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YANG data model for Flexi-Grid Optical Networks
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Abstract

This document defines a YANG model for managing flexi-grid optical Networks. The model described in this document is composed of two submodels: one to define a flexi-grid traffic engineering database, and other one to describe the flexi-grid paths or media channels.

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1. Introduction

Internet-based traffic is dramatically increasing every year. Moreover, such traffic is also becoming more dynamic. Thus, transport networks need to evolve from current DWDM systems towards elastic optical networks, based on flexi-grid transmission and switching technologies. This technology aims at increasing both

transport network scalability and flexibility, allowing the optimization of bandwidth usage.

This document presents a YANG model for flexi-grid objects in the dynamic optical network, including the nodes, transponders and links between them, as well as how such links interconnect nodes and transponders.

The YANG model for flexi-grid [RFC7698] networks allows the representation of the flexi-grid optical layer of a network, combined with the underlying physical layer. The model is defined in two YANG modules:

- Flexi-grid-TED (Traffic Engineering Database): This module defines all the information needed to represent the flexi-grid optical node, transponder and link.
- Media-channel: This module defines the whole path from a source transponder to the destination through a number of intermediate nodes in the flexi-grid optical network.

This document identifies the flexi-grid components, parameters and their values, characterizes the features and the performances of the flexi-grid elements. An application example is provided towards the end of the document to better understand their utility.

2. Conventions used in this document

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

In this document, these words will appear with that interpretation only when in ALL CAPS. Lower case uses of these words are not to be interpreted as carrying RFC-2119 significance.

In this document, the characters ">>" preceding an indented line(s) indicates a compliance requirement statement using the key words listed above. This convention aids reviewers in quickly identifying or finding the explicit compliance requirements of this RFC.

3. Flexi-grid network topology model overview

YANG is a data modeling language used to model configuration data manipulated by the NETCONF protocol. Several YANG models have already been specified for network configurations. For instance, the work in [I-D.draft-ietf-i2rs-yang-network-topo] has proposed a generic YANG model for network/service topologies and inventories. The work in [I-D.draft-ietf-teas-yang-te-topo] presents a data model to represent, retrieve and manipulate Traffic Engineering (TE) Topologies. These models serve as base models that other technology specific models can augment. A YANG model has also been proposed in [I-D.draft-dharini-ccamp-dwdm-if-yang] to manage single channel

optical interface parameters of DWDM applications, and in

[I-D.draft-ietf-ccamp-wson-yang] another model has been specified for the routing and wavelength assignment TE topology in wavelength switched optical networks (WSONs). None of them are specific for flexi-grid technology.

Then, as stated before, we propose a model to describe a flexi-grid topology that is split in two YANG sub-modules:

- Flexi-grid-TED: In order to be compatible with existing proposals, we augment the definitions contained in [I-D.draft-ietf-i2rs-yang-network-topo] and [I-D.draft-ietf-teas-yang-te-topo], by defining the different elements we find in a flexi-grid network: a node, a transponder and a link. For that, each of those elements is defined as a container that includes a group of attributes. References to the elements are provided to be later used in the definition of a media channel. It also includes the data types for the type of modulation, the flexi-grid technology, the FEC, etc.
- Media-channel: This module defines the whole path from a source transponder to the destination through a number of intermediate nodes and links. For this, it takes the information defined before in the flexi-grid TED.

  The following section provides a detailed view of each module.

4. Main building blocks

Subsections below detail each of the defined YANG modules. They are listed in Appendix A.

4.1. Flexi-grid TED

The description of the three main components, flexi-grid-node, flexi-grid-transponder and flexi-grid-link is provided below. flexi-grid-sliceable-transponders are also defined.

<flexi-grid-node> ::= <config> <state>

    <flexi-grid-node>: This element designates a node in the network.

    <config> ::= <flexi-grid-node-attributes-config>

        <config>: Contains the configuration of a node.
        <flexi-grid-node-attributes-config> ::= <list-interface>
        <connectivity_matrix>

            <flexi-grid-node-attributes-config>: Contains all the

attributes related to the node configuration, such as its interfaces or its management addresses.

<list-interface> ::= <name> <port-number>
<input-port> <output-port> <description>
<interface-type>
[<numbered-interface> / <unnumbered-interface>]

<list-interface>: The list containing all the information of the interfaces.

<name>: Determines the interface name.

<port-number>: Port number of the interface.

<input-port>: Boolean value that defines whether the interface is input or not.

<output-port>: Boolean value that defines whether the interface is output or not.

<description>: Description of the usage of the interface.

<interface-type>: Determines if the interface is numbered or unnumbered.

<numbered-interface> ::= <n-i-ip-address>

<numbered-interface>: An interface with its own IP address.

<n-i-ip-address>: Only available if <interface-type> is "numbered-interface". Determines the IP address of the interface.

<unnumbered-interface> ::= <u-i-ip-address>
<label>

<unnumbered-interface>: A interface that needs a label to be unique.

<u-i-ip-address>: Only available if <interface-type> is "numbered-interface". Determines the node IP address, which with the label defines the interface.

<label>: Label that determines the interface, joint with the node IP address.

<connectivity-matrix> ::= <connections>

<connectivity-matrix>: Determines whether a

connection port in/port out exists.

