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Common YANG Data Types for Layer 1 Networks
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Abstract

This document defines a collection of common common data types, identities, and groupings in the YANG data modeling language. These derived common common data types, identities, and groupings are intended to be imported by modules that model Layer 1 configuration and state capabilities. The Layer 1 types are representative of Layer 1 client signals applicable to transport networks, such as Optical Transport Networks (OTN). The Optical Transport Network (OTN) data structures are included in this document as Layer 1 types.

Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

Status of This Memo

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

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This Internet-Draft will expire on 26 August 2024.

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1. Introduction

This document specifies common data types, groupings, and identities for use in YANG [RFC7950] data models of Layer 1 networks. The derived types and groupings apply to Traffic Engineered (TE) Layer 1 networks.

The Layer 1 (L1) Optical Transport Network (OTN) is specified in [RFC7062]. The corresponding routing and signaling protocols are specified in [RFC7138] and [RFC7139]. The types and groupings defined in this document are consistent with those documents, and can

be imported into other Layer 1 data models, including but not limited to, [I-D.ietf-ccamp-otn-topo-yang], [I-D.ietf-ccamp-otn-tunnel-model], [I-D.ietf-ccamp-client-signal-yang] and [I-D.ietf-ccamp-l1csm-yang].

The document is consistent with other specifications, including [MEF63] for Layer 1 service attributes, [ITU-T_G.709] and [ITU-T_G.Sup43] for OTN data plane definitions.

The YANG data model in this document only defines groupings, typedef, and identities. It does not define any configuration or state data, as specified in the Network Management Datastore Architecture defined in [RFC8342].

2. Terminology and Notations

Specific terms used within this document are as follows:

OTN: Optical Transport Network.

ODU: Optical Data Unit. An ODU has the frame structure and overhead, as defined in Figure 12-1 of [ITU-T_G709]. ODUs can be formed in two ways: a) by encapsulating a single non-OTN client, such as SONET/SDH (Synchronous Optical Network / Synchronous Digital Hierarchy) or Ethernet, or b) by multiplexing lower-rate ODUs. In general, the ODU layer represents the path layer in OTN. The only exception is the ODUCn signal (defined below), which is defined to be a section-layer signal. In the classification based on bitrates of the ODU signals, ODUs are of two types: fixed rate and flexible rate. Flexible-rate ODUs, called "ODUflex", have a rate that is 239/238 times the bitrate of the client signal they encapsulate.

ODUCn: Optical Data Unit-C. This signal has a bandwidth of approximately 100 Gbit/s and is of a slightly higher bitrate than the fixed rate ODU4 signal. This signal has the format defined in Figure 12-1 of [ITU-T_G.709]. This signal represents the building block for constructing a higher-rate signal called "ODUCn".

ODUk: Optical Data Unit-k, where k is one of {0, 1, 2, 2e, 3, 4}. The term "ODUk" refers to an ODU whose bitrate is fully specified by the index k. The bitrates of the ODUk signal for k = {0, 1, 2, 2e, 3, 4} are approximately 1.25 Gbit/s, 2.5 Gbit/s, 10 Gbit/s, 10.3 Gbit/s, 40 Gbit/s, and 100 Gbit/s, respectively.

LO ODU: Lower Order ODU. The LO ODUj (j can be 0, 1, 2, 2e, 3, 4,

or flex) represents the container transporting a client of the OTN that is either directly mapped into an OTUk (k = j) or multiplexed into a server HO ODUk (k > j) container.

HO ODU: Higher Order ODU. The HO ODUk (k can be 1, 2, 2e, 3, or 4) represents the entity transporting a multiplex of LO ODUj tributary signals in its OPUk area.

The reader may also refer to [RFC7062] and [RFC9376] for other key terms used in this document. The terminology for describing YANG data models can be found in [RFC7950].

3. Prefix in Data Node Names

In this document, the names of data nodes and other data model objects are prefixed using the standard prefix associated with the corresponding YANG imported modules, as shown in Table 1.

Prefix	YANG module	Reference
rt-types	ietf-routing-types	[RFC8294]
l1-types	ietf-layer1-types	RFC XXXX

Table 1: Prefixes and Corresponding YANG Modules

RFC Editor Note: Please replace XXXX with the number assigned to the RFC once this draft becomes an RFC.

