominal central frequencies

* The '--' represents the nominal central frequency granularity in units of 6.25 GHz

* The '^' represents the slot nominal central frequency

* The number on the top of the '+' symbol represents the 'n' in the frequency calculation formula.

* The nominal central frequency is 193.1 THz when n equals to zero.

o Effective Frequency Slot [G.870]: The effective frequency slot of a media channel is that part of the frequency slots of the filters along the media channel that is common to all of the filters' frequency slots. Note that both the Frequency Slot and Effective Frequency Slot are local terms.

o Figure 4 shows the effect of combining two filters along a channel. The combination of frequency slot 1 and frequency slot 2 applied to the media channel is effective frequency slot shown.

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

              Frequency Slot 2
             -------------------
             |                 |
      -3 -2 -1  0  1  2  3  4  5  6  7  8  9 10 11
      ..--+--+--+--+--X--+--+--+--+--+--+--+--+--+--...

   ===============================================
           Effective Frequency Slot
                -------------
                |           |
      -3 -2 -1  0  1  2  3  4  5  6  7  8  9 10 11
      ..--+--+--+--+--X--+--+--+--+--+--+--+--+--+--...
```

Figure 4: Effective Frequency Slot

#### 3.2.2. Media Layer Elements

- Media Element: A media element directs an optical signal or affects the properties of an optical signal. It does not modify the properties of the information that has been modulated to produce the optical signal [G.870]. Examples of media elements include fibers, amplifiers, filters, and switching matrices.

- Media Channel Matrixes: The media channel matrix provides flexible connectivity for the media channels. That is, it represents a point of flexibility where relationships between the media ports at the edge of a media channel matrix may be created and broken. The relationship between these ports is called a matrix channel. (Network) Media Channels are switched in a Media Channel Matrix.

#### 3.2.3. Media Channels

This section defines concepts such as (Network) Media Channel; the mapping to GMPLS constructs (i.e., LSP) is detailed in Section 4.

- Media Channel: A media association that represents both the topology (i.e., path through the media) and the resource (frequency slot) that it occupies. As a topological construct, it represents a frequency slot (an effective frequency slot) supported by a concatenation of media elements (fibers, amplifiers, filters, switching matrices...). This term is used to identify the end-to-end physical layer entity with its corresponding (one or more) frequency slots local at each link filters.

- Network Media Channel: [G.870] defines the Network Media Channel as a media channel that transports a single OTSi, defined next.

#### 3.2.4. Optical Tributary Signals

- Optical Tributary Signal (OTSi) [G.959.1-2013]: The optical signal that is placed within a network media channel for transport across the optical network. This may consist of a single modulated optical carrier or a group of modulated optical carriers or subcarriers. To provide a connection between the OTSi source and the OTSi sink the optical signal must be assigned to a network media channel.

- OTSi Group (OTSiG): The set of OTSi that are carried by a group of network media channels. Each OTSi is carried by one network media channel. From a management perspective it SHOULD be possible to manage both the OTSiG and a group of Network Media Channels as single entities.

#### 3.2.5. Composite Media Channels

- It is possible to construct an end-to-end media channel as a composite of more than one network media channels. A composite media channel carries a group of OTSi (i.e., OTSiG). Each OTSi is carried by one network media channel. This group of OTSi are carried over a single fibre.

- In this case, the effective frequency slots may be contiguous (i.e., there is no spectrum between them that can be used for other media channels) or non-contiguous.

- It is not currently envisaged that such composite media channels may be constructed from slots carried on different fibers whether those fibers traverse the same hop-by-hop path through the network or not.

- Furthermore, it is not considered likely that a media channel may be constructed from a different variation of slot composition on each hop. That is, the slot composition (i.e., the group of OTSi carried by the composite media channel) must be the same from one end to the other of the media channel even if the specific slot for each OTSi and the spacing among slots may vary hop by hop.

   o  How the signal is carried across such groups of network media
      channels is out of scope for this document.

### 3.3. Hierarchy in the Media Layer

In summary, the concept of frequency slot is a logical abstraction that represents a frequency range, while the media layer represents the underlying media support. Media Channels are media associations, characterized by their (effective) frequency slot, respectively; and media channels are switched in media channel matrixes. From the control and management perspective, a media channel can be logically split into network media channels.

In Figure 5, a media channel has been configured and dimensioned to support two network media channels, each of them carrying one OTSi.

```
                             Media Channel Frequency Slot
     +-------------------------------X------------------------------+
     |                                                              |
     |      Frequency Slot                  Frequency Slot          |
     |   +-----------X-----------+       +-----------X-----------+  |
     |   |         OTSi          |       |         OTSi          |  |
     |   |           o           |       |           o           |  |
     |   |           |           |       |           |           |  |
    -4  -3  -2  -1   0   1   2   3   4   5   6   7  8   9  10  11  12
   --+---+---+---+---+---+---+---+---+---+---+---+--+---+---+---+---+--

         <- Network Media Channel->     <- Network Media Channel->

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

         X - Frequency Slot Central Frequency

         o - Signal Central Frequency
```

Figure 5: Example of Media Channel / Network Media Channels and Associated Frequency Slots

### 3.4. Flexi-grid Layered Network Model

In the OTN layered network, the network media channel transports a single OTSi (see Figure 6)

```
  |                           OTSi                             |
  O - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - O
  |                                                              |
  | Channel Port         Network Media Channel        Channel Port |
  O - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - O
  |                                                              |
+--------+                +-----------+                   +--------+
|  \ (1) |                |    (1)    |                   | (1)  / |
|   \----|----------------|-----------|-------------------|-----/  |
+--------+ Link Channel   +-----------+  Link Channel     +--------+
  Media Channel           Media Channel                Media Channel
  Matrix                  Matrix                       Matrix
```

The symbol (1) indicates a Matrix Channel

Figure 6: Simplified Layered Network Model

Note that a particular example of OTSi is the OCh-P. Figure 7 shows this specific example as defined in G.805 [G.805].

```
 OCh AP                     Trail (OCh)                    OCh AP
  O- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - O
  |                                                            |
 --- OCh-P                                               OCh-P ---
 \ / source                                              sink  \ /
  +                                                            +
  | OCh-P              OCh-P Network Connection          OCh-P |
  O TCP - - - - - - - - - - - - - - - - - - - - - - - - - -TCP O
  |                                                            |
  |Channel Port         Network Media Channel      Channel Port |
  O - - - - - - - - - - - - - - - - - - - - - - - - - - - - -  O
  |                                                            |
+--------+                +-----------+                 +---------+
|  \ (1) |  OCh-P LC      |    (1)    |  OCh-P LC       |  (1)  / |
|   \----|----------------|-----------|-----------------|------/  |
+--------+ Link Channel   +-----------+  Link Channel   +---------+
Media Channel             Media Channel                Media Channel
  Matrix                    Matrix                        Matrix
```

The symbol (1) indicates a Matrix Channel

Figure 7: Layered Network Model According to G.805

### 3.4.1. DWDM Flexi-grid Enabled Network Element Models

A flexible grid network is constructed from subsystems that include WDM links, tunable transmitters, and receivers, (i.e, media elements including media layer switching elements that are media matrices) as well as electro-optical network elements. This is just the same as in a fixed grid network except that each element has flexible grid characteristics.

As stated in Clause 7 of [G.694.1] the flexible DWDM grid has a nominal 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 might not be capable of supporting 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. 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).

## 4. GMPLS Applicability

The goal of this section is to provide an insight into the application of GMPLS as a control mechanism in flexi-grid networks. Specific control plane requirements for the support of flexi-grid networks are covered in Section 5. This framework is aimed at controlling the media layer within the OTN hierarchy, and controlling the required adaptations of the signal layer. This document also defines the term Spectrum-Switched Optical Network (SSON) to refer to a Flexi-grid enabled DWDM network that is controlled by a GMPLS/PCE control plane.

This section provides a mapping of the ITU-T G.872 architectural aspects to GMPLS/Control plane terms, and considers the relationship between the architectural concept/construct of media channel and its control plane representations (e.g., as a TE link, as defined in [RFC3945]).

### 4.1. General Considerations

The GMPLS control of the media layer deals with the establishment of media channels that are switched in media channel matrices. GMPLS labels are used to locally represent the media channel and its associated frequency slot. Network media channels are considered a particular case of media channels when the end points are transceivers (that is, source and destination of an OTSi).

### 4.2. Consideration of TE Links

From a theoretical / abstract point of view, a fiber can be modeled as having a frequency slot that ranges from minus infinity to plus infinity. This representation helps understand the relationship between frequency slots and ranges.

The frequency slot is a local concept that applies within a component or element. When applied to a media channel, we are referring to its effective frequency slot as defined in [G.872].

The association sequence of the three components (i.e., a filter, a fiber, and a filter), is a media channel in its most basic form. From the control plane perspective this may modeled as a (physical) TE-link with a contiguous optical spectrum. This can be represented by saying that the portion of spectrum available at time t0 depends on which filters are placed at the ends of the fiber and how they have been configured. Once filters are placed we have a one-hop media channel. In practical terms, associating a fiber with the terminating filters determines the usable optical spectrum.

```
   ---------------+                             +------------------+
                  |                             |
         +--------+                             +--------+
         |        |                             |        |  +---------
     ---o|        ===============================        o--|
         |        |             Fiber           |        |  | --\  /--
     ---o|        |                             |        o--|    \/
         |        |                             |        |  |    /\
     ---o|        ===============================        o--| --/  \--
         | Filter |                             | Filter |  |
         |        |                             |        |  +---------
         +--------+                             +--------+
                  |                             |
               |------- Basic Media Channel  ---------|
   ---------------+                             +------------------+


       --------+                                      +--------
               |--------------------------------------|
        LSR    |              TE link                 |  LSR
               |--------------------------------------|
      +--------+                                      +--------
```

Figure 8: (Basic) Media Channel and TE Link

Additionally, when a cross-connect for a specific frequency slot is considered, the resulting media support of joining basic media channels is still a media channel, i.e., a longer association sequence of media elements and its effective frequency slot. In other words, It is possible to "concatenate" several media channels (e.g., patch on intermediate nodes) to create a single media channel.

The architectural construct resulting of the association sequence of basic media channels and media layer matrix cross-connects can be represented as (i.e., corresponds to) a Label Switched Path (LSP) from a control plane perspective.

```
   ----------+       +------------------------------+       +---------
             |       |                              |       |
      +------+       +------+                +------+       +------+
      |      |       |      |  +----------+  |      |       |      |
   --o|      =========      o--|          |--o      =========      o--
      |      | Fiber |      |  | --\  /-- |  |      | Fiber |      |
   --o|      |       |      o--|    \/    |--o      |       |      o--
      |      |       |      |  |    /\    |  |      |       |      |
   --o|      =========      o--***********|--o      =========      o--
      |Filter|       |Filter|  |          |  |Filter|       |Filter|
      |      |       |      |                |      |       |      |
      +------+       +------+                +------+       +------+
             |       |                              |       |
         <- Basic Media ->    <- Matrix ->       <- Basic Media->
             |Channel|           Channel            |Channel|
   ----------+       +------------------------------+       +---------

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

   ------+                  +---------------+                  +------
         |------------------|               |------------------|
    LSR  |       TE link    |      LSR      |   TE link        |  LSR
         |------------------|               |------------------|
   ------+                  +---------------+                  +------
```

Figure 9: Extended Media Channel

Furthermore, if appropriate, the media channel can also be represented as a TE link or Forwarding Adjacency (FA) [RFC4206], augmenting the control plane network model.

```
   ----------+       +------------------------------+       +---------
             |       |                              |       |
      +------+       +------+                +------+       +------+
      |      |       |      |  +----------+  |      |       |      |
   --o|      =========      o--|          |--o      =========      o--
      |      | Fiber |      |  | --\  /-- |  |      | Fiber |      |
   --o|      |       |      o--|    \/    |--o      |       |      o--
      |      |       |      |  |    /\    |  |      |       |      |
   --o|      =========      o--***********|--o      =========      o--
      |Filter|       |Filter|  |          |  |Filter|       |Filter|
      |      |       |      |                |      |       |      |
      +------+       +------+                +------+       +------+
             |       |                              |       |
   ----------+       +------------------------------+       +---------

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

   ------+                                                      +-----
         |------------------------------------------------------|
    LSR  |                               TE link                | LSR
         |------------------------------------------------------|
   ------+                                                      +-----
```

Figure 10: Extended Media Channel / TE Link / FA

### 4.3. Consideration of LSPs in Flexi-grid

The flexi-grid LSP is a control plane representation of a media channel. Since network media channels are media channels, an LSP may also be the control plane representation of a network media channel (without considering the adaptation functions). From a control plane perspective, the main difference (regardless of the actual effective frequency slot which may be dimensioned arbitrarily) is that the LSP that represents a network media channel also includes the endpoints (transceivers), including the cross-connects at the ingress and egress nodes. The ports towards the client can still be represented as interfaces from the control plane perspective.

Figure 11 shows an LSP routed between 3 nodes. The LSP is terminated before the optical matrix of the ingress and egress nodes and can represent a media channel. This case does not (and cannot) represent a network media channel because it does not include (and cannot include) the transceivers.