<connections> ::= <input-port-id>
<output-port-id>

```
          <state> ::= <flexi-grid-node-attributes-config>
          <flexi-grid-node-attributes-state>

              <state>: Contains the state of a node.

              <flexi-grid-node-attributes-config>: See above.

              <flexi-grid-node-attributes-state>: Contain all the
              attributes related to the state of a node.

   <flexi-grid-transponder> ::= <config> <state>
       <config> ::= <flexi-grid-transponder-attributes-config>

          <config>: Contains the configuration of a transponder.

          <flexi-grid-transponder-attributes-config> ::=
          <available-modulation> <modulation-type>
          <available-FEC> <FEC-enabled> [<FEC-type>]

              <flexi-grid-transponder-attributes>: Contains all the
              attributes related to the transponder, such as whether
              it has FEC enabled or not, or its modulation type.

                 <available-modulation>: It provides a list of the
                 modulations available at this transponder.

                 <modulation-type>: Determines the type of modulation
                 in use: QPSK, QAM16, QAM64...

                 <available-FEC>: It provides a list of the FEC
                 algorithms available at this transponder.

                 <FEC-enabled>: Boolean value that determines whether
                 is the FEC enabled or not.

               <FEC-type>: Determines the type of FEC in use:
               reed-solomon, hamming-code, enum golay, BCH...

        <state> ::= <flexi-grid-transponder-attributes-config>
        <flexi-grid-transponder-attributes-state>

            <state>: Contains the state of a transponder.

            <flexi-grid-transponder-attributes-config>: See above.

            <flexi-grid-transponder-attributes-state>: Contains the
            state of a transponder.
```

```
   <flexi-grid-sliceable-transponder> ::= <config> <state>

       <flexi-grid-sliceable-transponder>: A list of transponders.

       <config> ::= <flexi-grid-transponder-attributes-config>
       <flexi-grid-sliceable-transponder-attributes-config>

           <flexi-grid-transponder-attributes-config>: See above.

           <flexi-grid-sliceable-transponder-attributes-config> ::=
           <transponder-list>

               <flexi-grid-sliceable-transponder-attributes-config>:
               Contains the configuration of a sliceable transponder

               <transponder-list> ::= <carrier-id>
                   <transponder-list>: A list of transponders.

                   <carrier-id>: An identifier for each one of the
                   transponders in the list.

       <state> ::= <flexi-grid-transponder-attributes-state>
       <flexi-grid-sliceable-transponder-attributes-state>
       <flexi-grid-transponder-attributes-config>
       <flexi-grid-sliceable-transponder-attributes-config>

           <state>: Contains the state of a sliceable transponder.

           <flexi-grid-transponder-attributes-state>: See above.

           <flexi-grid-sliceable-transponder-attributes-state>:
           Contains the state attributes of a sliceable transponders.

           <flexi-grid-transponder-attributes-config>: See above.

           <flexi-grid-sliceable-transponder-attributes-config>: See
           above.



    <link> ::= <config> <state>

        <link>: This element describes all the information of a link.

        <config> ::= <flexi-grid-link-attributes-config>

            <config>: Contains the configuration of a link.

            <flexi-grid-link-attributes-config> ::= <technology-type>
            <available-label-flexi-grid> <N-max> <base-frequency>
            <nominal-central-frequency-granularity>
```

<slot-width-granularity>

<flexi-grid-link-attributes>: Contains all the attributes related to the link, such as its unique id, its N value, its latency, etc.

<link-id>: Unique id of the link.

<available-label-flexi-grid>: Array of bits that determines, with each bit, the availability of each interface for flexi-grid technology.

<N-max>: The max value of N in this link, being N the number of slots.

<base-frequency>: The default central frequency used in the link.

<nominal-central-frequency-granularity>: It is the spacing between allowed nominal central frequencies and it is set to 6.25 GHz (note: sometimes referred to as 0.00625 THz).

<slot-width-granularity>: 12.5 GHz, as defined in G.694.1.

<state> ::= <flexi-grid-link-attributes-config> <flexi-grid-link-attributes-state>

<state>: Contains the state of a link.

<flexi-grid-link-attributes-config>: See above.

<flexi-grid-link-attributes-state>: Contains all the the information related to the state of a link.

4.2. Media-channel/network-media-channel

The model defines two types of media channels, following the terminology summarized in [RFC7698]:
media-channel, which represents a (effective) frequency slot supported by a concatenation of media elements (fibers, amplifiers, filters, switching matrices...);
network-media-channel: It is a media channel that transports an Optical Tributary Signal. In the model, the network media channel has as end-points transponders, which are the source and destination of the optical signal. The description of these components is provided below:

<media-channel> ::= <source> <destination> <link-channel> <effective-freq-slot>

<media-channel>: Determines a media-channel and its components.

<source > ::= <source-node> <source-port>

<source>: In a media-channel, the source is a node and a port.

<source-node>: Reference to the source node of the media channel.

<source-port>: Reference to the source port in the source <node.

<destination> ::= <destination-node> <destination-port>

<destination>: In a media-channel, the destination is a node and a port.

<destination-node>: Reference to the destination node of the media channel.

<destination-port>: Reference to the destination port in the destination node.

<link-channel> ::= <link-id> <N> <M> <source-node> <source-port> <destination-node> <destination-port> <link> <bidirectional>

<link-channel>: Defines a list with each of the links between elements in the media channel.

<link-id>: Unique identifier for the link channel

<N>: N used for this link channel.

<M>: M used for this link channel.

