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A YANG data model for WSON and Flexi-Grid Optical Networks
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Abstract

This document defines a YANG model for managing dynamic Optical networks, including Wavelength Switched Optical Networks (WSON) and Flexi-Grid DWDM Networks. The model described in this document is composed of two submodels: one to define an optical traffic engineering database, and other one to describe the optical 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 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 model presented in this document considers two different optical technologies: Wavelength Switched Optical Networks (WSON) [1] and flexi-grid DWDM Networks [2]. The YANG model allows the representation of the optical layer of a network, combined with the underlying physical layer. The model is defined in two YANG modules:

o Optical-TED (Traffic Engineering Database): This module defines all the information needed to represent an optical node, an optical transponder and an optical link.

o Media-channel: This module defines the whole path from a source transponder to the destination through a number of intermediate nodes.

This document identifies the WSON and Flexi-Grid optical components, parameters and their values, characterizes the features and the performances of the optical 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 RFC-2119 [3].

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. Optical network topology model overview

YANG is a data modeling language used to model configuration data manipulated by the NETCONF protocol. For more information on YANG, the document [9] provides a tutorial with some examples on how to model the information and use the YANG structures.

Several YANG models have already been specified for network configurations. For instance, the work in [4] has proposed a YANG model of a TED, but only covering the IP layer. A YANG model has also been proposed in [5] to configure optical DWDM parameters. On the other hand, a TED has been proposed for optical networks in [10], but this approach did not specify a YANG model to enable its configuration.

As stated before, we propose a model to describe an optical topology that is split in two YANG sub-modules:

- Optical-TED: In order to be compatible with existing proposals, we augment the definitions contained in [4], by defining the different elements we find in an optical 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 optical 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 optical TED.

Next 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, and have been validated using the pyang tool [11].

4.1. Optical TED

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

<optical-node> ::= <optical-node-attributes>

<optical-node>: This element designates a node in the network

<optical-node-attributes> ::= <node-id> <list-interface> <connectivity_matrix>

<optical-node-attributes>: Contains all the attributes related to the node, such as its unique id, its interfaces or its management addresses.

<node-id>: An unique numeric identifier for the node. It is also used as a reference in order to point to it in the media-channel module.

<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>: A 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>

<connections>: The actual connection between an input port and an output port

<input-port-id>: The input port associated with the output port.

<output-port-id>: The output port associated with the input port.

<optical-transponder> ::= <optical-transponder-attributes> <optical-node-attributes>

<optical-transponder>: Determines an optical transponder in the network

<optical-transponder-attributes> ::= <available-modulation> <modulation-type> <available-FEC> <FEC-enabled> [<FEC-type>]

<optical-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...

<optical-node-attributes>: See above, node attributes are reused also for transponders.

<optical-sliceable-transponder> ::= <carrier-id>
<optical-transponder-attributes>

<optical-sliceable-transponder>: Provides a list of transponders.

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

<optical-transponder-attributes>: See above, transponder attributes are reused also for sliceable transponders.

<link> ::= <optical-link-attributes>

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

<optical-link-attributes> ::= <link-id> <technology-type>
<available-label-flexigrid> <available-label-WSON> <N-max>
<base-frequency> <nominal-central-frequency-granularity>
<slot-width-granularity>

<optical-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

<technology-type>: Optical technology used in this link: Flexigrid, WDM50, WDM100...

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

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

4.2. Media-channel/network-media-channel

The model defines two types of media channel, following the terminology summarized in [2]: 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.

```
                   Media channel
<====================================================>
                      Path x
<---------------------------------------------------->

         +---------+          +---------+
  Link 1 | Optical |  Link 2  | Optical | Link 3
    .--->|  node   |<-------->|  node   |<---.
    |    |    B    |          |    C    |    |
    |    +---------+          +---------+    |
    v                                        v
+-------------+                      +-------------+
|   Optical   |                      |   Optical   |
| transponder |                      | transponder |
|      A      |                      |      E      |
+-------------+                      +-------------+
      ^                                    ^
      |            +---------+             |
      |    Link 4  | Optical |   Link 5    |
      '----------->|  node   |<-----------'
                   |    D    |
                   +---------+
<---------------------------------------------------->
                      Path y
```

Figure 1. Topology example.