```
   ---------+       +--------------------------------+       +--------
            |       |                                |       |
     +------+       +------+                  +------+       +------+
     |      |       |      |   +----------+   |      |       |      |
   -o|      =========      o---|          |---o      =========      o-
     |      | Fiber |      |   | --\  /-- |   |      | Fiber |      |
   -o|>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>o-
     |      |       |      |   |    /\    |   |      |       |      |
   -o|      =========      o---***********|---o      =========      o-
     |Filter|       |Filter|   |          |   |Filter|       |Filter|
     |      |       |      |                  |      |       |      |
     +------+       +------+                  +------+       +------+
            |       |                                |       |
   ---------+       +--------------------------------+       +--------

          >>>>>>>>>>>>>>>>>>>>>>>>>>>> LSP >>>>>>>>>>>>>>>>>>>>>>>>
     -----+                  +---------------+                +-----
          |------------------|               |----------------|
     LSR  |       TE link    |     LSR       |      TE link   | LSR
          |------------------|               |----------------|
     -----+                  +---------------+                +-----
```

Figure 11: Flex-grid LSP Representing a Media Channel that Starts at the Filter of the Outgoing Interface of the Ingress LSR and ends at the Filter of the Incoming Interface of the Egress LSR

In Figure 12 a Network Media Channel is represented as terminated at the network side of the transceivers. This is commonly named an OTSi-trail connection.

```
   |--------------------- Network Media Channel ----------------------|

        +----------------------+           +----------------------+
        |                                  |                      |
        +------+        +------+           +------+        +------+
        |      | +----+ |      |           |      | +----+ |      |OTSi
    OTSi|      o-|    |-o      |  +-----+  |      o-|    |-o      |sink
    src |      | |    | |      ===+-+ +-+==|      | |    | |      O---|R
   T|***o******o********************************************************
        |      | |\  /| |         | | | |  |      | |\  /| |      |
        |      o-| \/ |-o      ===| | | |==|      o-| \/ |-o      |
        |      | | /\ | |      |  +-+ +-+  |      | | /\ | |      |
        |      o-|/  \|-o      |  |  \/ |  |      o-|/  \|-o      |
        |Filter| |    | |Filter|  |  /\ |  |Filter| |    | |Filter|
        +------+ |    | +------+  +-----+  +------+ |    | +------+
        |        |    |        |           |        |    |        |
        +----------------------+           +----------------------+
                                      LSP
   <------------------------------------------------------------------->

                                      LSP
    <------------------------------------------------------------------>
         +-----+                   +--------+                +-----+
    o--- |     |-------------------|        |----------------|     |---o
         | LSR |       TE link     |  LSR   |    TE link     | LSR |
         |     |-------------------|        |----------------|     |
         +-----+                   +--------+                +-----+
```

Figure 12: LSP Representing a Network Media Channel (OTSi Trail)

In a third case, a Network Media Channel is terminated on the Filter ports of the Ingress and Egress nodes. This is named in G.872 as OTSi Network Connection. As can be seen from the figures, there is no difference from a GMPLS modelling perspective between these cases, but they are shown as distinct examples to highlight the differences in the data plane.

```
     |---------------------  Network Media Channel --------------------|

     +------------------------+               +------------------------+
     +------+        +------+                 +------+          +------+
     |      | +----+ |      |                 |      | +----+ |      |
     |      o-|    |-o      |    +------+     |      o-|    |-o      |
     |      | |    | |      =====+-+  +-+=====|      | |    | |      |
   T-o******o********************************************************O-R
     |      | |\  /| |           | |  | |     |      | |\  /| |      |
     |      o-| \/ |-o      =====| |  | |=====|      o-| \/ |-o      |
     |      | | /\ | |      |    +-+  +-+     |      | | /\ | |      |
     |      o-|/  \|-o      |    |  \/  |     |      o-|/  \|-o      |
     |Filter| |    | |Filter|    |  /\  |     |Filter| |    | |Filter|
     +------+ |    | +------+    +------+     +------+ |    | +------+
     |        |    |        |                 |        |    |        |
     +----------------------+                 +----------------------+
     <----------------------------------------------------------------->
                                    LSP

                                     LSP
     <-------------------------------------------------------------->
      +-----+                    +--------+                   +-----+
   o--|     |--------------------|        |-------------------|     |--o
      | LSR |       TE link      |  LSR   |      TE link      | LSR |
      |     |--------------------|        |-------------------|     |
      +-----+                    +--------+                   +-----+
```

Figure 13: LSP Representing a Network Media Channel (OTSi Network Connection)

Applying the notion of hierarchy at the media layer, by using the LSP as an FA (i.e., by using hierarchical LSPs), the media channel created can support multiple (sub-)media channels.

```
+--------------+                      +--------------+
| Media Channel|          TE          | Media Channel|  Virtual TE
|              |         link         |              |    link
|    Matrix    |o- - - - - - - - - - o|    Matrix    |o- - - - - -
+--------------+                      +--------------+
               |     +---------+      |
               |     |  Media  |      |
               |o----| Channel |-----o|
                     |         |
                     | Matrix  |
                     +---------+
```

Figure 14: Topology View with TE Link / FA

Note that there is only one media layer switch matrix (one implementation is a FlexGrid ROADM) in SSON, while a signal layer LSP (Network Media Channel) is established mainly for the purpose of management and control of individual optical signals. Signal layer LSPs with the same attributes (such as source and destination) can be grouped into one media-layer LSP (media channel): this has advantages in spectral efficiency (reduce guard band between adjacent OChs in one FSC channel) and LSP management. However, assuming some network elements perform signal layer switching in an SSON, there must be enough guard band between adjacent OTSis in any media channel to compensate for the filter concatenation effects and other effects caused by signal layer switching elements. In such a situation, the separation of the signal layer from the media layer does not bring any benefit in spectral efficiency or in other aspects, but makes the network switch and control more complex. If two OTSis must be switched to different ports, it is better to carry them by diferent FSC channels, and the media layer switch is enough in this scenario.

As discussed in Section 3.2.5, a media channel may be constructed from a compsite of network media channels. This may be achieved in two ways using LSPs. These mechanisms may be compared to the techniques used in GMPLS to support inverse multiplexing in Time Division Multiplexing (TDM) networks and in OTN [RFC4606], [RFC6344], and [RFC7139].

o In the first case, a single LSP may be established in the control plane. The signaling messages include information for all of the component network media channels that make up the composite media channel.

o In the second case, each component network media channel is established using a separate control plane LSP, and these LSPs are associated within the control plane so that the end points may see them as a single media channel.

### 4.4. Control Plane Modeling of Network Elements

Optical transmitters and receivers may have different tunability constraints, and media channel matrixes may have switching restrictions. Additionally, a key feature of their implementation is their highly asymmetric switching capability which is described in detail in [RFC6163]. Media matrices include line side ports that are connected to DWDM links, and tributary side input/output ports that can be connected to transmitters/receivers.

A set of common constraints can be defined:

- Slot widths: The minimum and maximum slot width.

- Granularity: The optical hardware may not be able to select parameters with the lowest granularity (e.g., 6.25 GHz for nominal central frequencies or 12.5 GHz for slot width granularity).

- Available frequency ranges: The set or union of frequency ranges that have not been allocated (i.e., are available). The relative grouping and distribution of available frequency ranges in a fiber is usually referred to as "fragmentation".

- Available slot width ranges: The set or union of slot width ranges supported by media matrices. It includes the following information.

  * Slot width threshold: The minimum and maximum Slot Width supported by the media matrix. For example, the slot width could be from 50GHz to 200GHz.

  * Step granularity: The minimum step by which the optical filter bandwidth of the media matrix can be increased or decreased. This parameter is typically equal to slot width granularity (i.e., 12.5GHz) or integer multiples of 12.5GHz.

### 4.5. Media Layer Resource Allocation Considerations

A media channel has an associated effective frequency slot. From the perspective of network control and management, this effective slot is seen as the "usable" end-to-end frequency slot. The establishment of an LSP is related to the establishment of the media channel and the configuration of the effective frequency slot.

A "service request" is characterized (at a minimum) by its required effective slot width. This does not preclude that the request may add additional constraints such as also imposing the nominal central frequency. A given effective frequency slot may be requested for the media channel in the control plane LSP setup messages, and a specific frequency slot can be requested on any specific hop of the LSP setup. Regardless of the actual encoding, the LSP setup message specifies a minimum effective frequency slot width that needs to be fulfilled in order to successful establish the requsted LSP.

An effective frequency slot must equally be described in terms of a central nominal frequency and its slot width (in terms of usable spectrum of the effective frequency slot). That is, it must be possible to determine the end-to-end values of the n and m parameters. We refer to this by saying that the "effective frequency slot of the media channel/LSP must be valid".

In GMPLS the requested effective frequency slot is represented to the TSpec present in the RSVP-TE Path message, and the effective frequency slot is mapped to the FlowSpec carried in the RSVP-TE Resv message.

In GMPLS-controlled systems, the switched element corresponds to the 'label'. In flexi-grid where the switched element is a frequency slot, the label represents a frequency slot. In consequence, the label in flexi-grid conveys the necessary information to obtain the frequency slot characteristics (i.e, central frequency and slot width: the n and m parameters). The frequency slot is locally identified by the label.

The local frequency slot may change at each hop, given hardware constraints and capabilities (e.g., a given node might not support the finest granularity). This means that the values of n and m may change at each hop. As long as a given downstream node allocates enough optical spectrum, m can be different along the path. This covers the issue where media matrices can have different slot width granularities. Such variations in the local value of m will appear in the allocated label that encodes the frequency slot as well as the in the FlowSpec that describes the flow.

Different operational modes can be considered. For Routing and Spectrum Assignment (RSA) with explicit label control, and for Routing and Distributed Spectrum Assignment (R+DSA), the GMPLS signaling procedures are similar to those described in section 4.1.3 of [RFC6163] for Routing and Wavelength Assignment (RWA) and for Routing and Distributed Wavelength Assignment (R+DWA). The main difference is that the label set specifies the available nominal central frequencies that meet the slot width requirements of the LSP.

The intermediate nodes use the control plane to collect the acceptable central frequencies that meet the slot width requirement hop by hop. The tail-end node also needs to know the slot width of an LSP to assign the proper frequency resource. Except for identifying the resource (i.e., fixed wavelength for WSON, and frequency resource for flexible grids), the other signaling requirements (e.g., unidirectional or bidirectional, with or without converters) are the same as for WSON as described in section 6.1 of [RFC6163].

Regarding how a GMPLS control plane can assign n and m hop-by-hop along the path of an LSP, different cases can apply:

a. n and m can both change. It is the effective frequency slot that matters, it needs to remain valid along the path.

b. m can change, but n needs to remain the same along the path. This ensures that the nominal central frequency stays the same, but the width of the slot can vary along the path. Again, the important thing is that the effective frequency slot remains valid and satisfies the requested parameters along the whole path of the LSP.

c. n and m need to be unchanging along the path. This ensures that the frequency slot is well-known end-to-end, and is a simple way to ensure that the effective frequency slot remains valid for the whole LSP.

d. n can change, but m needs to remain the same along the path. This ensures that the effective frequency slot remains valid, but allows the frequency slot to be moved within the spectrum from hop to hop.

The selection of a path that ensures n and m continuity can be delegated to a dedicated entity such as a Path Computation Element (PCE). Any constraint (including frequency slot and width granularities) can be taken into account during path computation. Alternatively, A PCE can compute a path leaving the actual frequency slot assignment to be done, for example, with a distributed (signaling) procedure:

- Each downstream node ensures that m is >= requested_m.

- A downstream node cannot foresee what an upstream node will allocate. A way to ensure that the effective frequency slot is valid along the length of the LSP is to ensure that the same value of n is allocated at each hop. By forcing the same value of n we avoid cases where the effective frequency slot of the media channel is invalid (that is, the resulting frequency slot cannot be described by its n and m parameters).

- This may be too restrictive, since a node (or even a centralized/ combined RSA entity) may be able to ensure that the resulting end-to-end effective frequency slot is valid even if n varies locally. That means, the effective frequency slot that characterizes the media channel from end to end is consistent and is determined by its n and m values, but that the effective frequency slot and those values are logical (i.e., do not map direct to the physically assigned spectrum) in the sense that they are the result of the intersection of locally-assigned frequency slots applicable at local components (such as filters) each of which may have assigned different frequency slots.

For Figure 15 the effective slot is made valid by ensuring that the minimum m is greater than the requested m. The effective slot (intersection) is the lowest m (bottleneck).

For Figure 16 the effective slot is made valid by ensuring that it is valid at each hop in the upstream direction. The intersection needs to be computed because invalid slots could result otherwise.