<source-node>: Reference to the source node of this link channel.

<source-port>: Reference to the source port of this link channel.

<destination-node>: Reference to the destination node of this link channel.

<destination-port>: Reference to the destination port of this link channel.

<link>: Reference to the link of this link channel.

<bidirectional>: Indicates if this link is bidirectional or not.

<effective-freq-slot> ::= <N> <M>

<effective-freq-slot>: Defines the effective frequency slot of the media channel, which could be different from the one defined in the link channels.

<N>: Defines the effective N for this media channel.

<M>: Defines the effective M for this media channel.

<network-media-channel> ::= <source> <destination> <link-channel> <effective-freq-slot>

<network-media-channel>: Determines a network media-channel and its components.

<source > ::= <source-node> <source-transponder>

<source>: In a network media channel, the source is defined by a node and a transponder.

<source-node>: Reference to the source node of the media channel.

<source-transponder>: Reference to the source transponder in the source node.

<destination> ::= <destination-node> <destination-transponder>

<destination>: In a network media channel, the destination is defined by a node and a transponder

<destination-node>: Reference to the destination node of the media channel.

<destination-port>: Reference to the destination port in the destination node.

<link-channel>: See above, the information is reused for both types of media channels.

<effective-freq-slot>: See above, this information is reused for both types of media channels.

5. Example of use

In order to explain how this model is used, we provide the following example. An optical network usually has multiple transponders, switches (nodes) and links between them. Figure 1 shows a simple topology, where two physical paths interconnect two optical transponders.

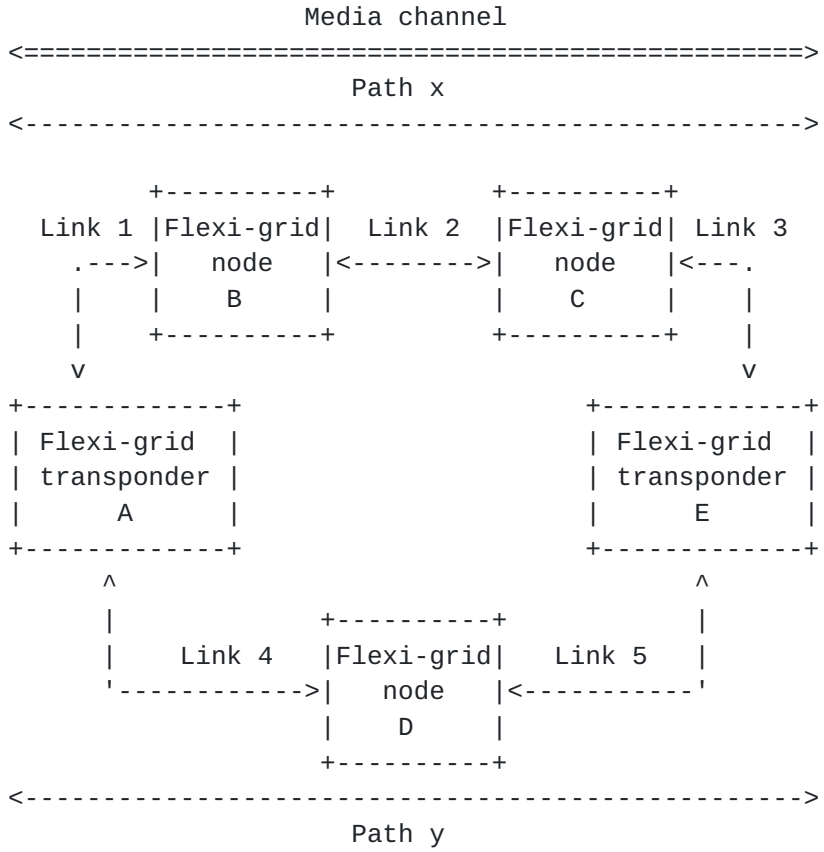

Figure 1. Topology example.

In order to configure a media channel to interconnect transponders A and E, first of all we have to populate the flexi-grid TED YANG model with all elements in the network:

1. We define the transponders A and E, including their FEC type, if enabled, and modulation type. We also provide node identifiers and addresses for the transponders, as well as interfaces included in the transponders. Sliceable transponders can also be defined if needed.

2. We do the same for the nodes B, C and D, providing their identifiers, addresses and interfaces, as well as the internal connectivity matrix between interfaces.

3. Then, we also define the links 1 to 5 that interconnect nodes and transponders, indicating which flexi-grid labels are available. Other information, such as the slot frequency and granularity are also provided.

Next, we can configure the media channel from the information we have stored in the flexi-grid TED, by querying which elements are available, and planning the resources that have to be provided on each situation. Note that every element in the flexi-grid TED has a reference, and this is the way in which they are called in the media channel.

4. Depending on the case, it is possible to define either the source and destination node ports, or the source and destination node and transponder. In our case, we would define a network media channel, with source transponder A and source node B, and destination transponder E and destination node C. Thus, we are going to follow path x.

5. Then, for each link in the path x, we indicate which channel we are going to use, providing information about the slots, and what nodes are connected.

Finally, the flexi-grid TED has to be updated with each element usage status each time a media channel is created or torn down.

6. Formal Syntax

The following syntax specification uses the augmented Backus-Naur Form (BNF) as described in [RFC5234].

7. Security Considerations

The transport protocol used for sending the managed information MUST support authentication and SHOULD support encryption.