In order to configure a media channel to interconnect transponders A and E, first of all we have to populate the optical 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. It is also possible sliceable transponders 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 labels are available, both in flexi-grid or WSON. 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 optical 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 optical 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 optical 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 RFC-2234 [6].

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 [7], as well as in the YANG Module Names registry [8].

9. References

9.1. Normative References

[1] Lee, Y., Bernstein, G., "Framework for GMPLS and PCE Control of Wavelength Switched Optical Networks (WSON)", RFC 6163, April 2011.

[2] Gonzalez de Dios, O., Casellas, R., "Framework and Requirements for GMPLS based control of Flexi-grid DWDM networks", draft-ietf-ccamp-flexi-grid-fwk-02, August 2014.

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[4] Clemm, A., Ananthakrishnan, H., Medved, J., Tkacik, T., Varga, R., Bahadur, N., "A YANG Data Model for Network Topologies", Internet Draft draft-clemm-i2rs-yang-network-topo-00.txt, February 2014.

[5] Galimberti, G., Kunze, R., Kam Lam, Hiremagalur, D., Grammel, G., Eds., "A YANG model to manage t optical interface parameters of DWDM applications", Internet Draft, draft-dharini-netmod-g-698-2-yang-00, July 2014.

[6] Crocker, D. and Overell, P.(Editors), "Augmented BNF for Syntax Specifications: ABNF", RFC 2234, Internet Mail Consortium and Demon Internet Ltd., November 1997.

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

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

9.2. Informative References

[9] Schoenwaelder, J., "Network Configuration Management with NETCONF and YANG", IETF 84 - Vancouver, BC, Canada, July 2012.

[10] Gonzalez de Dios, O., Lopez, V., Haya, C., Liou, C., Pan, P., Grammel, G., Antich, J., Fernandez-Palacios, J.P., "Traffic Engineering Database dissemination for Multi-layer SDN orchestration", Proc. European Conference on Optical Communication (ECOC), Mo.4.E.2, Sep 2013.

[11] "Pyang - An extensible YANG validator and converter in python", https://code.google.com/p/pyang/