```
                            C                B                A
             |Path(m_req)   |                ^                |
             |--------->    |                #                |
             |              |                #                ^
            -^--------------^----------------#----------------#--
   Effective #              #                #                #
   FS n, m   # . . . . . . .#. . . . . . . . # . . . . . . . .# <-fixed
             #              #                #                #   n
            -v--------------v----------------#----------------#---
             |              |                #                v
             |              |                #        Resv    |
             |              |                v      <------   |
             |              |                |FlowSpec(n, m_a)|
             |              |       <--------|                |
             |              |  FlowSpec (n,  |
                  <--------|      min(m_a, m_b))
             FlowSpec (n,   |
               min(m_a, m_b, m_c))

               m_a, m_b, m_c: Selected frequency slot widths
```

Figure 15: Distributed Allocation with Different m and Same n

```
                           C                B                 A
             |Path(m_req)  ^                |                 |
             |--------->   #                |                 |
             |             #                ^                 ^
            -^-------------#----------------#-----------------#---------
   Effective #             #                #                 #
   FS n, m   #             #                #                 #
             #             #                #                 #
            -v-------------v----------------#-----------------#---------
             |             |                #                 v
             |             |                #           Resv  |
             |             |                v         <------ |
             |             |                |FlowSpec(n_a, m_a)
             |             |       <--------|                 |
             |             |  FlowSpec (FSb [intersect] FSa)
                  <--------|
            FlowSpec ([intersect] FSa,FSb,FSc)

             n_a: Selected nominal central frequencyfr by node A
             m_a: Selected frequency slot widths by node A
             FSa, FSb, FSc: Frequency slot at each hop A, B, C
```

Figure 16: Distributed Allocation with Different m and Different n

Note, when a media channel is bound to one OTSi (i.e., is a network media channel), the effective FS must be the one of the OTSi. The media channel setup by the LSP may contain the effective FS of the network media channel effective FS. This is an endpoint property: the egress and ingress have to constrain the Effective FS to be the OTSi Effective FS.

## 4.6. Neighbor Discovery and Link Property Correlation

There are potential interworking problems between fixed-grid DWDM and flexi-grid DWDM nodes. Additionally, even two flexi-grid nodes may have different grid properties, leading to link property conflict with resulting limited interworking.

Devices or applications that make use of the flexi-grid might not be able to support every possible slot width. In other words, different applications may be defined where each supports a different grid granularity. In this case the link between two optical nodes with different grid granularities must be configured to align with the larger of both granularities. Furthermore, different nodes may have different slot-width tuning ranges.

In summary, in a DWDM Link between two nodes, at least the following properties need to be negotiated:

- o Grid capability (channel spacing) - Between fixed-grid and flexi-grid nodes.
- o Grid granularity - Between two flexi-grid nodes.
- o Slot width tuning range - Between two flexi-grid nodes.

### 4.7. Path Computation / Routing and Spectrum Assignment (RSA)

In WSON, if there is no (available) wavelength converter in an optical network, an LSP is subject to the "wavelength continuity constraint" (see section 4 of [RFC6163]). Similarly in flexi-grid, if the capability to shift or convert an allocated frequency slot is absent, the LSP is subject to the "Spectrum Continuity Constraint".

Because of the limited availability of wavelength/spectrum converters (in what is called a "sparse translucent optical network") the wavelength/spectrum continuity constraint always has to be considered. When available, information regarding spectrum conversion capabilities at the optical nodes may be used by RSA mechanisms.

The RSA process determines a route and frequency slot for an LSP. Hence, when a route is computed the spectrum assignment process (SA) determines the central frequency and slot width based on the slot width and available central frequencies information of the transmitter and receiver, and utilizing the available frequency ranges information and available slot width ranges of the links that the route traverses.

#### 4.7.1. Architectural Approaches to RSA

Similar to RWA for fixed grids [RFC6163], different ways of performing RSA in conjunction with the control plane can be considered. The approaches included in this document are provided for reference purposes only: other possible options could also be deployed.

Note that all of these models allow the concept of a composite media channel supported by a single control plane LSP or by a set of associated LSPs.

#### 4.7.1.1. Combined RSA (R&SA)

In this case, a computation entity performs both routing and frequency slot assignment. The computation entity needs access to detailed network information, e.g., the connectivity topology of the nodes and links, the available frequency ranges on each link, the node capabilities, etc.

The computation entity could reside on a dedicated PCE server, in the provisioning application that requests the service, or on the ingress node.

#### 4.7.1.2. Separated RSA (R+SA)

In this case, routing computation and frequency slot assignment are performed by different entities. The first entity computes the routes and provides them to the second entity. The second entity assigns the frequency slot.

The first entity needs the connectivity topology to compute the proper routes. The second entity needs information about the available frequency ranges of the links and the capabilities of the nodes in order to assign the spectrum.

#### 4.7.1.3. Routing and Distributed SA (R+DSA)

In this case an entity computes the route, but the frequency slot assignment is performed hop-by-hop in a distributed way along the route. The available central frequencies which meet the spectrum continuity constraint need to be collected hop-by-hop along the route. This procedure can be implemented by the GMPLS signaling protocol.

### 4.8. Routing and Topology Dissemination

In the case of the combined RSA architecture, the computation entity needs the detailed network information, i.e., connectivity topology, node capabilities, and available frequency ranges of the links. Route computation is performed based on the connectivity topology and node capabilities, while spectrum assignment is performed based on the available frequency ranges of the links. The computation entity may get the detailed network information via the GMPLS routing protocol.

For WSON, the connectivity topology and node capabilities can be advertised by the GMPLS routing protocol (refer to section 6.2 of [RFC6163]. Except for wavelength-specific availability information, the information for flexi-grid is the same as for WSON and can equally be distributed by the GMPLS routing protocol.

This section analyses the necessary changes on link information brought by flexible grids.

#### 4.8.1. Available Frequency Ranges/Slots of DWDM Links

In the case of flexible grids, channel central frequencies span from 193.1 THz towards both ends of the C band spectrum with 6.25 GHz granularity. Different LSPs could make use of different slot widths on the same link. Hence, the available frequency ranges need to be advertised.

#### 4.8.2. Available Slot Width Ranges of DWDM Links

The available slot width ranges need to be advertised in combination with the available frequency ranges, in order that the computing entity can verify whether an LSP with a given slot width can be set up or not. This is constrained by the available slot width ranges of the media matrix. Depending on the availability of the slot width ranges, it is possible to allocate more spectrum than strictly needed by the LSP.

#### 4.8.3. Spectrum Management

The total available spectrum on a fiber can be described as a resource that can be partitioned. For example, a part of the spectrum could be assigned to a third party to manage, or parts of the spectrum could be assigned by the operator for different classes of traffic. This partitioning creates the impression that spectrum is a hierarchy in view of Management and Control Plane: each partition could be itself be partitioned. However, the hierarchy is created purely within a management system: it defines a hierarchy of access or management rights, but there is no corresponding resource hierarchy within the fiber.

The end of fiber is a link end and presents a fiber port which represents all of spectrum available on the fiber. Each spectrum allocation appears as Link Channel Port (i.e., frequency slot port) within fiber. Thus, while there is a hierarchy of ownership (the Link Channel Port and corresponding LSP are located on a fiber and so associated with a fiber port) there is no continued nesting hierarchy of frequency slots within larger frequency slots. In its way, this mirrors the fixed grid behavior where a wavelength is associated with a port/fiber, but cannot be subdivided even though it is a partition of the total spectrum available on the fiber.

### 4.8.4. Information Model

This section defines an information model to describe the data that represents the capabilities and resources available in an flexi-grid network. It is not a data model and is not intended to limit any protocol solution such as an encoding for an IGP. For example, information required for routing/path selection may be the set of available nominal central frequencies from which a frequency slot of the required width can be allocated. A convenient encoding for this information is for further study in an IGP encoding document.

Fixed DWDM grids can also be described via suitable choices of slots in a flexible DWDM grid. However, devices or applications that make use of the flexible grid may not be capable of supporting every possible slot width or central frequency position. Thus, the information model needs to enable:

exchange of information to enable RSA in a flexi-grid network

representation of a fixed grid device participating in a flexi-grid network

full interworking of fixed and flexible grid devices within the same network

interworking of flexgrid devices with different capabilities.

The information model is represented using Routing Backus-Naur Format (RBNF) as defined in [RFC5511].

```
   <Available Spectrum> ::=
     <Available Frequency Range-List>
     <Available NCFs>
     <Available Slot Widths>

   where

   <Available Frequency Range-List> ::=
     <Available Frequency Range> [<Available Frequency Range-List>]

   <Available Frequency Range> ::=
     ( <Start NCF> <End NCF> ) |
     <FS defined by (n, m) containing  contiguous available NCFs>

   and

   <Available NCFs> ::=
     <Available NCF Granularity> [<Offset>]
     -- Subset of supported n values given by p x n + q
     -- where p is a positive integer
     -- and q (offset) belongs to 0,..,p-1.

   and

   <Available Slot Widths> ::=
     <Available Slot Width Granularity>
     <Min Slot Width>
     -- given by j x 12.5GHz, with j a positive integer
     <Max Slot Width>
     -- given by k x 12.5GHz, with k a positive integer (k >= j)
```

Figure 17: Routing Information Model

# 5. Control Plane Requirements

The control of a flexi-grid networks places additional requirements on the GMPLS protocols. This section summarizes those requirements for signaling and routing.

## 5.1. Support for Media Channels

The control plane SHALL be able to support Media Channels, characterized by a single frequency slot. The representation of the Media Channel in the GMPLS control plane is the so-called flexi-grid LSP. Since network media channels are media channels, an LSP may also be the control plane representation of a network media channel.

Consequently, the control plane will also be able to support Network Media Channels.

#### 5.1.1. Signaling

The signaling procedure SHALL be able to configure the nominal central frequency (n) of a flexi-grid LSP.

The signaling procedure SHALL allow a flexible range of values for the frequency slot width (m) parameter. Specifically, the control plane SHALL allow setting up a media channel with frequency slot width (m) ranging from a minimum of m=1 (12.5GHz) to a maximum of the entire C-band (the wavelength range 1530 nm to 1565 nm, which corresponds to the amplification range of erbium doped fiber amplifiers) with a slot width granularity of 12.5GHz.

The signaling procedure SHALL be able to configure the minimum width (m) of a flexi-grid LSP. In addition, the signaling procedure SHALL be able to configure local frequency slots.

The control plane architecture SHOULD allow for the support of L-band (the wavelength range 1565 nm to 1625 nm) and S-band (the wavelength range 1460 nm to 1530 nm).

The signalling process SHALL be able to collect the local frequency slot assigned at each link along the path.

The signaling procedures SHALL support all of the RSA architectural models (R&SA, R+SA, and R+DSA) within a single set of protocol objects although some objects may only be applicable within one of the models.

#### 5.1.2. Routing

The routing protocol will support all functions as described in [RFC4202] and extend them to a flexi-grid data plane.

The routing protocol SHALL distribute sufficient information to compute paths to enable the signaling procedure to establish LSPs as described in the previous sections. This includes, at a minimum the data described by the Information Model in Figure 17.

The routing protocol SHALL update its advertisements of available resources and capabilities as the usage of resources in the network varies with the establishment or tear-down of LSPs. These updates SHOULD be amenable to damping and thresholds as in other traffic engineering routing advertisements.

The routing protocol SHALL support all of the RSA architectural models (R&SA, R+SA, and R+DSA) without any configuration or change of behavior. Thus, the routing protocols SHALL be agnostic to the computation and signaling model that is in use.

## 5.2. Support for Media Channel Resizing

The signaling procedures SHALL allow resizing (grow or shrink) the frequency slot width of a media channel/network media channel. The resizing MAY imply resizing the local frequency slots along the path of the flexi-grid LSP.

The routing protocol SHALL update its advertisements of available resources and capabilities as the usage of resources in the network varies with the resizing of LSP. These updates SHOULD be amenable to damping and thresholds as in other traffic engineering routing advertisements.

## 5.3. Support for Logical Associations of Multiple Media Channels

A set of media channels can be used to transport signals that have a logical association between them. The control plane architecture SHOULD allow multiple media channels to be logically associated. The control plane SHOULD allow the co-routing of a set of media channels that are logically associated.

## 5.4. Support for Composite Media Channels

As described in Section 3.2.5 and Section 4.3, a media channel may be composed of multiple network media channels.

The signaling procedures SHOULD include support for signaling a single control plane LSP that includes information about multiple network media channels that will comprise the single compound media channel.

The signaling procedures SHOULD include a mechanism to associate separately signaled control plane LSPs so that the end points may correlate them into a single compound media channel.

The signaling procedures MAY include a mechanism to dynamically vary the composition of a composite media channel by allowing network media channels to be added to or removed from the whole.

The routing protocols MUST provide sufficient information for the computation of paths and slots for composite media channels using any of the three RSA architectural models (R&SA, R+SA, and R+DSA).

### 5.5. Support for Neighbor Discovery and Link Property Correlation

The control plane MAY include support for neighbor discovery such that an flexi-grid network can be constructed in a "plug-and-play" manner. Note, however, that in common operational practice validation processes are used rather than automatic discovery.

The control plane SHOULD allow the nodes at opposite ends of a link to correlate the properties that they will apply to the link. Such correlation SHOULD include at least the identities of the node and the identities they apply to the link. Other properties such as the link characteristics described for the routing information model in Figure 17 SHOULD also be correlated.

Such neighbor discovery and link property correlation, if provided, MUST be able to operate in both an out-of-band and an out-of-fiber control channel.

## 6. IANA Considerations

This framework document makes no requests for IANA action.

## 7. Security Considerations

The control plane and data plane aspects of a flexi-grid system are fundamentally the same as a fixed grid system and there is no substantial reason to expect the security considerations to be any different.

A good overview of the security considerations for a GMPLS-based control plane can be found in [RFC5920].

[RFC6163] includes a section describing security considerations for WSON, and it is reasonable to infer that these considerations apply and may be exacerbated in a flexi-grid SSON system. In particular, the detailed and granular information describing a flexi- grid network and the capabilities of nodes in that network could put stress on the routing protocol or the out-of-band control channel used by the protocol. An attacker might be able to cause small variations in the use of the network or the available resources (perhaps by modifying the environment of a fiber) and so trigger the routing protocol to make new flooding announcements. This situation is explicitly mitigated in the requirements for the routing protocol extensions where it is noted that the protocol must include damping and configurable thresholds as already exist in the core GMPLS routing protocols.

## 8. Manageability Considerations

GMPLS systems already contain a number of management tools.

- o MIB modules exist to model the control plane protocols and the network elements [RFC4802], [RFC4803], and there is early work to provide similar access through YANG. The features described in these models are currently designed to represent fixed-label technologies such as optical networks using the fixed grid: extensions may be needed in order to represent bandwidth, frequency slots, and effective frequency slots in flexi- grid networks.

- o There are protocol extensions within GMPLS signaling to allow control plane systems to report the presence of faults that affect LSPs [RFC4783], although it must be carefully noted that these mechanisms do not constitute an alarm mechanism that could be used to rapidly propagate information about faults in a way that would allow the data plane to perform protection switching. These mechanisms could easily be enhanced with the addition of technology-specific reasons codes if any are needed.

- o The GMPLS protocols, themselves, already include fault detection and recovery mechanisms (such as the PathErr and Notify messages in RSVP-TE signaling as used by GMPLS [RFC3473]. It is not anticipated that these mechanisms will need enhancement to support flexi-grid although additional reason codes may be needed to describe technology-specific error cases.

- o [RFC7260] describes a framework for the control and configuration of data plane Operations, Administration, and Management (OAM). It would not be appropriate for the IETF to define or describe data plane OAM for optical systems, but the framework described in RFC 7260 could be used (with minor protocol extensions) to enable data plane OAM that has been defined by the originators of the flexi-grid data plane technology (the ITU-T).

- o The Link Management Protocol [RFC4204] is designed to allow the two ends of a network link to coordinate and confirm the configuration and capabilities that they will apply to the link. This protocol is particularly applicable to optical links where the characteristics of the network devices may considerably affect how the link is used and where misconfiguration of mis-fibering could make physical interoperability impossible. LMP could easily be extended to collect and report information between the end points of links in a flexi-grid network.

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

draft-ietf-ccamp-flexible-grid-ospf-ext-09.txt

## Abstract

The International Telecommunication Union Telecommunication Standardization Sector (ITU-T) has extended its Recommendations G.694.1 and G.872 to include a new Dense Wavelength Division Multiplexing (DWDM) grid by defining a set of nominal central frequencies, channel spacings, and the concept of the "frequency slot". Corresponding techniques for data-plane connections are known as flexi-grid.

Based on the characteristics of flexi-grid defined in G.694.1, RFC 7698 and 7699, this document 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 ranges from 12.5 GHz, 25 GHz, 50 GHz, 100 GHz to 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.

[RFC7698] 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 [RFC7688] defines the requirements and OSPF-TE extensions in support of GMPLS control of a WSON.

[RFC7792] describes requirements and protocol extensions for signaling to set up LSPs in networks that support the flexi-grid, and this document complements [RFC7792] by describing the requirement and extensions for OSPF-TE routing in a flexi-grid network.

This document complements 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 [RFC7698] 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 [RFC7698].

A flexi-grid LSP occupies a specific frequency slot, i.e., a frequency range. The process of computing a route and the allocation of a frequency slot is referred to as RSA (Routing and Spectrum Assignment). [RFC7698] 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 [RFC7698].

The remainder of this section states the additional extensions on the routing protocols in a flexi-grid 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 do not overlap with each other. However, the border frequencies of two frequency slots may be the same frequency, i.e., the upper bound of a frequency slot and the lower bound of the directly adjacent frequency slot are the same.