The defined data-model by itself does not create any security implications.

8. IANA Considerations

The namespace used in the defined models is currently based on the IDEALIST project URI. Future versions of this document could register a URI in the IETF XML registry [RFC3688], as well as in the YANG Module Names registry [RFC6020].

9. References

9.1. Normative References

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

[RFC5234] Crocker, D. and P. Overell, "Augmented BNF for Syntax Specifications: ABNF", STD 68, RFC 5234, January 2008, <http:/www.rfc-editor.org/info/rfc5234>.

[RFC6020] Bjorklund, M., Ed., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", RFC 6020, October 2010.

[RFC3688] Mealling, M., "The IETF XML Registry", BCP 81, RFC 3688, January 2004.

9.2. Informative References

[RFC7698] Gonzalez de Dios, O., Casellas, R., "Framework and Requirements for GMPLS-Based Control of Flexi-Grid Dense Wavelength Division Multiplexing (DWDM) Networks", RFC7698, November 2015.

[I-D.draft-ietf-i2rs-yang-network-topo] Clemm, A., Medved, J., Varga, R., Tkacik, T., Bahadur, N., Ananthakrishnan, H., Liu, X., "A Data Model for Network Topologies", Internet Draft draft-ietf-i2rs-yang-network-topo-03.txt, 2016.

[I-D.draft-ietf-teas-yang-te-topo] Liu, X., Bryskin, I., Pavan Beeram, V., Saad, T., Shah, H., Gonzalez De Dios, O., "YANG Data Model for TE Topologies", Internet Draft draft-ietf-teas-yang-te-topo-04.txt, 2016

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10. Contributors

The model presented in this paper was contributed to by more people than can be listed on the author list. Additional contributors include:

- Daniel Michaud Vallinoto, Universidad Autonoma de Madrid
- Daniel Perdices Burrero, Universidad Autonoma de Madrid

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Appendix A. YANG models

A.1. Flexi-grid TED YANG Model

A.1.1. Yang Model - Tree Structure

```
module: ietf-flexi-grid-topology
flexi-grid-network-type
   augment /nd:networks/nd:network/nd:network-types:
      +--rw flexi-grid-network!
flexi-grid-link-attributes-config
   augment /nd:networks/nd:network/lnk:link/tet:te/tet:config:
      +--rw available-label-flexi-grid*              bits
      +--rw N-max?                                   int32
      +--rw base-frequency?                          decimal64
      +--rw nominal-central-frequency-granularity?   decimal64
      +--rw slot-width-granularity?                  decimal64
flexi-grid-link-attributes-state
   augment /nd:networks/nd:network/lnk:link/tet:te/tet:state:
      +--ro available-label-flexi-grid*              bits
      +--ro N-max?                                   int32
      +--ro base-frequency?                          decimal64
      +--ro nominal-central-frequency-granularity?   decimal64
      +--ro slot-width-granularity?                  decimal64
flexi-grid-node-attributes-config
   augment /nd:networks/nd:network/nd:node/tet:te/tet:config:
      +--rw interfaces* [name]
         +--rw name                    string
         +--rw port-number?            uint32
         +--rw input-port?             boolean
         +--rw output-port?            boolean
         +--rw description?            string
         +--rw type?                   interface-type
         +--rw numbered-interface
         |  +--rw n-i-ip-address?   inet:ip-address
         +--rw unnumbered-interface
            +--rw u-i-ip-address?   inet:ip-address
            +--rw label?            uint32
```

```
   flexi-grid-node-attributes-state
      augment /nd:networks/nd:network/nd:node/tet:te/tet:state:
         +--ro interfaces* [name]
            +--ro name                    string
            +--ro port-number?            uint32
            +--ro input-port?             boolean
            +--ro output-port?            boolean
            +--ro description?            string
            +--ro type?                   interface-type
            +--ro numbered-interface
            |  +--ro n-i-ip-address?   inet:ip-address
            +--ro unnumbered-interface
               +--ro u-i-ip-address?   inet:ip-address
               +--ro label?            uint32
   flexi-grid-connectivity-matrix-attributes
      augment /nd:networks/nd:network/nd:node/tet:te/tet:config/
      tet:te-node-attributes/tet:connectivity-matrix:
         +--rw connections* [input-port-id]
            +--rw input-port-id     flexi-grid-node-port-ref
            +--rw output-port-id?   flexi-grid-node-port-ref
   flexi-grid-connectivity-matrix-attributes
      augment /nd:networks/nd:network/nd:node/tet:te/tet:state/
      tet:te-node-attributes/tet:connectivity-matrix:
         +--ro connections* [input-port-id]
            +--ro input-port-id     flexi-grid-node-port-ref
            +--ro output-port-id?   flexi-grid-node-port-ref
   flexi-grid-transponder
      augment /nd:networks/nd:network/nd:node:
         +--rw config
         |  +--rw available-modulation*   modulation
         |  +--rw modulation-type?        modulation
         |  +--rw available-FEC*          FEC
         |  +--rw FEC-enabled?            boolean
         |  +--rw FEC-type?               FEC
         +--rw state
         |  +--rw available-modulation*   modulation
         |  +--rw modulation-type?        modulation
         |  +--rw available-FEC*          FEC
         |  +--rw FEC-enabled?            boolean
         |  +--rw FEC-type?               FEC
         +--rw node-type?   flexi-grid-node-type
```

```
   flexi-grid-sliceable-transponder
      augment /nd:networks/nd:network/nd:node:
         +--rw config
         |  +--rw available-modulation*   modulation
         |  +--rw modulation-type?        modulation
         |  +--rw available-FEC*          FEC
         |  +--rw FEC-enabled?            boolean
         |  +--rw FEC-type?               FEC
         |  +--rw transponder-list* [carrier-id]
         |     +--rw carrier-id           uint32
         +--rw state
         |  +--rw available-modulation*   modulation
         |  +--rw modulation-type?        modulation
         |  +--rw available-FEC*          FEC
         |  +--rw FEC-enabled?            boolean
         |  +--rw FEC-type?               FEC
         +--rw node-type?   flexi-grid-node-type
```