10. Contributors

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

o Daniel Michaud Vallinoto, Universidad Autonoma de Madrid

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Appendix A. YANG models

A.1. Optical TED YANG Model

```
module optical-TED {

        namespace "http://www.tid.es/idealist";

        prefix o-ted;

        import ietf-inet-types {
                prefix inet;
        }

        import network-topology {
                prefix nt;
        }
        revision 2015-05-04;

        typedef optical-node-type {
                description "Determines the node type: optical-node,
optical-transponder or optical-sliceable-transponder";
                type enumeration {
                        enum optical-node;
```

```
                        enum optical-transponder;

                        enum optical-sliceable-transponder;

                }

        }



        typedef modulation {



                description "Enumeration that defines the type of
   wave modulation";



                type enumeration {

                        enum BPSK;

                        enum DC_DP_BPSK;

                        enum QPSK;

                        enum DP_QPSK;

                        enum QAM16;

                        enum DP_QAM16;

                        enum DC_DP_QAM16;

                }

        }



        typedef optical-technology {
```

```
                  description "Enumeration that defines the type of
   optical technology";


                  type enumeration {

                          enum Flexigrid;

                          enum WDM50;

                          enum WDM100;

                  }

          }


          typedef FEC {


                  description "Enumeration that defines the type of
   FEC";


                  type enumeration {

                          enum reed-solomon;

                          enum hamming-code;

                          enum golay;

                  }

          }
```

```
          typedef interface-type {

                  description "Enumeration that defines if an interface
   is numbered or unnumbered";

                  type enumeration {

                          enum numbered-interfaces;

                          enum unnumbered-interfaces;

                  }

          }

          typedef optical-transponder-ref {

                  type leafref {

                          path "/nt:network-
   topology/nt:topology/nt:node/nt:node-id";

                  }

                  description

                          "This type is used by data models that need
   to reference

                           an optical transponder.";

          }
```

```
        typedef optical-node-ref {

                type leafref {

                        path "/nt:network-
   topology/nt:topology/nt:node/nt:node-id";

                }

                description

                        "This type is used by data models that need
   to reference

                         an optical node.";

        }



        typedef optical-link-ref {

                type leafref {

                        path "/nt:network-
   topology/nt:topology/nt:link/nt:link-id";

                }

                description

                        "This type is used by data models that need
   to reference

                         an optical link.";

        }



        typedef optical-node-port-ref {

                type leafref {
```

```
                        path "/nt:network-
   topology/nt:topology/nt:node/o-ted:interface/o-ted:port-number";

                }

                description

                        "This type is used by data models that need
   to reference

                         an optical link.";

        }






        grouping optical-ted-topology-type {

                container optical-ted-topology {

                        presence "indicates optical TED Topology";

                }

        }


        grouping optical-ted-topology-attributes {

                container optical-ted-topology-attributes {

                        leaf name {

                                description "Name of the topology";

                                type string;

                        }
```

```
   }

          }



          grouping optical-node-type {



                  description "Used to determine the type of the
   optical node.";



                  leaf type {

                          type optical-node-type;

                  }

          }






          grouping optical-node-attributes {



                  description "Set of attributes of an optical node.";



                  list interface {



                          key "name";



                          unique "port-number";
```

```
                          description "List of interfaces contained by
   the node";

                          leaf name {

                                  type string;

                          }

                          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 interfaces-type {

                                type interface-type;

                                description "Determines the type of
   the interface";

                        }


                        container numbered-interface {


                                when "interfaces-type == numbered-
   interfaces";


                                description "Grouping that defines an
   numbered interface with an ip-address";


                                leaf n-i-ip-address{

                                        type inet:ip-address;

                                }

                        }
```

```
                          container unnumbered-interface {

                                  when "interfaces-type == unnumbered-
   interfaces";

                                  description "Grouping that defines an
   unnumbered interface with an ip-address and a label";

                                  leaf u-i-ip-address{
                                          type inet:ip-address;
                                  }
                                  leaf label {
                                          type uint32;
                                  }
                          }
                  }

                  container connectivity-matrix {

                          list connections {

                                  key "input-port-id";
```

```
                                  leaf input-port-id {

                                          type optical-node-port-ref;

                                  }


                                  leaf output-port-id {

                                          type optical-node-port-ref;

                                  }

                          }

                  }

          }


          grouping optical-transponder-attributes {


                  description "Set of attributes 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";

                }



              uses optical-node-attributes;

        }
```

```
        grouping optical-sliceable-transponder-attributes {

                description
                        "Grouping that defines a sliceable
   transponder which is composed by several transponders.";
                list transponder-list {

                        key "carrier-id";

                        leaf carrier-id {
                                type uint32;
                        }

                        uses optical-transponder-attributes;
                }

        }

        grouping optical-link-attributes {

                description "Set of attributes of an optical link";


                leaf-list available-label-flexigrid {
```

```
                              type bits {

                                      bit is-available;

                              }

                              description "Array of bits that determines
   whether a spectral slot is available or not.";



                              when "technology-type == Flexigrid";

                      }



                      leaf-list available-label-WSON {

                              type bits {

                                      bit is-available;

                              }

                              description "Array of bits that determines
   whether a wavelength is available or not.";



                              when "technology-type != Flexigrid";

                      }



                      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 "draft-ietf-ccamp-flexi-grid-fwk-
   01";

                  }



                  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 "draft-ietf-ccamp-flexi-grid-fwk-
   01";

                  }



                  leaf slot-width-granularity {

                          type decimal64 {
```

```
                                  fraction-digits 5;

                          }

                          units GHz;

                          description "Minimum space between slot
   widths";

                          reference "draft-ietf-ccamp-flexi-grid-fwk-
   01";

                  }



                  leaf technology-type {

                          type optical-technology;

                          description "Determines which technology is
   used at optical-level";

                  }



   }







          augment "/nt:network-topology/nt:topology/nt:topology-types"
   {

                  uses optical-ted-topology-type;

          }
```

```
        augment "/nt:network-topology/nt:topology" {

                when "nt:topology-types/optical-ted-topology";

                uses optical-ted-topology-attributes;

        }



        augment "/nt:network-topology/nt:topology/nt:node" {

                when "../nt:topology-types/o-ted:optical-ted-
   topology";

                uses optical-node-type;

        }



        augment "/nt:network-topology/nt:topology/nt:node" {

                when "../nt:topology-types/o-ted:optical-ted-
   topology";

                uses optical-node-attributes;

        }



        augment "/nt:network-topology/nt:topology/nt:node" {

                when "o-ted:optical-node-type/o-ted:optical-
   transponder";

                uses optical-transponder-attributes;

        }



        augment "/nt:network-topology/nt:topology/nt:node" {
```

```
                  when "o-ted:optical-node-type/o-ted:optical-
   sliceable-transponder";

                  uses optical-sliceable-transponder-attributes;

          }



          augment "/nt:network-topology/nt:topology/nt:link" {

                  when "../nt:topology-types/o-ted:optical-ted-
   topology";

                  uses optical-link-attributes;

          }

   }
```