```
                      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 unavailable to other flexi-grid LSPs. Available central frequencies are advertised for m=1, which means that for an available central frequency n, the frequency slot from central frequency n-1 to central frequency n+1 is available.

Hence, in order to clearly show which LSPs can be supported and what frequency slots are unavailable, the available frequency ranges are advertised by the routing protocol for the flexi-grid DWDM links. A set of non-overlapping available frequency ranges are disseminated in order to allow efficient resource management of flexi-grid DWDM links and RSA procedures which are described in Section 4.8 of [RFC7698].

### 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 Channel Spacing (C.S.): as defined in [RFC7699] 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 conveys 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 are advertised for a flexi-grid DWDM link instead of the specific "wavelengths" points that are sufficient for a fixed-grid link. Moreover, this advertisement is represented by the combination of Central Frequency Granularity and Slot Width Granularity.

## 4. Extensions

As described in [RFC7698], 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 using opaque LSAs [RFC3630] in the case of OSPF-TE [RFC4203] (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 |

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 is interpreted as in [RFC4203] with the optional inclusion of one or more Switching Capability Specific Information sub-TLVs.

As the "Max LSP Bandwidth at priority x" (x from 0 to 7) fields in the generic part of the Interface Switching Capability Descriptor [RFC4203] are not meaningful for flexi-grid DWDM links, the values of these fields MUST be set to zero and MUST be ignored. The Switching Capability Specific Information (SCSI) as defined below provides the corresponding information for flexi-grid DWDM links.

### 4.1.1. Switching Capability Specific Information (SCSI)

The technology specific part of the Flexi-grid ISCD includes 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 k  |   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, in octets.

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 is set (1) corresponding to each priority represented in the sub-TLV, and clear (0) for each priority not represented in the sub-TLV. At least one priority level MUST be advertised. If only one priority level is advertised, it MUST be at priority level 0.

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

Max Slot Width at priority k(16 bits): This field indicates maximal frequency slot width supported at a particular priority level, up to 8. This field is 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 be present for priority levels that are 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 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. This field MUST be set to 0 and MUST be ignored on receipt.

C.S. (4 bits): As defined in [RFC7699] and it is currently set to 5.

Starting n (16 bits): as defined in [RFC7699] 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; and when setting to 0, it means the corresponding central frequency is unavailable. 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): Padded 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.

An example is provided in section 4.1.2.

#### 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 k  |   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. It is observed from the bit map that n = -1 to 7 can be used to set up LSPs. Note other starting n values can be chosen to represent the bit map, 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 k  |   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 flexi-grid LSP set up.

If a LSP with slot width m equals 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 k  |   Unreserved padding          ~
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |   5   |       Starting n (-1)         | No. of Effec. Bits(9)|
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |0|0|1|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 field 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 [RFC7699] 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 | [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.

Upon approval of this document, IANA will create and maintain a new sub-registry, the "Types for sub-TLVs of Flexi-Grid-LSC 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 7942. 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 7942, "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 [RFC7699] 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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## 10. References

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Expires: May 19, 2016 November 20, 2015

# RSVP-TE Signaling Extensions in support of Flexi-grid DWDM networks

draft-ietf-ccamp-flexible-grid-rsvp-te-ext-05.txt

Abstract

This memo describes the extensions to the Resource reSerVation Protocol Traffic Engineering (RSVP-TE) signaling protocol to support Label Switched Paths (LSPs) in a GMPLS-controlled network that includes devices using the flexible optical grid.

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 that utilize WDM transmission. The channel spacing is the frequency spacing between two allowed nominal central frequencies. All of the wavelengths on a fiber use different central frequencies and occupy a designated range 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", 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 introduced in [G.694.1] to define a flexible grid.

[FLEX-FWK] defines a framework and the associated control plane requirements for the Generalized Multi-Protocol Label Switching (GMPLS) [RFC3945] 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-SIG] describes the requirements and protocol extensions for signaling to set up Label Switched Paths (LSPs) in WSONs.

This document describes the additional requirements and protocol extensions to Resource reSerVation Protocol-Traffic Engineering (RSVP-TE) [RFC3473] to set up LSPs in networks that support the flexi-grid.

## 2. Terminology

For terminology related to flexi-grid, please refer to [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 Flexible Grid Signaling

The architecture for establishing LSPs in a flexi-grid network is described in [FLEX-FWK].

An optical spectrum 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 Routing and

Spectrum Assignment (RSA). [FLEX-FWK] describes three architectural approaches to RSA: combined RSA, separated RSA, and distributed SA. The first two approaches are referred to as "centralized SA" because both routing and spectrum (frequency slot) assignment are performed by a centralized entity before the signaling procedure.

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

If the capability to switch or convert the whole optical spectrum allocated to an optical spectrum LSP is not available at some 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 requirements for signaling in a flexi-grid network.

## 3.1. Slot Width

The slot width is an end-to-end parameter representing how much frequency resource is requested for a flexi-grid LSP. It is the equivalent of optical bandwidth, although the amount of bandwidth associated with a slot width will depend on the signal encoding.

Different LSPs may request different amounts of frequency resource in flexible grid networks, so the slot width MUST be carried in the signaling message during LSP establishment. This enables the nodes along the LSP to know how much frequency resource has been requested (in a Path message) and has been allocated (by a Resv message) for the LSP.

## 3.2. Frequency Slot

The frequency slot information identifies which part of the frequency spectrum is allocated on each link for an LSP in a flexi-grid network.

This information MUST be present in a Resv message to indicate, hop-by-hop, the central frequency of the allocated resource. In combination with the slot width indicated in a Resv message (see Section 3.1) the central frequency carried in a Resv message identifies the resources reserved for the LSP (known as the frequency slot).

The frequency slot can be represented by the two parameters as follows:

```
Frequency slot = [(central frequency) - (slot width)/2] ~
                 [(central frequency) + (slot width)/2]
```

As is common with other resource identifiers (i.e., labels) in GMPLS signaling, it must be possible for the head-end node when sending a Path message to suggest or require the central frequency to be used for the LSP. Furthermore, for bidirectional LSPs, the Path message MUST be able to specify the central frequency to be used for reverse direction traffic.

As described in [G.694.1], the allowed frequency slots for the flexible DWDM grid have a nominal central frequency (in THz) defined by:

193.1 + n * 0.00625

where n is zero or a positive or negative integer.

The slot width (in GHz) is defined as:

12.5 * m

where m is a positive integer.

It is possible that an implementation supports only a subset of the possible slot widths and central frequencies. For example, an implementation could be built where the nominal central frequency granularity is 12.5 GHz (by only allowing values of n that are even) and that only supports slot widths as a multiple of 25 GHz (by only allowing values of m that are even).

Further details can be found in [FLEX-FWK].

## 4. Protocol Extensions

This section defines the extensions to RSVP-TE signaling for GMPLS [RFC3473] to support flexible grid networks.

### 4.1. Traffic Parameters

In RSVP-TE, the SENDER_TSPEC object in the Path message indicates the requested resource reservation. The FLOWSPEC object in the Resv message indicates the actual resource reservation.

As described in Section 3.1, the slot width represents how much frequency resource is requested for a flexi-grid LSP. That is, it describes the end-to-end traffic profile of the LSP. Therefore, the traffic parameters for a flexi-grid LSP encode the slot width.

This document defines new C-Types for the SENDER_TSPEC and FLOWSPEC objects to carry Spectrum Switched Optical Network (SSON) traffic parameters:

SSON SENDER_TSPEC: Class = 12, C-Type = TBD1.

SSON FLOWSPEC: Class = 9, C-Type = TBD2.

The SSON traffic parameters carried in both objects MUST have the same format as shown in Figure 1.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              m                |          Reserved             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 1: The SSON Traffic Parameters

m (16 bits): a positive integer and the slot width is specified by m*12.5 GHz.

The Reserved bits MUST be set to zero and ignored upon receipt.

#### 4.1.1. Applicability to Fixed Grid Networks

Note that the slot width (i.e., traffic parameters) of a fixed grid defined in [G.694.1] can also be specified by using the SSON traffic parameters. The fixed grid channel spacings (12.5 GHz, 25 GHz, 50 GHz, 100 GHz and integer multiples of 100 GHz) are also the multiples of 12.5 GHz, so the m parameter can be used to represent these slot widths.

Therefore, it is possible to consider using the new traffic parameter object types in common signaling messages for flexi-grid and legacy DWDM networks.

### 4.2. Generalized Label

In the case of a flexible grid network, the labels that have been requested or allocated as signaled in the RSVP-TE objects are encoded as described in [FLEX-LBL]. This new label encoding can appear in any RSVP-TE object or sub-object that can carry a label.

As noted in Section 4.2 of [FLEX-LBL], the m parameter forms part of the label as well as part of the traffic parameters.

As described in Section 4.3 of [FLEX-LBL], a "compound label", constructed from a concatenation of the flexi-grid LABELs, is used when signaling an LSP that uses multiple flexi-grid slots.

## 4.3. Signaling Procedures

There are no differences between the signaling procedure described for LSP control in [FLEX-FWK] and those required for use in a fixed-grid network [WSON-SIG]. Obviously, the TSpec, FlowSpec, and label formats described in Sections 4.1 and 4.2 are used. The signaling procedures for distributed SA and centralized SA can be applied.

# 5. IANA Considerations

## 5.1. RSVP Objects Class Types

This document introduces two new Class Types for existing RSVP objects. IANA is requested to make allocations from the "Resource ReSerVation Protocol (RSVP) Parameters" registry using the "Class Names, Class Numbers, and Class Types" sub-registry.

| Class Number | Class Name | Reference |
|---|---|---|
| 9 | FLOWSPEC | [RFC2205] |
| | Class Type (C-Type): | |
| | (TBD2) SSON FLOWSPEC | [This.I-D] |

| Class Number | Class Name | Reference |
|---|---|---|
| 12 | SENDER_TSPEC | [RFC2205] |
| | Class Type (C-Type): | |
| | (TBD1) SSON SENDER_TSPEC | [This.I-D] |

IANA is requested to assign the same value for TBD1 and TBD2, and a value of 8 is suggested.

## 6. Manageability Considerations

This document makes minor modifications to GMPLS signaling, but does not change the manageability considerations for such networks. Clearly, protocol analysis tools and other diagnostic aids (including logging systems and MIB modules) will need to be enhanced to support the new traffic parameters and label formats.

## 7. Implementation Status

[RFC Editor Note: Please remove this entire seciton 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."