4. Layer 1 Types Overview

4.1. Relationship with other Modules

This document defines one YANG module for common Layer 1 types. The aim is to specify common Layer 1 TE types (i.e., typedef, identity, grouping) that can be imported by layer 1 specific technology, for example, layer 1 OTN, in its technology-specific modules, such as topology and tunnels. It is worth noting that the generic traffic-engineering (TE) types module is specified as ietf-te-types in [I-D.ietf-teas-rfc8776-update], and both YANG modules, ietf-te-types and ietf-layer1-types, will need importing when the OTN is configured. Generic attributes such as te-bandwidth and te-label, which are specified as ietf-te-types in [I-D.ietf-teas-rfc8776-update], need to be augmented with the OTN-

specific attributes, such as odu-type, which are specified as ietf-layer1-types in this document, when OTN is configured.

4.2. Content in Layer 1 Type Module

The module ietf-layer1-types contains the following YANG reusable types and groupings:

tributary-slot-granularity:

This specifies the granularity levels for tributary slots utilized by the server layer Optical Data Unit (ODU). Specifically, it addresses how ODU links, including both Higher Order Optical Data Unit-k (HO ODUk) and Optical Data Unit-Cn (ODUCn), accommodate client layer ODUs within Label Switched Paths (LSPs). These client layer ODUs could be Lower Order Optical Data Unit-j (LO ODUj) or ODUk, respectively. The specified granularity levels for these configurations are 1.25G, 2.5G, and 5G.

odu-type:

This specifies the type of ODUk LSP, including the types specified in [ITU-T_G.709] and [RFC7139].

Since, as described in [RFC7963], [ITU-T_G.Sup43] does not guarantee interoperability in the data plane for these containers, the type of ODUk LSPs defined in [ITU-T_G.Sup43] and [RFC7963] can be defined in vendor-specific YANG modules using the odu-type identity, defined in this document, as the base.

client-signal:

This specifies the common Layer 1 client signal types, including ETH [IEEE_802.3], STM-n [ITU-T_G.707], OC [ANSI_T1.105] and Fiber Channel [ANSI_INCITS_230]. The input was based on the G-PID types specified in [RFC7139].

otn-label-range-type:

The label range type of OTN is represented in one of two ways, tributary slots (TS) and tributary port number (TPN), as specified in [RFC7139]. Two representations are enumerated in the otn-label-range-type.

otn-link-bandwidth:

This grouping defines the link bandwidth information, usually as the number of ODUs that can be supported by the link for each ODU type: for example an OTN link with 100G bandwidth can support either 1xODU4, 10xODU2 or 80xODU0.

It is also used to represent the ODUflex resources available on a link, as described in Section 4.4.

This grouping could be used in the OTN topology model for link bandwidth representation. In general, all the bandwidth-related sections, which are defined in a generic module, e.g., using the groupings defined in [I-D.ietf-teas-rfc8776-update], need to be augmented with this grouping when used to represent the bandwidth of an OTN link.

otn-path-bandwidth:

This grouping defines the path bandwidth information, usually as the type of ODU (e.g., ODU0, ODU2, ODU4) being set up along the path.

In the case of ODUflex paths, more information about the bandwidth of the ODUflex needs to be provided, as described in Section 4.4.

This grouping could be used in the OTN topology model for path bandwidth representation as well as when setting up the OTN tunnel. In general, all the bandwidth-related sections, which are defined in a generic module, e.g., using the groupings defined in [I-D.ietf-teas-rfc8776-update], need to be augmented with this grouping when used to represent the bandwidth of an OTN tunnel or path.

otn-label-range-info:

This grouping is used to augment the label-restriction list, defined in [I-D.ietf-teas-rfc8776-update], with OTN technology-specific attributes, as defined in Section 4.3.

otn-label-start-end:

This grouping is used to augment the label-start and label-end containers within the label-restriction list, defined in [I-D.ietf-teas-rfc8776-update], with OTN technology-specific attributes, as defined in Section 4.3.

otn-label-step:

This grouping is used to augment the label-step container within the label-restriction list, defined in [I-D.ietf-teas-rfc8776-update], with OTN technology-specific attributes, as defined in Section 4.3.

otn-label-hop:

This grouping is used to augment the label-hop container, defined in [I-D.ietf-teas-rfc8776-update], with OTN technology-specific attributes, as defined in Section 4.3.

optical-interface-func:

The optical interface function is specified in [MEF63]. Identities that describe the functionality are specified to encode bits for transmission and to decode bits upon reception.