A.1.2. YANG Model - Code

```
   <CODE BEGINS> file "ietf-flexi-grid-ted.yang"

module ietf-flexi-grid-ted {
  yang-version 1.1;

  namespace "urn:ietf:params:xml:ns:yang:ietf-flexi-grid-ted";
  prefix "fg-topo";

  import ietf-network {
    prefix "nd";
  }

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

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

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

```
  organization
         "IETF CCAMP Working Group";

      contact
         "Editor: Jorge Lopez de Vergara
                  <jorge.lopez_vergara@uam.es>";

      description
         "This module contains a collection of YANG definitions for
         a Flexi-Grid Traffic Engineering Database (TED).

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

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

      revision 2016-07-08 {
         description
            "version 4.";

         reference
             "RFC XXX: A Yang Data Model for
             Flexi-Grid Optical Networks ";
      }

  /*
  typedef
  */

   typedef flexi-grid-node-type {
         type enumeration {
             enum flexi-grid-node {
                description
                   "Flexi-grid node";
             }
             enum flexi-grid-transponder {
                description
                   "Flexi-grid transponder";
             }
             enum flexi-grid-sliceable-transponder {
                description
                   "Flexi-grid sliceable transponder";
             }
```

```
        }
```

```
        description "Determines the node type:
            flexi-grid-node,
            flexi-grid-transponder or
            flexi-grid-sliceable-transponder";
   }

  typedef modulation {
        type enumeration {
           enum QPSK {
               description
               "QPSK (Quadrature Phase Shift Keying) modulation";
               }
           enum DP_QPSK {
               description "DP-QPSK (Dual Polarization Quadrature
               Phase Shift Keying) modulation";
               }
           enum QAM16 {
               description "QAM16 (Quadrature Amplitude Modulation
               - 4 bits per symbol) modulation";
               }
           enum DP_QAM16 {
               description "DP-QAM16 (Dual Polarization
               Quadrature Amplitude Modulation - 4 bits per
               symbol) modulation";
               }
           enum DC_DP_QAM16 {
               description "DC DP-QAM16 (Dual Polarization
               Quadrature Amplitude Modulation - 4 bits per
               symbol) modulation";
               }
        }
        description
           "Enumeration that defines the type of wave modulation";
   }

   typedef FEC {
        type enumeration {
           enum reed-solomon {
               description "Reed-Solomon error correction";
           }
           enum hamming-code{
               description "Hamming Code error correction";
           }
           enum golay{
               description "Golay error correction";
           }
        }
        description "Enumeration that defines the type of
```

```
          Forward Error Correction";
    }
```

```
   typedef interface-type {
         type enumeration {
            enum numbered-interface {
                description "The interface is numbered";
            }
            enum unnumbered-interface {
                description "The interface is unnumbered";
            }
         }
         description
            "Enumeration that defines if an interface is numbered or
            unnumbered";
   }

   /*
      Typedef related to references
   */

   typedef flexi-grid-transponder-ref {
         type leafref {
            path
             "/nd:networks/nd:network/nd:node/nd:node-id";
         }
         description
            "This type is used by data models that need to reference
            a flexi-grid optical transponder.";
      }

      typedef flexi-grid-node-ref {
         type leafref {
            path
             "/nd:networks/nd:network/nd:node/tet:te/tet:te-node-id";
         }
         description
            "This type is used by data models that need to reference
            a flexi-grid optical node.";
      }

      typedef flexi-grid-link-ref {
         type leafref {
            path
               "/nd:networks/nd:network/lnk:link/lnk:link-id";
         }

         description
            "This type is used by data models that need to reference
            a flexi-grid optical link.";
      }
```

```
      typedef flexi-grid-node-port-ref {
         type leafref {
            path "/nd:networks/nd:network/nd:node/tet:te/tet:config/"
            +"fg-topo:interfaces/fg-topo:port-number";
         }
         description
            "This type is used by data models that need to reference
            a flexi-grid optical link.";
      }

  /*
  Groupings
  */

   grouping flexi-grid-network-type {
         container flexi-grid-network {
            presence "indicates a flexi-grid optical network";
            description "flexi-grid optical network";
         }
         description "If present, it indicates a flexi-grid
         optical TED network";
   }

   grouping flexi-grid-node-attributes-config {
         description "Set of attributes of an optical node.";

         list interfaces {
            key "name";
            unique "port-number";
            description "List of interfaces contained in the node";
            leaf name {
               type string;
               description "Interface name";
            }
            leaf port-number {
               type uint32;
               description "Number of the port used by the interface";
            }
            leaf input-port {
               type boolean;
               description "Determines if the port is an input port";
            }
            leaf output-port {
               type boolean;
               description
               "Determines if the port is an output port";
            }
            leaf description {
```