### 7.1. Centre Tecnologic de Telecomunicacions de Catalunya (CTTC)

Organization Responsible for the Implementation:
 Centre Tecnologic de Telecomunicacions de Catalunya (CTTC)
 Optical Networks and Systems Department

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 Tspec, FlowSpec, and label formats as described version 03 of this document. Label format support extends to the following RSVP-TE objects and sub-objects:

- Generalized Label Object
- Suggested Label Object
- Upstream Label Object
- ERO Label Subobjects

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

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Interoperability:
No report.

## 8. Acknowledgments

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

## 9. Security Considerations

This document introduces no new security considerations to [RFC3473].

See also [RFC5920] for a discussion of security considerations for GMPLS signaling.

## 10. References

### 10.1. Normative References

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[RFC Editor Note: This reference can be removed when Section 7 is removed]

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10 September 2015

# Generalized Labels for the Flexi-Grid in Lambda Switch Capable (LSC) Label Switching Routers

draft-ietf-ccamp-flexigrid-lambda-label-05.txt

## Abstract

GMPLS supports the description of optical switching by identifying entries in fixed lists of switchable wavelengths (called grids) through the encoding of lambda labels. Work within the ITU-T Study Group 15 has defined a finer granularity grid, and the facility to flexibly select different widths of spectrum from the grid. This document defines a new GMPLS lambda label format to support this flexi-grid.

This document updates RFC 3471 and RFC 6205 by introducing a new label format.

## Status of this Memo

Copyright Notice



Table of Contents

## 1. Introduction

As described in [RFC3945], GMPLS extends MPLS from supporting only Packet Switch Capable (PSC) interfaces and switching, to also support four new classes of interfaces and switching that include Lambda Switch Capable (LSC).

A functional description of the extensions to MPLS signaling needed to support this new class of interface and switching is provided in [RFC3471].

Section 3.2.1.1 of [RFC3471] states that wavelength labels "only have significance between two neighbors": global wavelength semantics are not considered. [RFC6205] defines a standard lambda label format that has a global semantic and which is compliant with both the Dense Wavelength Division Multiplexing (DWDM) grid [G.694.1] and the Coarse Wavelength Division Multiplexing (CWDM) grid [G.694.2]. The terms DWDM and CWDM are defined in [G.671].

A flexible grid network selects its data channels as arbitrarily assigned pieces of the spectrum. Mixed bitrate transmission systems can allocate their channels with different spectral bandwidths so that the channels can be optimized for the bandwidth requirements of the particular bit rate and modulation scheme of the individual channels. This technique is regarded as a promising way to improve the network utilization efficiency and fundamentally reduce the cost of the core network.

The "flexi-grid" has been developed within the ITU-T Study Group 15 to allow selection and switching of pieces of the optical spectrum chosen flexibly from a fine granularity grid of wavelengths with variable spectral bandwidth [G.694.1].

[RFC3471] defines several basic label types including the lambda label. [RFC3471] states that wavelength labels "only have significance between two neighbors" (Section 3.2.1.1); global wavelength semantics are not considered. In order to facilitate interoperability in a network composed of LSC equipment, [RFC6205] defines a standard lambda label format and is designated an update of RFC 3471.

This document continues the theme of defining global semantics for the wavelength label by adding support for the flexi-grid. Thus, this document updates [RFC6205] and [RFC3471].

This document relies on [G.694.1] for the definition of the optical data plane and does not make any updates to the work of the ITU-T.

### 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. Overview of Flexi-Grid

[G.694.1] defines DWDM fixed grids. The latest version of that document extends the DWDM fixed grids to add support for flexible grids. The basis of the work is to allow a data channel to be formed from an abstract grid anchored at 193.1 THz and selected on a channel spacing of 6.25 GHz with a variable slot width measured in units of 12.5 GHz. Individual allocations may be made on this basis from anywhere in the spectrum, subject to allocations not overlapping.

[G.694.1] provides clear guidance on the support of flexible grid by implementations in Section 2 of Appendix I:

> The flexible DWDM grid defined in clause 7 has a nominal 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 have to be capable of supporting 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.
>
> 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).

Some additional background on the use of GMPLS for flexible grids can be found in [FLEXFWRK].

### 2.1. Composite Labels

It is possible to construct an end-to-end connection as a composite of more than one flexi-grid slot. The mechanism used in GMPLS is similar to that used to support inverse multiplexing familiar in time-division multiplexing (TDM) and optical transport networks (OTN). The slots in the set could potentially be contiguous or non-contiguous (only as allowed by the definitions of the data plane) and could be signaled as a single LSP or constructed from a group of LSPs. For more details, refer to Section 4.3.

How the signal is carried across such groups of channels is out of scope for this document.

# 3. Fixed Grid Lambda Label Encoding

[RFC6205] defines an encoding for a global semantic for a DWDM label based on four fields:

- Grid: used to select which grid the lambda is selected from. Values defined in [RFC6205] identify DWDM [G.694.1] and CWDM [G.694.2].

- C.S. (Channel Spacing): used to indicate the channel spacing. [RFC6205] defines values to represent spacing of 100, 50, 25 and 12.5 GHz.

- Identifier: a local-scoped integer used to distinguish different lasers (in one node) when they can transmit the same frequency lambda.

- n: a two's-complement integer to take a positive, negative, or zero value. This value is used to compute the frequency as defined in [RFC6205] and based on [G.694.1]. The use of n is repeated here for ease of reading the rest of this document: in case of discrepancy, the definition in [RFC6205] is normative.

  Frequency (THz) = 193.1 THz + n * frequency granularity (THz)

  where the nominal central frequency granularity for the flexible grid is 0.00625 THz

# 4. Flexi-Grid Label Format and Values

## 4.1 Flexi-Grid Label Encoding

This document defines a generalized label encoding for use in flexi-grid systems. As with the other GMPLS lambda label formats defined in [RFC3471] and [RFC6205], the use of this label format is known a priori. That is, since the interpretation of all lambda labels is determined hop-by-hop, the use of this label format requires that all nodes on the path expect to use this label format.

For convenience, however, the label format is modeled on the fixed grid label defined in [RFC6205] and briefly described in Section 3.

Figure 1 shows the format of the Flexi-Grid Label. It is a 64 bit label.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Grid | C.S.  |    Identifier   |              n                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              m                |          Reserved             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 1 : The Flexi-Grid Label Encoding

This document defines a new Grid value to supplement those in [RFC6205]:

| Grid | Value |
|---|---|
| ITU-T Flex | 3 |

Within the fixed grid network, the C.S. value is used to represent the channel spacing, as the spacing between adjacent channels is constant.  For the flexible grid situation, this field is used to represent the nominal central frequency granularity.

This document defines a new C.S. value to supplement those in [RFC6205]:

| C.S(GHz) | Value |
|---|---|
| 6.25 | 5 |

The meaning of the Identifier field is maintained from [RFC6205] (see also Section 3).

The meaning of n is maintained from [RFC6205] (see also Section 3).

The m field is used to identify the slot width according to the formula given in [G.694.1] as follows.  It is a 16 bit integer value encoded in line format.

Slot Width (GHz) = 12.5 GHz * m

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

An implementation that wishes to use the flexi-grid label encoding

MUST follow the procedures of [RFC3473] and of [RFC3471] as updated by [RFC6205]. It MUST set Grid to 3 and C.S. to 5. It MUST set Identifier to indicate the local identifier of the laser in use as described in [RFC6205]. It MUST also set n according to the formula in Section 3 (inherited unchanged from [RFC6205]). Finally, the implementation MUST set m as described in the formula stated above.

### 4.2. Considerations of Bandwidth

There is some overlap between the concepts of bandwidth and label in many GMPLS-based systems where a label indicates a physical switching resource. This overlap is increased in a flexi-grid system where a label value indicates the slot width and so affects the bandwidth supported by an LSP. Thus the 'm' parameter is both a property of the label (i.e., it helps define exactly what is switched) and of the bandwidth.

In GMPLS signaling [RFC3473], bandwidth is requested in the TSpec object and confirmed in the Flowspec object. The 'm' parameter that is a parameter of the GMPLS flexi-grid label as described above, is also a parameter of the flexi-grid TSpec and Flowspec as described in [FLEXRSVP].

### 4.3. Composite Labels

The creation of a composite of multiple channels to support inverse multiplexing is already supported in GMPLS for TDM and OTN [RFC4606], [RFC6344], [RFC7139]. The mechanism used for flexi-grid is similar.

To signal an LSP that uses multiple flexi-grid slots a "compound label" is constructed. That is, the LABEL object is constructed from a concatenation of the 64-bit Flexi-Grid Labels shown in Figure 1. The number of elements in the label can be determined from the length of the LABEL object. The resulting LABEL object is shown in Figure 2 including the object header that is not normally shown in diagrammatic representations of RSVP-TE objects. Note that r is the count of component labels, and this is backward compatible with the label shown in Figure 1 where the value of r is 1.

The order of component labels MUST be presented in increasing order of the value n. Implementations MUST NOT infer anything about the encoding of a signal into the set of slots represented by a compound label from the label itself. Information about the encoding MAY be handled in other fields in signaling messages or through an out of band system, but such considerations are out of the scope of this document.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Object Length (4 + 8r)      | Class-Num (16)|  C-Type (2)   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Grid | C.S. |    Identifier   |              n                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              m                |          Reserved             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~                                                               ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Grid | C.S. |    Identifier   |              n                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              m                |          Reserved             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2 : A Compound Label for Virtual Concatenation

Note that specific rules must be applied as follows:

- Grid MUST show "ITU-T Flex" value 3 in each component label.
- C.S. MUST have the same value in each component label.
- Identifier in each component label may identify different physical equipment.
- Values of n and m in each component label define the slots that are concatenated.

At the time of writing [G.694.1] only supports only groupings of adjacent slots (i.e., without intervening unused slots that could be used for other purposes) of identical width (same value of m), and the component slots must be in increasing order of frequency (i.e., increasing order of the value n).  The mechanism defined here MUST NOT be used for other forms of grouping unless and until those forms are defined and documented in Recommendations published by the ITU-T.

Note further that while the mechanism described here naturally means that all component channels are corouted, a composite channel can also be achieved by constructing individual LSPs from single flexi-grid slots and managing those LSPs as a group.  A mechanism for achieving this for TDM is described in [RFC6344], but is out of scope for discussion in this document because the labels used are normal, single slot labels and require no additional definitions.

## 5. Manageability and Backward Compatibility Considerations

This section briefly considers issues of manageability and backward compatibility.

### 5.1. Control Plane Backward Compatibility

Labels are carried in two ways in GMPLS: for immediate use on the next hop and for use at remote hops.

It is an assumption of GMPLS that both ends of a link know what label types are supported and only use appropriate label types. If a label of an unknown type is received it will be processed as if it was of a known type since the Label Object and similar label-carrying objects do not contain a type identifier. Thus the introduction of a flexi-grid label in this document does not change the compatibility issues and a legacy node that does not support the new flexi-grid label should not expect to receive or handle such labels. If one is incorrectly used in communication with a legacy node it will attempt to process it as an expected label type with a potentially poor outcome.

It is possible that a GMPLS message transitting a legacy node will contain a flexi-grid label destined for or reported by a remote node. For example, an LSP that transits links of different technologies might record flexi-grid labels in a Record Route Object that is subsequently passed to a legacy node. Such labels will not have any impact on legacy implementations except as noted in the manageability considerations in the next section.

### 5.2. Manageability Considerations

This document introduces no new elements for management. That is, labels can continue to be used in the same way by the GMPLS protocols and where those labels were treated as opaque quantities with local or global significance, no change is needed to the management systems.

However, this document introduces some changes to the nature of a label that may require changes to management systems. Although Section 3.2 of [RFC3471] makes clear that a label is of variable length according to the type and that the type is supposed to be known a priori by both ends of a link, a management system is not guaranteed to be updated in step with upgrades or installations of new flexi-grid functionality in the network.

But an implementation expecting a 32 bit lambda label would not fail ungracefully because the first 32 bits follow the format of [RFC6205]. It would look at theses labels and read but not recognize the new grid type value. It would then give up trying to parse the label and (presumably) the whole of the rest of the message.

The management system can be upgraded in two steps:

- Firstly, systems that handle lambda labels as 32 bit quantities need to be updated to handle the increase length (64 bits) of labels as described in this document. These "unknown" 64 bit labels could be displayed as opaque 64 bit quantities and still add a lot of value for the operator (who might need to parse the label by hand). However, an implementation that already supports lambda labels as defined in [RFC6205] can safely continue to process the first 32 bits and display the fields defined in RFC 6205 as before leaving just the second 32 bits as opaque data.

- Second, a more sophisticated upgrade to a management system would fully parse the flex-gird labels and display them field-by-field as described in this document.

## 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:
Centre Tecnologic de Telecomunicacions de Catalunya (CTTC)
Optical Networks and Systems Department

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 as described version 07 of this document.
This affects mainly the implementation of RSVP-TE and PCEP protocols:

- Generalized Label Support
- Suggested Label Support
- Upstream Label Support
- ERO Label Subobjects and Explicit Label Control

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. Security Considerations

[RFC6205] notes that the definition of a new label encoding does not introduce any new security considerations to [RFC3471] and [RFC3473]. That statement applies equally to this document.

For a general discussion on MPLS and GMPLS-related security issues, see the MPLS/GMPLS security framework [RFC5920].

## 8. IANA Considerations

IANA maintains the "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Parameters" registry that contains several subregistries.