4.3. OTN Label and Label Range

As described in [RFC7139], the OTN label usually represents the Tributary Port Number (TPN) and the related set of Tributary Slots (TS) assigned to a client layer ODU LSP (LO ODUj or ODUk) on a given server layer ODU (HO-ODU or ODUCn, respectively) Link (e.g., ODU2 LSP over ODU3 Link). Some special OTN label values are also defined for an ODUk LSP being set up over an OTUk Link.

The same OTN label MUST be assigned to the same ODUk LSP at the two ends of an OTN Link.

As described in [RFC7139], TPN can be a number from 1 to 4095 and TS are numbered from 1 to 4095, although the actual maximum values depend on the type of server layer ODU. For example, a server layer ODU4 provides 80 tributary slots (numbered from 1 to 80), and the TPN values can be any number from 1 to 80.

The OTN Label Range specifies the available values for the Tributary Port Number (TPN) and Tributary Slots (TS) for setting up ODUk Label Switched Paths (LSPs) over an OTN Link, with priorities as defined in [RFC4203]. This range is established according to the guidelines in [RFC7139].

The OTN Label Range is defined by the label-restriction list, defined in [I-D.ietf-teas-rfc8776-update], which, for OTN, SHOULD be augmented using the otn-label-range-info grouping.

Each entry in the label-restriction list represents either the range of the available TPN values or the range of the available TS values: the range-type attribute in the otn-label-range-info grouping defines the type of range for each list entry.

Each entry of the label-restriction list, as defined in [I-D.ietf-teas-rfc8776-update], defines a label-start, a label-end, a label-step, and a range-bitmap. The label-start and label-end definitions for OTN SHOULD be augmented using the otn-label-start-end grouping. The label-step definition for OTN SHOULD be augmented using the otn-label-step grouping. It is expected that the otn-label-step will always be equal to its default value (i.e., 1), which is defined in [I-D.ietf-teas-rfc8776-update].

As described in [RFC7139], in some cases, the TPN assignment rules are flexible (e.g., ODU4 Link) while in other cases the TPN assignment rules are fixed (e.g., ODU1 Link). In the former case, both TPN and TS ranges are reported, while in the latter case, the TPN range is not reported which indicates that the TPN SHALL be set equal to the TS number assigned to the ODUk LSP.

As described in [RFC7139], in some cases, the TPN assignment rules depend on the TS Granularity (e.g., ODU2 or ODU3 Links). Different entries in the label-restriction list will report different TPN ranges for each TS granularity supported by the link, as indicated by the tsg attribute in the otn-label-range-info grouping.

As described in [RFC7139], in some cases the TPN ranges are different for different types of ODUk LSPs. For example, on an ODU2 Link with 1.25G TS granularity, the TPN range is 1-4 for ODU1 but 1-8 for ODU0 and ODUflex. Therefore, different entries in the label-restriction list will report different TPN ranges for a different set of ODUk types, as indicated by the odu-type-list in the otn-label-range-info grouping.

Appendix A provides some examples of how the TPN and TS label ranges described in Table 3 and Table 4 of [RFC7139] can be represented in YANG using the groupings defined in this document.

4.4. ODUflex

ODUflex is a type of ODU with a flexible bit rate which is configured when setting up an ODUflex LSP.

[ITU-T_G.709] defines six types of ODUflex: ODUflex(CBR), ODUflex(GFP), ODUflex(GFP,n,k), ODUflex(IMP), ODUflex(IMP,s), and ODUflex(FlexE-aware).