```
            type string;
            description "Description of the interface";
          }
```

```
            leaf type {
               type interface-type;
               description "Determines the type of the interface";
            }
            container numbered-interface {
               when "type == numbered-interface" {
                 description
                 "If the interface is a numbered interface";
               }
               description "Container that defines an numbered
               interface with an ip-address";
               leaf n-i-ip-address{
                  type inet:ip-address;
                  description "IP address of the numbered interface";
               }
            }
            container unnumbered-interface {
               when "type == unnumbered-interface" {
                 description
                   "If the interface is an unnumbered interface";
               }
               description "Container that defines an unnumbered
               interface with an ip-address and a label";
               leaf u-i-ip-address{
                  type inet:ip-address;
                  description "IP address of the interface";
               }
               leaf label {
                  type uint32;
                  description "Number as label for the interface";
               }
            }
         }
      }

   grouping flexi-grid-node-attributes-state {
         description "Flexigrid node attributes (state).";
   }
```

```
   grouping flexi-grid-link-attributes-config {
         description "Set of attributes of an optical link";
            leaf-list available-label-flexi-grid {
               type bits {
                  bit is-available{
                    description "Set to 1 when it is available";
                  }
               }
               description
                  "Array of bits that determines whether a spectral
                  slot is available or not.";
            }

            leaf N-max {
               type int32;
               description "Maximum number of channels available.";
            }

            leaf base-frequency {
               type decimal64 {
                  fraction-digits 5;
               }
               units THz;
               default 193.1;
               description "Default central frequency";
               reference "rfc7698";
            }

            leaf nominal-central-frequency-granularity {
               type decimal64 {
                  fraction-digits 5;
               }
               units GHz;
               default 6.25;
               description
                  "It is the spacing between allowed nominal central
                  frequencies and it is set to 6.25 GHz";
               reference "rfc7698";
            }

            leaf slot-width-granularity {
               type decimal64 {
                  fraction-digits 5;
               }
               units GHz;
               description "Minimum space between slot widths";
               reference "rfc7698";
            }
```

```
   }
```

```
   grouping flexi-grid-link-attributes-state {
      description "Flexigrid link attributes (state)";
   }

   grouping flexi-grid-transponder-attributes-config {
      description "Configuration of an optical transponder";
      leaf-list available-modulation {
         type modulation;
         description
            "List determining all the available modulations";
      }
      leaf modulation-type {
         type modulation;
         description "Modulation type of the wave";
      }
      leaf-list available-FEC {
         type FEC;
         description "List determining all the available FEC";
      }
      leaf FEC-enabled {
         type boolean;
         description
            "Determines whether the FEC is enabled or not";
      }
      leaf FEC-type {
         type FEC;
         description "FEC type of the transponder";
      }
   }

   grouping flexi-grid-transponder-attributes-state {
      description "State of an optical transponder";
   }

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

   grouping flexi-grid-sliceable-transponder-attributes-state {
```

```
      description "State of a sliceable transponder.";
      uses flexi-grid-transponder-attributes-state;
   }
```

```
   grouping flexi-grid-connectivity-matrix-attributes {
      description "Connectivity matrix between the input and
          output ports";
      list connections {
         key "input-port-id";
         leaf input-port-id {
            type flexi-grid-node-port-ref;
            description "Identifier of the input port";
         }
         leaf output-port-id {
            type flexi-grid-node-port-ref;
            description "Identifier of the output port";
         }
         description "List of connections between input and
          output ports";
      }
   }

  /*
   * Data nodes
   */

   augment "/nd:networks/nd:network/nd:network-types" {
            uses flexi-grid-network-type;
             description "Augment network-types including flexi-grid
             topology";
   }

  augment "/nd:networks/nd:network/lnk:link/tet:te/tet:config" {
    when "/nd:network-types/tet:te-topology/flexi-grid-network" {
      description "Augment only for Flexigrid network.";
    }
    description "Augment link configuration";

    uses flexi-grid-link-attributes-config;
  }

  augment "/nd:networks/nd:network/lnk:link/tet:te/tet:state" {
    when "nd:network-types/tet:te-topology/flexi-grid-network" {
      description "Augment only for Flexigrid network.";
    }
    description "Augment link state";

    uses flexi-grid-link-attributes-config;
    uses flexi-grid-link-attributes-state;
  }
```

```
   augment "/nd:networks/nd:network/nd:node/tet:te/tet:config"  {
      when "nd:network-types/tet:te-topology/flexi-grid-network" {
         description "Augment only for Flexigrid network.";
      }
      uses flexi-grid-node-attributes-config;
      description "Augment node config with flexi-grid attributes";
   }

   augment "/nd:networks/nd:network/nd:node/tet:te/tet:state"  {
      when "nd:network-types/tet:te-topology/flexi-grid-network" {
         description "Augment only for Flexigrid network.";
      }
      uses flexi-grid-node-attributes-config;
      uses flexi-grid-node-attributes-state;
      description "Augment node config with flexi-grid attributes";
   }

   augment "/nd:networks/nd:network/nd:node/tet:te/tet:config"+
         "/tet:te-node-attributes/tet:connectivity-matrix" {
       when "nd:network-types/tet:te-topology/flexi-grid-network"{
          description "Augment only for Flexigrid network.";
       }

      uses flexi-grid-connectivity-matrix-attributes;
      description "Augment node connectivity-matrix for node config";
    }

    augment "/nd:networks/nd:network/nd:node/tet:te/tet:state"+
         "/tet:te-node-attributes/tet:connectivity-matrix" {
       when "nd:network-types/tet:te-topology/flexi-grid-network"{
          description "Augment only for Flexigrid network.";
       }

      uses flexi-grid-connectivity-matrix-attributes;
      description "Augment node connectivity-matrix for node config";
    }
```