### 8.1. Grid Subregistry

IANA is requested to allocate a new entry in this subregistry as follows:

| Value | Grid | Reference |
|---|---|---|
| 3 | ITU-T Flex | [This.I-D] |

### 8.2. DWDM Channel Spacing Subregistry

IANA is requested to allocate a new entry in this subregistry as follows:

| Value | Channel Spacing (GHz) | Reference |
|---|---|---|
| 5 | 6.25 | [This.I-D] |

## 9. Acknowledgments

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

Very many thanks to Lou Berger for discussions of labels of more than 32 bits. Many thanks to Sergio Belotti and Pietro Vittorio Grandi for their support of this work. Thanks to Gabriele Galimberti for discussion of the size of the "m" field, and to Iftekhar Hussain for discussion of composite labels. Robert Sparks, Carlos Pignataro, and Paul Wouters provided review comments during IETF last call.

Special thanks to the Vancouver 2012 Pool Party for discussions and rough consensus: Dieter Beller, Ramon Casellas, Daniele Ceccarelli, Oscar Gonzalez de Dios, Iftekhar Hussain, Cyril Margaria, Lyndon Ong, Fatai Zhang, and Adrian Farrel.

# 10. References

## 10.1. Normative References

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[G.694.1] ITU-T Recommendation G.694.1 (revision 2), "Spectral grids for WDM applications: DWDM frequency grid", February 2012.

## 10.2. Informative References

[RFC3945] Mannie, E., Ed., "Generalized Multi-Protocol Label Switching (GMPLS) Architecture", RFC 3945, October 2004.

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[RFC5920] Fang, L., Ed., "Security Framework for MPLS and GMPLS Networks", RFC 5920, July 2010.

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[RFC6982] Sheffer, Y. and A. Farrel, "Improving Awareness of Running Code: The Implementation Status Section", RFC 6982, July 2013.
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[G.671] ITU-T Recommendation G.671, "Transmission characteristics of optical components and subsystems", 2009.

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[FLEXFWRK] O. Gonzalez de Dios, et al., "Framework and Requirements for GMPLS based control of Flexi-grid DWDM networks", draft-ogrcetal-ccamp-flexi-grid-fwk, work in progress.

[FLEXRSVP] Zhang, F., Gonzalez de Dios, O., and D. Ceccarelli, "RSVP-TE Signaling Extensions in support of Flexible Grid", draft-zhang-ccamp-flexible-grid-rsvp-te-ext, work in progress.

## Appendix A. Flexi-Grid Example

Consider a fragment of an optical LSP between node A and node B using the flexible grid. Suppose that the LSP on this hop is formed:
- using the ITU-T Flexi-Grid
- the nominal central frequency of the slot 193.05 THz
- the nominal central frequency granularity is 6.25 GHz
- the slot width is 50 GHz.

In this case the label representing the switchable quantity that is the flexi-grid quantity is encoded as described in Section 4.1 with the following parameter settings. The label can be used in signaling or in management protocols to describe the LSP.

```
Grid = 3 : ITU-T Flexi-Grid

C.S. = 5 : 6.25 GHz nominal central frequency granularity

Identifier = local value indicating the laser in use

n = -8 :

     Frequency (THz) = 193.1 THz + n * frequency granularity (THz)

     193.05 (THz) = 193.1 (THz) + n * 0.00625 (THz)

     n = (193.05-193.1)/0.00625 = -8

m = 4 :

     Slot Width (GHz) = 12.5 GHz * m

     50 (GHz) = 12.5 (GHz) * m

     m = 50 / 12.5 = 4
```

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September 22, 2016

# Link Management Protocol Extensions for Grid Property Negotiation
draft-ietf-ccamp-grid-property-lmp-04

## 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



## Copyright Notice

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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 [RFC7698]. 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 [RFC7698].

In this contribution, some definitions are listed below except those defined in [RFC7698]:

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: 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: Fixed grid 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 (the values of m SHOULD be 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: Flexible-grid capability negotiation

Note: we should avoid the use of LMP in the case that a DWDM or Flex port is connected to a CWDM port, for this it is likely to cause the upgrade of hardware and LMP can not work in a "plug-and-play" way.

## 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.

And for ports on a link that do not have any grid properties in common, the link and its properties SHOULD not be advertised.

# 4. Application of Grid Property Negotiation

As described in [RFC7698], the control plane MAY include support for neighbor discovery such that a flexi-grid network can be constructed in a "plug-and-play" manner. The control plane SHOULD allow the nodes at opposite ends of a link to correlate the properties that they will apply to the link. Such a correlation SHOULD include at least the identities of the nodes and the identities that they apply to the link. As described in this draft, for ports on a link that do not have any grid properties in common, the link and its properties SHOULD not be advertised to the PCE or other nodes in the same domain. Especially in the scenario of inter-domain, LMP can not be replaced by some other protocol. For example, if Path Computation Element (PCE) or a serial of PCEs coordinate to compute an end-to-end path which crosses more than one domain, it should take the inter-domain grid properties into consideration. Given the OSPF can not advertise the attributes of the border device on the other side, the inter-domain attributes must be negotiated in advance, otherwise the end-to-end path may not be set up successfully.

## 5. LMP extensions

### 5.1. 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 13.12.1 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 RFC 6205 [RFC6205] identify DWDM

[G.694.1] and CWDM [G.694.2]. The value defined in [RFC7699] 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.

## 6. Messages Exchange Procedure

### 6.1. 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.

## 6.2. Flexible Nodes Messages Exchange

To demonstrate the procedure of grid property correlation between two 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.

## 7. 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.)

## 8. Acknowledgments

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

## 9. Security Considerations

LMP message security uses IPsec, as described in [RFC4204]. This document only defines new LMP objects that are carried in existing LMP messages. As such, this document introduces no other new security considerations not covered in [RFC4204].

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# Information Model for Wavelength Switched Optical Networks (WSONs) with Impairments Validation
draft-ietf-ccamp-wson-iv-info-12

Abstract

This document defines an information model to support Impairment-Aware (IA) Routing and Wavelength Assignment (RWA) functionality. This information model extends the information model for impairment-free RWA process in WSON to facilitate computation of paths where optical impairment constraints need to considered.

Table of Contents



## 1. Introduction

In the context of Wavelength Switched Optical Network (WSON), [RFC6163] describes the basic framework for a GMPLS and PCE-based Routing and Wavelength Assignment (RWA) control plane. The associated information model [RFC7446] defines information/parameters required by an RWA process without optical impairment considerations.

There are cases of WSON where optical impairments play a significant role and are considered as important constraints. The framework document [RFC6566] defines the problem scope and related control plane architectural options for the Impairment Aware RWA (IA-RWA) operation. Options include different combinations of Impairment Validation (IV) and RWA functions in term of different combination of control plane functions (i.e., PCE, Routing, Signaling).

A Control Plane with RWA-IA will not be able to solve the optical impairment problem in a detailed and exhaustive way, however, it may take advantage of some data plane knowledge to make better decisions during its path computing phase. The final outcome will be a path, instantiated through a wavelength in the data plane, that has a "better chance" to work than that path were calculated without IA information. "Better chance" means that path setup may still fail and the GMPLS control plane will follow its usual procedures upon errors and failures. A control plane will not replace a the network design phase that remains a fundamental step for DWDM Optical Networks. As the non-linear impairments which need to be considered in the calculation of an optical path will be vendor-dependent, the parameters considered in this document is not an exhaustive list.

This document provides an information model for the impairment aware case to allow the impairment validation function implemented in the control plane or enabled by control plane available information. This model goes in addition to [RFC7446] and shall support any control plane architectural option described by the framework document (see sections 4.2 and 4.3 of [RFC6566]) where a set of combinations of control plane functions vs. IV function is provided.

## 2. Definitions, Applicability and Properties

This section provides some concepts to help understand the model and to make a clear separation from data plane definitions (ITU-T recommendations). The first sub-section provides definitions while the Applicability sections uses the defined definitions to scope this document.

### 2.1. Definitions

- o Computational Model / Optical Computational Model.
  Defined by ITU standard documents (e.g. [ITU.G680]). In this context we look for models able to compute optical impairments for a given lightpath.

- o Information Model.
  Defined by IETF (this document) and provides the set of information required by control plane to apply the Computational Model.

- o Level of Approximation.
  This concept refers to the Computational Model as it may compute optical impairment with a certain level of uncertainty. This level is generally not measured but [RFC6566] Section 4.1.1 provides a rough classification about it.

- o Feasible Path.
  It is the output of the C-SPF with RWA-IV capability. It's an optical path that satisfies optical impairment constraints. The path, instantiated through wavelength(s), may actually work or not work depending of the level of approximation.

- o Existing Service Disruption.
  An effect known to optical network designers is the cross-interaction among spectrally adjacent wavelengths: an existing wavelength may experience increased BER due to the setup of an adjacent wavelength. Solving this problem is a typical optical network design activity. Just as an example, a simple solution is adding optical margins (e.g., additional OSNR), although complex and detailed methods exist.

- o DWDM Line Segments.
  [ITU.G680] provides definition and picture for the "Situation 1" DWDM Line segments: " Situation 1 - The optical path between two consecutive 3R regenerators is composed of DWDM line segments from a single vendor and OADMs and PXCs from another vendor". Document [RFC6566] Figure 1 shows an LSP composed by two DWDM line segments according to [ITU.G680] definition.

## 2.2. Applicability

This document targets at Scenario C defined in [RFC6566] section 4.1.1. as approximate impairment estimation. The Approximate concept refer to the fact that this Information Model covers information mainly provided by [ITU.G680] Computational Model.

Computational models having no or little approximation, referred as IV-Detailed in the [RFC6566], currently does not exist in term of ITU-T recommendation. They generally deal with non-linear optical impairment and are usually vendor specific.

The Information Model defined in this document does not speculate about the mathematical formulas used to fill up information model parameters, hence it does not preclude changing the computational model. At the same time, the authors do not believe this Information Model is exhaustive and if necessary further documents will cover additional models after they become available.

The result of RWA-IV process implementing this Information Model is a path (and a wavelength in the data plane) that has better chance to be feasible than if it was computed without any IV function. The Existing Service Disruption, as per the definition above, would still be a problem left to a network design phase.

## 2.3. Properties

An information model may have several attributes or properties that need to be defined for each optical parameter made available to the control plane. The properties will help to determine how the control plane can deal with a specific impairment parameter, depending on architectural options chosen within the overall impairment framework [RFC6566]. In some case, properties value will help to identify the level of approximation supported by the IV process.

- Time Dependency
  This identifies how an impairment parameter may vary with time. There could be cases where there is no time dependency, while in other cases there may be need of re-evaluation after a certain time. In this category, variations in impairments due to environmental factors such as those discussed in [ITU.GSUP47] are considered. In some cases, an impairment parameter that has time dependency may be considered as a constant for approximation. In this information model, we do neglect this property.

- Wavelength Dependency
  This property identifies if an impairment parameter can be considered as constant over all the wavelength spectrum of interest or not. Also in this case a detailed impairment evaluation might lead to consider the exact value while an approximation IV might take a constant value for all wavelengths. In this information model, we consider both case: dependency / no dependency on a specific wavelength. This property appears directly in the information model definitions and related encoding.

- Linearity
  As impairments are representation of physical effects, there are some that have a linear behaviour while other are non-linear. Linear approximation is in scope of Scenario C of [RFC6566]. During the impairment validation process, this property implies that the optical effect (or quantity) satisfies the superposition

principle, thus a final result can be calculated by the sum of each component. The linearity implies the additivity of optical quantities considered during an impairment validation process. The non-linear effects in general do not satisfy this property. The information model presented in this document however, easily allow introduction of non-linear optical effects with a linear approximated contribution to the linear ones.

o Multi-Channel
There are cases where a channel's impairments take different values depending on the aside wavelengths already in place, this is mostly due to non-linear impairments. The result would be a dependency among different LSPs sharing the same path. This information model do not consider this kind of property.

The following table summarise the above considerations where in the first column reports the list of properties to be considered for each optical parameter, while the second column states if this property is taken into account or not by this information model.

| Property | Info Model Awareness |
|---|---|
| Time Dependency | no |
| Wavelength Dependency | yes |
| Linearity | yes |
| Multi-channel | no |

Table 1: Optical Impairment Properties

## 3. ITU-T List of Optical Parameters

As stated by Section 2.2 this Information Model does not intend to be exhaustive and targets an approximate computational model although not precluding future evolutions towards more detailed or different impairments estimation methods.

On the same line, ITU SG15/Q6 provides (through [LS78]) a list of optical parameters with following observations:

(a) the problem of calculating the non-linear impairments in a multi-vendor environment is not solved. The transfer functions works only for the so called [ITU.G680] "Situation 1".

(b) The generated list of parameters is not exhaustive however provide a guideline for control plane optical impairment awareness.

In particular, [ITU.G680] contains many parameters that would be required to estimate linear impairments. Some of the Computational Models defined within [ITU.G680] requires parameters defined in other documents like [ITU.G671]. The purpose of the list here below makes this match between the two documents.

[ITU.G697] defines parameters can be monitored in an optical network. This Information Model and associated encoding document will reuse [ITU.G697] parameters identifiers and encoding for the purpose of path computation.

The list of optical parameters starts from [ITU.G680] Section 9 which provides the optical computational models for the following p:

G-1  OSNR.  Section 9.1

G-2  Chromatic Dispersion (CD).  Section 9.2

G-3  Polarization Mode Dispersion (PMD).  Section 9.3

G-4  Polarization Dependent Loss (PDL).  Section 9.3

In addition to the above, the following list of parameters has been mentioned by [LS78]:

L-1   "Channel frequency range", [ITU.G671]. This parameter is part of the application code and encoded through Optical Interface Class as defined in [RFC7446].

L-2   "Modulation format and rate". This parameter is part of the application code and encoded through Optical Interface Class as defined in [RFC7446].