A.2. Media Channel YANG Model

```
   module media-channel {



          namespace "http://www.tid.es/idealist ";



          prefix m-c;



          import optical-TED {

                  prefix o-ted;

          }



          revision 2014-06-05;
```

```
        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 "draft-ietf-ccamp-flexi-grid-fwk-01";

                container source {

                        leaf source-node {
                                type o-ted:optical-node-ref;
                        }
```

```
                        leaf source-port {

                                type o-ted:optical-node-port-ref;

                        }

                }


                container destination {

                        leaf destination-node {

                                type o-ted:optical-node-ref;

                        }


                        leaf destination-port {

                                type o-ted:optical-node-port-ref;

                        }

                }


                uses media-channel-attributes;

        }



        container network-media-channel {



                description "It is a media channel that transports an
   Optical Tributary Signal ";



                reference "draft-ietf-ccamp-flexi-grid-fwk-01";
```

```
                container source {

                        leaf source-node {

                                type o-ted:optical-node-ref;

                        }


                        leaf source-transponder {

                                type o-ted:optical-transponder-ref;

                        }

                }


                container destination {

                        leaf destination-node {

                                type o-ted:optical-node-ref;

                        }


                        leaf destination-transponder {

                                type o-ted:optical-transponder-ref;

                        }

                }


                uses media-channel-attributes;

        }
```

```
        grouping media-channel-attributes {

                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 "draft-ietf-ccamp-flexi-grid-fwk-
   01";


                        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 "draft-ietf-ccamp-flexi-
   grid-fwk-01";

                  }



                          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 "draft-ietf-ccamp-flexi-
   grid-fwk-01";

                          }

                  }



                  list link-channel {



                          key "link-id";



                          leaf link-id {

                                  type int32;

                          }
```

```
                        uses link-channel;

                }

        }



        grouping link-channel {



                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 "draft-ietf-ccamp-flexi-grid-fwk-
   01";

                }



                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 "draft-ietf-ccamp-flexi-grid-fwk-
   01";

                  }



                  leaf source-node {

                          type o-ted:optical-node-ref;

                  }



                  leaf source-port {

                          type o-ted:optical-node-port-ref;

                  }



                  leaf destination-node {

                          type o-ted:optical-node-ref;

                  }



                  leaf destination-port {

                          type o-ted:optical-node-port-ref;
```

```
                  }



                  leaf link {

                          type o-ted:optical-link-ref;

                  }



                  leaf bidireccional {

                          type boolean;

                          description "Determines whether the link is
   bidireccional or not";

                  }

          }

   }
```

A.3. License

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