```
   /*
   Elements out of TE
   */

   augment "/nd:networks/nd:network/nd:node" {
      when "nd:network-types/tet:te-topology/flexi-grid-network"{
          description "Augment only for Flexigrid network.";
       }

       container config {
          description "Configuration of either a transponder or
          a sliceable transponder";

       }

       container state {
        description "State of either a transponder or
        a sliceable transponder";

       }

       leaf node-type {
            type flexi-grid-node-type;
            description "Type of flexi-grid node";
      }

       description "Augment node with configuration and state
       for transponder";
   }

   augment "/nd:networks/nd:network/nd:node/fg-topo:config" {
      when "/nd:networks/nd:network/nd:node/fg-topo:node-type/
              fg-topo:flexi-grid-transponder|/nd:networks/
              nd:network/nd:node/fg-topo:node-type/
              fg-topo:flexi-grid-sliceable-transponder"{
          description "When it is either a flexi-grid transponder
           or a sliceable transponder";
      }
      uses flexi-grid-transponder-attributes-config;
      description "Augment node state with transponder attributes";
   }
```

```
   augment "/nd:networks/nd:network/nd:node/fg-topo:state" {
      when "/nd:networks/nd:network/nd:node/fg-topo:node-type/
              fg-topo:flexi-grid-transponder|/nd:networks/
              nd:network/nd:node/fg-topo:node-type/
              fg-topo:flexi-grid-sliceable-transponder"{
          description "When it is either a flexi-grid transponder
           or a sliceable transponder";
      }
      uses flexi-grid-transponder-attributes-state;
      uses flexi-grid-transponder-attributes-config;
      description "Augment node state with transponder attributes";
   }

   augment "/nd:networks/nd:network/nd:node/fg-topo:config" {
      when "/nd:networks/nd:network/nd:node/fg-topo:node-type/
              fg-topo:flexi-grid-sliceable-transponder"{
          description
              "When it is a flexi-grid sliceable transponder";
      }
      uses flexi-grid-sliceable-transponder-attributes-config;
      description "Augment node with sliceable transponder
          attributes";
   }

   augment "/nd:networks/nd:network/nd:node/fg-topo:state" {
      when "/nd:networks/nd:network/nd:node/fg-topo:node-type/
              fg-topo:flexi-grid-sliceable-transponder"{
          description
              "When it is a flexi-grid sliceable transponder";
    }
    uses flexi-grid-sliceable-transponder-attributes-state;
    uses flexi-grid-sliceable-transponder-attributes-config;
    description "Augment node with sliceable transponder
        attributes";
   }
}

   <CODE ENDS>
```

A.2. Media Channel YANG Model

A.2.1. YANG Model - Tree

```
module: ietf-flexi-grid-media-channel
   +--rw media-channel
   |  +--rw source
   |  |  +--rw source-node?   fg-ted:flexi-grid-node-ref
   |  |  +--rw source-port?   fg-ted:flexi-grid-node-port-ref
   |  +--rw destination
   |  |  +--rw destination-node?   fg-ted:flexi-grid-node-ref
   |  |  +--rw destination-port?   fg-ted:flexi-grid-node-port-ref
   |  +--rw effective-freq-slot
   |  |  +--rw N?   int32
   |  |  +--rw M?   int32
   |  +--rw link-channel* [link-id]
   |     +--rw link-id             int32
   |     +--rw N?                  int32
   |     +--rw M?                  int32
   |     +--rw source-node?        fg-ted:flexi-grid-node-ref
   |     +--rw source-port?        fg-ted:flexi-grid-node-port-ref
   |     +--rw destination-node?   fg-ted:flexi-grid-node-ref
   |     +--rw destination-port?   fg-ted:flexi-grid-node-port-ref
   |     +--rw link?               fg-ted:flexi-grid-link-ref
   |     +--rw bidireccional?      boolean
   +--rw network-media-channel
      +--rw source
      |  +--rw source-node?          fg-ted:flexi-grid-node-ref
      |  +--rw source-transponder?   fg-ted:flexi-grid-transponder-ref
      +--rw destination
      |  +--rw destination-node?          fg-ted:flexi-grid-node-ref
      |  +--rw destination-transponder?
      |            fg-ted:flexi-grid-transponder-ref
      +--rw effective-freq-slot
      |  +--rw N?   int32
      |  +--rw M?   int32
      +--rw link-channel* [link-id]
         +--rw link-id             int32
         +--rw N?                  int32
         +--rw M?                  int32
         +--rw source-node?        fg-ted:flexi-grid-node-ref
         +--rw source-port?        fg-ted:flexi-grid-node-port-ref
         +--rw destination-node?   fg-ted:flexi-grid-node-ref
         +--rw destination-port?   fg-ted:flexi-grid-node-port-ref
         +--rw link?               fg-ted:flexi-grid-link-ref
         +--rw bidireccional?      boolean
```

A.2.2. YANG Model - Code

```
   <CODE BEGINS> file "ietf-flexi-grid-media-channel.yang"

module ietf-flexi-grid-media-channel {
   yang-version 1;

   namespace
     "urn:ietf:params:xml:ns:yang:ietf-flexi-grid-media-channel";
   prefix fg-mc;

   import ietf-flexi-grid-ted {
      prefix fg-ted;
   }

   organization
      "IETF CCAMP Working Group";

   contact
      "Editor: Jorge Lopez de Vergara
               <jorge.lopez_vergara@uam.es>";

   description
      "This module contains a collection of YANG definitions for
      a Flexi-Grid media channel.