L-3   "Channel power". Required by G-1.

L-4   "Ripple". According to [ITU.G680], this parameter can be taken into account as additional OSNR penalty.

L-5   "Channel signal-spontaneous noise figure", [ITU.G680]. Required by OSNR calculation (see G-1) above.

L-6   "Channel chromatic dispersion (for fibre segment or network element)". Already in G-2 above.

L-7   "Channel local chromatic dispersion (for a fibre segment)". Already in G-2 above (since consider both local and fiber dispersions).

L-8   "Differential group delay (for a network element)", [ITU.G671]. Required by G-3.

L-9   "Polarisation mode dispersion (for a fibre segment)", [ITU.G650.2], [ITU.G680].  Defined above as G-3.

L-10  "Polarization dependent loss (for a network element)", [ITU.G671] and [ITU.G680].  Defined above as G-4.

L-11  "Reflectance".  From [ITU.G671] Section 3.2.2.37 is the ratio of reflected power Pr to incident power Pi at a given port of a passive component, for given conditions of spectral composition, polarization and geometrical distribution. Generally expressed in dB.  Might be monitored in some critical cases.  We neglect this effect as first approximation.

L-12  "Channel Isolation".  From [ITU.G671] Section 3.2.2.2 (Adjacent Channel Isolation) and Section 3.2.2.29 (Non Adjacent Channel Isolation).  Document [ITU.GSUP39] provide the formula for calculation as channel cross-talk and measure it in dB.  This parameterer shall be considered for path computation.

L-13  "Channel extinction".  From [ITU.G671] Section 3.2.2.9 needed for Interferometric Crosstalk.  Document [ITU.GSUP39] has the formula for penalty computation.  Unit of measurement is dB.

L-14  "Attenuation coefficient (for a fibre segment)".  Document [ITU.G650.1] Section 3.6.2.  The unit of measure is dB.  This is a typical link parameter (as associated to a fiber).

L-15  "Non-linear coefficient (for a fibre segment)", [ITU.G650.2]. Required for Non-Linear Optical Impairment Computational Models.  Neglected by this document.

The final list of parameters is G-1, G-2, G-3, G-4, L-3, L-4, L-5, L-8, L-12, L-13, L-14.

## 4.  Background from WSON-RWA Information Model

In this section we report terms already defined for the WSON-RWA (impairment free) as in [RFC7446] and [RFC7579].  The purpose is to provide essential information that will be reused or extended for the impairment case.

In particular [RFC7446] Section 4.1 defines the ConnectivityMatrix and states that such matrix does not represent any particular internal blocking behaviour but indicates which input ports and wavelengths could possibly be connected to a particular output port.

```
<ConnectivityMatrix> ::= <MatrixID> <ConnType> <Matrix>
```

According to [RFC7579], this definition is further detailed as:

```
<ConnectivityMatrix> ::=
      <MatrixID> <ConnType> ((<LinkSet> <LinkSet>) ...)
```

This second formula highlights how the ConnectivityMatrix is built by pairs of LinkSet objects identifying the internal connectivity capability due to internal optical node constraint(s).  It's essentially binary information and tell if a wavelength or a set of wavelengths can go from an input port to an output port.

As an additional note, ConnectivityMatrix belongs to node information, is uniquely identified by advertising node and is a static information.  Dynamic information related to the actual state of connections is available through specific extension to link information.

The [RFC7446] introduces the concept of ResourceBlockInfo and ResourcePool for the WSON nodes.  The resource block is a collection of resources behaving in the same way and having similar characteristics.  The ResourceBlockInfo is defined as follow:

```
<ResourceBlockInfo> ::= <ResourceBlockSet> [<InputConstraints>]
      [<ProcessingCapabilities>] [<OutputConstraints>]
```

The usage of resource block and resource pool is an efficient way to model constrains within a WSON node.

## 5.  Optical Impairment Information Model

The idea behind this document is to put optical impairment parameters into categories and extend the information model already defined for impairment-free WSONs.  The three categories are:

- o Node Information.  The concept of connectivity matrix is reused and extended to introduce an impairment matrix, which represents the impairments suffered on the internal path between two ports. In addition, the concept of Resource Block is also reused and extended to provide an efficient representation of per-port impairment.

- o Link Information representing impairment information related to a specific link or hop.

- o Path Information representing the impairment information related to the whole path.

All the above three categories will make use of a generic container, the Impairment Vector, to transport optical impairment information.

This information model however will allow however to add additional parameters beyond the one defined by [ITU.G680] in order to support additional computational models. This mechanism could eventually applicable to both linear and non-linear parameters.

This information model makes the assumption that the each optical node in the network is able to provide the control plane protocols with its own parameter values. However, no assumption is made on how the optical nodes get those value information (e.g., internally computed, provisioned by a network management system, etc.). To this extent, the information model intentionally ignores all internal detailed parameters that are used by the formulas of the Optical Computational Model (i.e., "transfer function") and simply provides the object containers to carry results of the formulas.

## 5.1. The Optical Impairment Vector

Optical Impairment Vector (OIV) is defined as a list of optical parameters to be associated to a WSON node or a WSON link. It is defined as:

```
<OIV> ::= ([<LabelSet>] <OPTICAL_PARAM>) ...
```

The optional LabelSet object enables wavelength dependency property as per Table 1. LabelSet has its definition in [RFC7579].

OPTICAL_PARAM. This object represents an optical parameter. The Impairment vector can contain a set of parameters as identified by [ITU.G697] since those parameters match the terms of the linear impairments computational models provided by [ITU.G680]. This information model does not speculate about the set of parameters (since defined elsewhere, e.g. ITU-T), however it does not preclude extensions by adding new parameters.

## 5.2. Node Information

### 5.2.1. Impairment Matrix

Impairment matrix describes a list of the optical parameters that applies to a network element as a whole or ingress/egress port pairs of a network element. Wavelength dependency property of optical parameters is also considered.

```
ImpairmentMatrix ::=  <MatrixID> <ConnType>
      ((<LinkSet> <LinkSet> <OIV>) ...)
```

Where:

MatrixID. This ID is a unique identifier for the matrix. It shall be unique in scope among connectivity matrices defined in [RFC7446] and impairment matrices defined here.

ConnType. This number identifies the type of matrix and it shall be unique in scope with other values defined by impairment-free WSON documents.

LinkSet. Same object definition and usage as [RFC7579]. The pairs of LinkSet identify one or more internal node constrain.

OIV. The Optical Impairment Vector defined above.

The model can be represented as a multidimensional matrix shown in the following picture

```
                          _________________________________________
                         /        /       /       /       /       /|
                        /        /       /       /       /       / |
                       /________/_______/_______/_______/_______/  |
                      /        /       /       /       /       /| /|
                     /        /       /       /       /       / |  |
                    /________/_______/_______/_______/_______/  | /|
                   /        /       /       /       /       /| /|  |
                  /        /       /       /       /       / |  | /|
                 /________/_______/_______/_______/_______/  | /|  |
                /        /       /       /       /       /| /|  | /|
               /        /       /       /       /       / |  | /|  |
               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  | /|  | / PDL
   <LinkSet#1> |   -   |       |       |       |       | /|  | /|/
               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  | /|  /
   <linkSet#2> |       |   -   |       |       |       | /|  | / PND
               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  | /|/
   <linkSet#3> |       |       |   -   |       |       | /|  /
               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  | / Chr.Disp.
   <linkSet#4> |       |       |       |   -   |       | /|/
               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  /
   <linkSet#5> |       |       |       |       |   -   | / OSNR
               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                <LS#1>  <LS#2>  <LS#3>  <LS#4>  <LS#5>
```

The connectivity matrix from [RFC7579] is only a two dimensional matrix, containing only binary information, through the LinkSet pairs. In this model, a third dimension is added by generalizing the binary information through the Optical Impairment Vector associated with each LinkSet pair. Optical parameters in the picture are reported just as an example: proper list and encoding shall be defined by other documents.

This representation shows the most general case however, the total amount of information transported by control plane protocols can be greatly reduced by proper encoding when the same set of values apply to all LinkSet pairs.

### 5.2.2. Impairment Resource Block Information

This information model reuses the definition of Resource Block Information adding the associated impairment vector.

```
ResourceBlockInfo ::= <ResourceBlockSet> [<InputConstraints>]
    [<ProcessingCapabilities>] [<OutputConstraints>] [<OIV>]
```

The object ResourceBlockInfo is than used as specified within [RFC7446].

## 5.3. Link Information

For the list of optical parameters associated to the link, the same approach used for the node-specific impairment information can be applied. The link-specific impairment information is extended from [RFC7446] as the following:

```
<DynamicLinkInfo> ::=  <LinkID> <AvailableLabels>
        [<SharedBackupLabels>] [<OIV>]
```

DynamicLinkInfo is already defined in [RFC7446] while OIV is the Optical Impairment Vector is defined in the previous section.

## 5.4. Path Information

There are cases where the optical impairments can only be described as a constrains on the overall end to end path. In such case, the optical impairment and/or parameter, cannot be derived (using a simple function) from the set of node / link contributions.

An equivalent case is the option reported by [RFC6566] on IV-Candidate paths where, the control plane knows a list of optically feasible paths so a new path setup can be selected among that list. Independent from the protocols and functions combination (i.e. RWA vs. Routing vs. PCE), the IV-Candidates imply a path property stating that a path is optically feasible.

The concept of Optical Impairment Vector (OIV) might be used or extended to report optical impairment information at path level however this is case is letf for future studies.

## 6. Encoding Considerations

Details about encoding will be defined in a separate document [I-D.ietf-ccamp-wson-iv-encode] however worth remembering that, within [ITU.G697] Appending V, ITU already provides a guideline for encoding some optical parameters.

In particular [ITU.G697] indicates that each parameter shall be represented by a 32 bit floating point number.

Values for optical parameters are provided by optical node and it could provide by direct measurement or from some internal computation starting from indirect measurement. In such cases, it could be useful to understand the variance associated with the value of the optical parameter hence, the encoding shall provide the possibility to include a variance as well.

This kind of information will enable IA-RWA process to make some additional considerations on wavelength feasibility. [RFC6566] Section 4.1.3 reports some considerations regarding this degree of confidence during the impairment validation process.

## 7. Control Plane Architectures

This section briefly describes how the definitions contained in this information model will match the architectural options described by [RFC6566]. This section does not suggest suggested any specific protocol option.

The assumption is that WSON GMPLS extensions are available and operational. To such extent, the WSON-RWA will provide the following information through its path computation (and RWA process):

- o The wavelengths connectivity, considering also the connectivity constraints limited by reconfigurable optics, and wavelengths availability.

- o The interface compatibility at the physical level.

- o The Optical-Elettro-Optical (OEO) availability within the network (and related physical interface compatibility). As already stated by the framework this information it’s very important for impairment validation:

A. If the IV functions fail (path optically infeasible), the path computation function may use an available OEO point to find a feasible path. In normally operated networks OEO are mainly uses to support optically unfeasible path than mere wavelength conversion.

B. The OEO points reset the optical impairment information since a new light is generated.

### 7.1. IV-Centralized

Centralized IV process is performed by a single entity (e.g. a PCE or other external entities). Given sufficient impairment information, it can either be used to provide a list of paths between two nodes, which are valid in terms of optical impairments. Alternatively, it can help validate whether a particular selected path and wavelength is feasible or not.

Centralized IV functions requires exchange of impairment information to the entity performing the IV process from network nodes. This information exchange may requires implementation of this information model within an exsting protocol (i.e. routing procol vs PCEP vs BGP-LS vs others).

### 7.2. IV-Distributed

Assuming the information model is implemented through a routing protocol, every node in the WSON network shall be able to perform an RWA-IV function.

The signalling phase may provide additional checking as others traffic engineering parameters.

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## 10. IANA Considerations

This document does not contain any IANA requirement.

## 11. Security Considerations

This document defines an information model for impairments in optical networks. If such a model is put into use within a network it will by its nature contain details of the physical characteristics of an optical network.  Such information would need to be protected from intentional or unintentional disclosure.

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# Appendix A.  FAQ

## A.1.  Why the Application Code does not suffice for Optical Impairment Validation?

Application Codes are encoded within GMPLS WSON protocol through the Optical Interface Class as defined in [RFC7446].

The purpose of the Application Code in RWA is simply to assess the interface compatibility: same Application Code means that two interfaces can have an LSP connecting the two.

Application Codes contain other information useful for IV process (e.g., see the list of parameters) so they are required however Computational Models requires more parameteres to assess the path feasibility.

## A.2. Are DWDM network multivendor?

According to [ITU.G680] "Situation 1" the DWDM line segments are single are single vendor but an LSP can make use of different data planes entities from different vendors.  For example: DWDM interfaces (represented in the control plane through the Optical Interface Class) from a vendor and network elements described by Stutation 1 from another vendor.

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# A Yang Data Model for WSON Optical Networks

draft-lee-ccamp-wson-yang-00

## Abstract

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

## Status of this Memo



## Copyright Notice

Table of Contents



# 1. Introduction

This document provides a YANG data model for the routing and wavelength assignment (RWA) process 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].

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 [RFC7446] 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 did not make use of augmentation of other modules. The augmentation of other modules will be considered once other modules being developed have been well established and can be used as a basis of this module.]

```
module: wson-topology
   +--rw wson-topology
      +--rw wson-topology* [wson-topology-id]
         +--rw wson-topology-id    wson-topology-id
         +--rw name?               string
         +--rw wson-node* [wson-node-id]
            +--rw wson-node-id                   wson-node-id
            +--rw wson-interface* [wson-interface-id]
            |  +--rw wson-interface-id    linkset-format
            |  +--rw wavelength-available-bitmap*   uint32
            +--rw connectivity-matrix* [matrix-id]
            |  +--rw matrix-id           uint8
            |  +--rw device-type?        devicetype
            |  +--rw dir?                directionality
            |  +--rw format              linkset-format
            |  +--rw matrix-interface* [in-port-id]
            |     +--rw in-port-id     wson-interface-ref
            |     +--rw out-port-id    wson-interface-ref
            +--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   wson-topology {
   namespace "urn:ietf:params:xml:ns:yang:wson-topology";

   prefix wson;

   import ietf-inet-types {
      prefix inet;
   }

   organization
        "IETF CCAMP Working Group";

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

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

        Copyright (c) 2015 IETF Trust and the persons identified as
        authors of the code.  All rights reserved.

        Redistribution and use in source and binary forms, with or
        without modification, is permitted pursuant to, and subject
        to the license terms contained in, the Simplified BSD
        License set forth in Section 4.c of the IETF Trust's Legal
        Provisions Relating to IETF Documents
        (http://trustee.ietf.org/license-info).";

   revision 2015-03-05 {
        description
            "Initial revision.";
```

```
           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 linkset-format {
         type enumeration {
            enum link-local-identifier{
               value 1;
               description
                  "";
            }
            enum local-interface-ipv4{
               value 2;
               description
                  "";
            }
            enum local-interface-ipv6{
               value 3;
               description
                  "";
            }
         }
         description
            "linkset type; link local/ipv4/ipv6";
      }

      typedef wson-interface-ref {
         type leafref {
```

```
            path "/wson-topology/wson-topology/wson-node/" +
                 "wson-interface/wson-interface-id";
         }
         description
         "This type is used by data models that need to
         reference WSON interface.";
      }

      container wson-topology {
         description
            "TBD";
         list wson-topology {
            key "wson-topology-id";
            description
               "The WSON Topology";
            leaf wson-topology-id {
               type wson-topology-id;
               description
                  "The WSON Topology Identifier";
            }
            leaf name {
               type string;
               description
                  "TBD";
            }

            list wson-node {
               key "wson-node-id";
               description
                  "The WSON node";
               leaf wson-node-id {
                  type wson-node-id;
                  description
                     "The WSON Node ID";
               }

               list wson-interface {
                  key "wson-interface-id";
                  description
                     "The list of WSON Interface";
                  leaf wson-interface-id {
```

```
                     type linkset-format;
                     description
                        "TBD";
                  }

                  leaf-list wavelength-available-bitmap {
                     type uint32;
                     description
                       "The list of available channels, correponding
                         to the bitmap in the info model.";
                  }
               }

               list connectivity-matrix {
                  key "matrix-id";
                  description
                     "connectivity-matrix of WSON node";
                  reference
                     "based on draft-ietf-ccamp-general-constraint-
   encode";
                  leaf matrix-id {
                     type uint8;
                     description
                        "matrix identifier";
                  }

                  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";
                  }
                  leaf format {
                     type linkset-format;
                     description
```

```
                        "format of identifier";
                  }
                  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";
                     }
                  }
               }
               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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[Gen-Encode] G. Bernstein, Y. Lee, D. Li, W. Imajuku, "General Network Element Constraint Encoding for GMPLS Controlled Networks", work in progress: draft-ietf-ccamp-general-constraint-encode.

[WSON-Encode] G. Bernstein, Y. Lee, D. Li, W. Imajuku, "Routing and Wavelength Assignment Information Encoding for Wavelength Switched Optical Networks", work in progress: draft-ietf-ccamp-rwa-wson-encode.

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# A Yang Data Model for WSON Optical Networks

draft-lee-ccamp-wson-yang-04.txt

## Abstract

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

## Status of this Memo



## Copyright Notice

Table of Contents



# 1. Introduction

This document provides a YANG data model for the routing and wavelength assignment (RWA) Traffic Engineering (TE) topology in wavelength switched optical networks (WSONs). The YANG model described in this document is a WSON technology-specific Yang model based on the information model developed in [RFC7446] and the two encoding documents [RFC7581] and [RFC7579] that developed protocol independent encodings based on [RFC7446]. This document augments the 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 Secti
ons
2.3 and 2.4 in the later version.]

Sections 2.1 - 2.4 rehashes key information models from [RWA-Info] to facilit
ate
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 t
he
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 ei
ther
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 m
ore
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:t
e-
   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> file "ietf-wson-topology@2015-10-14.yang"

         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.

    Copyright (c) 2015 IETF Trust and the persons identified as
    authors of the code.  All rights reserved.

    Redistribution and use in source and binary forms, with or
    without modification, is permitted pursuant to, and subject
    to the license terms contained in, the Simplified BSD
    License set forth in Section 4.c of the IETF Trust's Legal
    Provisions Relating to IETF Documents
    (http://trustee.ietf.org/license-info).";

  revision 2015-10-14 {
    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

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

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

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

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

### 8.2. Informative References

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# Information Encoding for WSON with Impairments Validation
draft-martinelli-ccamp-wson-iv-encode-05

## Abstract

Impairment-Aware (IA) Routing and Wavelength Assignment (RWA) function might be required in Wavelength Switched Optical Networks (WSON) that already support RWA.  This document defines proper encoding to support this operation.  It goes in addition to the available impairment-free WSON encoding and it is fully compatible with it.

As the information model, the encoding is independent from control plane architectures and protocol implementations.  Its definitions can be used in related protocol extensions.

## Status of This Memo

Table of Contents



## 1. Introduction

In case of WSON where optical impairments play a significant role, the framework document [RFC6566] defines related control plane architectural options for Impairment Aware Routing and Wavelength Assignment (IA-RWA). This document provides a suitable encoding for the related WSON impairment information model as defined [I-D.ietf-ccamp-wson-iv-info].

This document directly refers to ITU recommendations [ITU.G680] and [ITU.G697] as already detailed in the information model.

### 1.1. Requirements Language

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

## 2. Encoding

This section details encoding for all elements defined within [I-D.ietf-ccamp-wson-iv-info]. Elements to encode are:

Optical Parameter (OPTICAL_PARAM)

Optical Impairment Vector (OIV)

Impairment Matrix

Impairment Resource Block Information

### 2.1. Optical Parameter

The OPTICAL_PARAM is defined as a sub-TLV object.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|S|V|      Reserved             | ParamSource  |    ParamID     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            Value                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Variance (Optional)                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The following flag is defined:

S: Standard bit.
S=1 indentifies a set of parameters standardized by ITU; while S=0 identifies a non-standardized set of parameters.

V: Variance bit.
V=0 only parameter value, V=1 parameter value and variance.

With the flag S=1 the following parameters are defined:

ParamSource = 1.
Identify the ITU document that defines the following parameter list. Currently [ITU.G697] defines this value 1 for this parameter.

ParamID.
Parameter identifier according to the source.  [ITU.G697] table V.3 defines the following identifiers:

1. Total Power (dBm)
   Not reported within [I-D.ietf-ccamp-wson-iv-info] parameter list but relates to Channel Power through the number of channels.

2. Channel Power (dBm).
   Referred as parameter L-3 in [I-D.ietf-ccamp-wson-iv-info]

3. Reserved ("Frequency Deviation from Nominal, GHz", defined in [ITU.G697] but not used)

4. Reserved ("Wavelength Deviation from Nominal, nm", defined in [ITU.G697] but not used)

5. OSNR (db).
   Referred as parameter G-1 in [I-D.ietf-ccamp-wson-iv-info]

6. Reserved.  (Q Factor, a pure number).
   Not reported within [I-D.ietf-ccamp-wson-iv-info] parameter list but is a known index for assessing channel quality.

7. PMD (ps).
   Referred as parameter G-3 in [I-D.ietf-ccamp-wson-iv-info]

8. Residual Chromatic Dispersion (ps/nm).
   Referred as parameter G-2 in [I-D.ietf-ccamp-wson-iv-info]

Value.
Value for the parameter.  As defined by [ITU.G697], it is a 32 bit IEEE floating point number.

Variance.
Variance for the parameter, a 32 bit IEEE floating point number.

According to [I-D.ietf-ccamp-wson-iv-info], there are some parameters required for the IV function not listed within [ITU.G697].  Current information source for such parameters is [LS78] hence, this document proposes to use a different value for the field parameter source.

ParamSource = 0 (proposal).
List of parameters within [I-D.ietf-ccamp-wson-iv-info].
[Editor Note: Value to be confirmed through ITU Liaison].

ParamID.
A number that take the following list of values.

1. Ripple (dBm). L-4 in [I-D.ietf-ccamp-wson-iv-info].

2. Channel signal-spontaneous noise figure. L-5 in [I-D.ietf-ccamp-wson-iv-info].

3. DGD, Differential Group Delay. L-8 in [I-D.ietf-ccamp-wson-iv-info].

4. Reflectance. L-11 in [I-D.ietf-ccamp-wson-iv-info].

5. Isolation. L-12 in [I-D.ietf-ccamp-wson-iv-info].

6. Channel extintion. L-13 in [I-D.ietf-ccamp-wson-iv-info].

7. Attenuation Coefficient. L-14 in [I-D.ietf-ccamp-wson-iv-info].

## 2.2. Impairment Vector

This sub-TLV is a list of optical parameters and they MAY have a wavelength dependency information.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|0|       Reserved              |   Number of Parameters        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Optical Param sub-TLV(s)                     |
:                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where:

W = 0. Wavelength Dependency flag. There is no wavelength dependency.

Number of Parameters contained in this vector.

Optical Param sub-TLV(s) present a list of Object as defined in Section 2.1.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|1|       Reserved              |   Number of Parameters        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Label Set                                    |
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Optical Param sub-TLV(s)                     |
:                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where:

W = 1. Wavelength Dependency flag. There is wavelength dependency.

The Label Set object is defined in [I-D.ietf-ccamp-general-constraint-encode] Section 2.1. Likely an inclusive range will be the only option required by the Action defined in the Label Set.

## 2.3. Impairment Matrix

As defined by the [I-D.ietf-ccamp-wson-iv-info], the impairment matrix follows the same structure as the connectivity matrix.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Conn  |   MatrixID    |              Reserved               |0|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Link Set A #1                         |
:                               :                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Link Set B #1                         |
:                               :                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Impairment Vector sub-TLV(s)                   |
:                               :                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       Additional Link Set pairs and Impairment Vector(s)      |
:                               :                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Conne |    MatrixID   |               Reserved              |1|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Impairment Vector sub-TLV(s)                   |
:                               :                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where:

Connectivity (Conn) (4 bits) has value 2 for the impairment matrix (Values 0 and 1 defined by [I-D.ietf-ccamp-general-constraint-encode]).

MatrixID: matrix identifier,following same rules as [I-D.ietf-ccamp-general-constraint-encode].

N: Node scope flag.  With this flag set there’s no Link Set information but only a list of optical parameters TLVs that apply to the whole optical node.

The usage of multiple matrixes with connectivity type equal to 2 (Impairment Matrix) MIGHT be used to grup optical parameters by connectivity.  For example, if a subset of parameters apply to the whole node, a unique matrix with flag N=1 is used.  At the same some another subset of parameters applies only to some LinkSet pairs, a specific Impairment Matrix will be added.

## 2.4. Resource Block Information

As defined by [I-D.ietf-ccamp-wson-iv-info], the concept of resource block is extended to support the description of the impairments related to that block. The encoding follows the same structure as the one defined in [I-D.ietf-ccamp-rwa-wson-encode], with the addition of an optional Impairment Vector sub-object:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          RB Set Field                         |
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|I|O|                          Reserved                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Optical Interface Class List(s) (opt)          |
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Acceptable Client Signal Type (opt)             |
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Input Bit Rate List (opt)                  |
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Processing Capabilities List (opt)             |
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   OIV-Impairment Vector (opt)                 |
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The Impairment Vector is defined within Section 2.2. All the other fields are defined within [I-D.ietf-ccamp-rwa-wson-encode].

## 3. Acknowledgements

Authors would like to acknoledge Greg Bernstein and Moustafa Kattan as authors of a previous similar draft whose content partially converged here.

Authors would like to thank ITU SG15/Q6 and in particular Peter Stassar and Pete Anslow for providing useful information and text to CCAMP through join meetings and liaisons.

## 4. IANA Considerations

This document does not contain any IANA request.

## 5. Security Considerations

This document defines an protocol-neutral encoding for an information model describing impairments in optical networks and it does not introduce any security issues. If such a encoding is put into use within a network it will by its nature contain details of the physical characteristics of an optical network. Such information would need to be protected from intentional or unintentional disclosure.

## 6. References

### 6.1. Normative References

[ITU.G680]
International Telecommunications Union, "Physical transfer functions of optical network elements", ITU-T Recommendation G.680, July 2007.

[ITU.G697]
International Telecommunications Union, "Optical monitoring for dense wavelength division multiplexing systems", ITU-T Recommendation G.697, February 2012.

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

### 6.2. Informative References

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Bernstein, G., Lee, Y., Li, D., and W. Imajuku, "General Network Element Constraint Encoding for GMPLS Controlled Networks", draft-ietf-ccamp-general-constraint-encode-20 (work in progress), February 2015.

[I-D.ietf-ccamp-rwa-wson-encode]
Bernstein, G., Lee, Y., Li, D., and W. Imajuku, "Routing and Wavelength Assignment Information Encoding for Wavelength Switched Optical Networks", draft-ietf-ccamp-rwa-wson-encode-28 (work in progress), February 2015.

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