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      authors of the code.  All rights reserved.

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

   revision 2016-07-08 {
      description
         "version 4.";

      reference
         "RFC XXX: A Yang Data Model for Flexi-Grid Optical
         Networks ";
   }
```

```
   container media-channel {
      description
         "Media association that represents both the topology
         (i.e., path through the media) and the resource
         (frequency slot) that it occupies.  As a topological
         construct, it represents a (effective) frequency slot
         supported by a concatenation of media elements (fibers,
         amplifiers, filters, switching matrices...).  This term
         is used to identify the end-to-end physical layer entity
         with its corresponding (one or more) frequency slots
         local at each link filters.";
      reference "rfc7698";
      container source {
         description "Source of the media channel";
         leaf source-node {
            type fg-ted:flexi-grid-node-ref;
            description "Source node";
         }
         leaf source-port {
            type fg-ted:flexi-grid-node-port-ref;
            description "Source port";
          }
      }
      container destination {
         description "Destination of the media channel";
         leaf destination-node {
            type fg-ted:flexi-grid-node-ref;
            description "Destination node";
         }
         leaf destination-port {
            type fg-ted:flexi-grid-node-port-ref;
            description "Destination port";
         }
      }
      uses media-channel-attributes;
   }
   container network-media-channel {
      description
         "It is a media channel that transports an Optical
         Tributary Signal ";
      reference "rfc7698";
      container source {
         description "Source of the network media channel";
         leaf source-node {
            type fg-ted:flexi-grid-node-ref;
            description "Source node";
         }
         leaf source-transponder {
```

```
            type fg-ted:flexi-grid-transponder-ref;
            description "Source transponder";
          }
        }
```

```
      container destination {
         description "Destination of the network media channel";
         leaf destination-node {
            type fg-ted:flexi-grid-node-ref;
            description "Destination node";
         }
         leaf destination-transponder {
            type fg-ted:flexi-grid-transponder-ref;
            description "Destination transponder";
         }
      }
      uses media-channel-attributes;
   }

   grouping media-channel-attributes {
      description "Set of attributes of a media channel";
      container effective-freq-slot {
         description
            "The effective frequency slot is an attribute of
            a media channel and, being a frequency slot, it is
            described by its nominal central frequency and slot
            width";
         reference "rfc7698";
         leaf N {
            type int32;
            description
               "Is used to determine the Nominal Central
               Frequency. The set of nominal central frequencies
               can be built using the following expression:
                  f = 193.1 THz + n x 0.00625 THz,
               where 193.1 THz is ITU-T ''anchor frequency'' for
               transmission over the C band, n is a positive or
               negative integer including 0.";
            reference "rfc7698";
         }
         leaf M {
            type int32;
            description
               "Is used to determine the slot width. A slot width
               is constrained to be M x SWG (that is, M x 12.5 GHz),
               where M is an integer greater than or equal to 1.";
            reference "rfc7698";
         }
      }
```

```
      list link-channel {
         key "link-id";
         description
             "A list of the concatenated elements of the media
             channel.";
         leaf link-id {
            type int32;
            description "Identifier of the link";
         }
         uses link-channel-attributes;
      }
   }

   grouping link-channel-attributes {
      description
         "A link channel is one of the concatenated elements of
         the media channel.";
      leaf N {
         type int32;
         description
            "Is used to determine the Nominal Central Frequency.
            The set of nominal central frequencies can be built
            using the following expression:
               f = 193.1 THz + n x 0.00625 THz,
            where 193.1 THz is ITU-T ''anchor frequency'' for
            transmission over the C band, n is a positive or
            negative integer including 0.";
         reference "rfc7698";
      }
      leaf M {
         type int32;
            description
               "Is used to determine the slot width. A slot
               width is constrained to be M x SWG (that is,
               M x 12.5 GHz), where M is an integer greater than
               or equal to 1.";
            reference "rfc7698";
      }
      leaf source-node {
         type fg-ted:flexi-grid-node-ref;
         description "Source node of the link channel";
      }
      leaf source-port {
         type fg-ted:flexi-grid-node-port-ref;
         description "Source port of the link channel";
      }
      leaf destination-node {
         type fg-ted:flexi-grid-node-ref;
```

```
         description "Destination node of the link channel";
      }
```

```
      leaf destination-port {
         type fg-ted:flexi-grid-node-port-ref;
         description "Destination port of the link channel";
      }
      leaf link {
         type fg-ted:flexi-grid-link-ref;
         description "Link of the link channel";
      }
      leaf bidireccional {
         type boolean;
         description
            "Determines whether the link is bidireccional or
            not";
      }
   }
}
```

<CODE ENDS>

A.3. License

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