The main difference between these types of ODUflex is the formula used to calculate the nominal bit rate of the ODUflex, as described in Table 7-2 of [ITU-T_G.709]. A YANG choice has been defined to describe these cases:

```
      +--rw (oduflex-type)?
         +--:(generic)
         |  +--rw nominal-bit-rate        union
         +--:(cbr)
         |  +--rw client-type             identityref
         +--:(gfp-n-k)
         |  +--rw gfp-n                   uint8
         |  +--rw gfp-k?                  l1-types:gfp-k
         +--:(flexe-client)
         |  +--rw flexe-client
         |          l1-types:flexe-client-rate
         +--:(flexe-aware)
         |  +--rw flexe-aware-n           uint16
         +--:(packet)
            +--rw opuflex-payload-rate    union
```

The OPUflex payload rate can be expressed either in a floating point notation or a scientific notation, as defined in [IEEE_754] and [ISO_IEC_9899_1999].

The 'generic' case has been added to allow the ODUflex nominal bit rate to be defined independently of the type of ODUflex. This could be useful for forward compatibility in the transit domain/nodes where the set up of ODUflex LSPs does not depend on the ODUflex type.

In order to simplify interoperability the 'generic' case SHOULD be used only when needed; the ODUflex type-specific case SHOULD be used whenever possible.

The 'cbr' case is used for Constant Bit Rate (CBR) client signals. The client-type indicates which CBR client signal is carried by the ODUflex and, implicitly, the client signal bit rate, which is then used to calculate the ODUflex(CBR) nominal bit rate as described in Table 7-2 of [ITU-T_G.709].

The 'gfp-n-k' case is used for GFP-F mapped client signals based on ODUk.ts and 'n' 1.25G tributary slots. 'gfp-k' defines the nominal bit-rate of the ODUk.ts which, together with the value of 'gfp-n', is used to calculate the ODUflex(GFP,n,k) nominal bit rate as described in Table 7-8 and Table L-7 of [ITU-T_G.709] . With a few exceptions, shown in Table L-7 of [ITU-T_G.709], the nominal bit-rate of the ODUk.ts could be inferred from the value of 'n', as shown in Table 7-8 of [ITU-T_G.709] and therefore the 'gfp-k' is optional.

The 'flexe-client' case is used for Idle Mapping Procedure (IMP) mapped FlexE client signals, The 'flexe-client' represents the type of FlexE client carried by the ODUflex which implicitly defines the value of 's' used to calculate the ODUflex(s) nominal bit rate as described in Table 7-2 of [ITU-T_G.709]. The '10G' and '40G' enumeration values are used for 10G and 40G FlexE clients to implicitly define the values of s=2 and s=8. For the 'n x 25G' FlexE Clients the value of 'n' is used to define the value of s=5 x n.

The 'flexe-aware' case is used for FlexE-aware client signals. The flexe-aware-n represents the value n (n = n1 + n2 + ... + np) which is used to calculate the ODUflex(FlexE-aware) nominal bit rate as described in Table 7-2 of [ITU-T_G.709].

The 'packet' case is used for both the GFP-F mapped client signals and the IMP mapped client signals. The opuflex-payload-rate is either the GFP-F encapsulated-packet client nominal bit rate or the 64b/66b encoded-packet client nominal bit rate. The calculation of ODUflex(GFP) nominal bit rate is defined in Section 12.2.5 of [ITU-T_G.709], and the calculation of ODUflex(IMP) nominal bit rate is defined in Section 12.2.6 of [ITU-T_G.709]. The same formula is used in both cases.

Sections 5.1 and 5.2 of [RFC7139] defines two rules to compute the number of tributary slots to be allocated to ODUflex(CBR) and ODUflex(GFP) LSPs when carried over a HO-ODUk link. According to Section 19.6 of [ITU-T_G.709], the rules in Section 5.2 apply only to ODUflex(GFP,n,k) while the rules defined in Section 5.1 apply to any other ODUflex type, including, but not limited, to ODUflex(CBR). Section 20.5 of [ITU-T_G.709] defines the rules for computing the number of tributary slots to be allocated to ODUflex LSPs when carried over an ODUCn link.

In order to compute the number of tributary slots required to set up an ODUflex LSP, or ODUflex LSPs, the type of Optical channel Data Tributary Unit (ODTU) is reported for the OTN Links or the OTN LTPs (Link Termination Points).

Following the [ITU-T_G.709] definitions, the rules defined for ODUflex(GFP,n,k) are used only when the 'gfp-n-k' case is used. In all the other cases, including the (generic) case, the rules defined for any other ODUflex type are used.

The number of available ODUs, defined for each ODUk type, including ODUflex, does not provide sufficient information to infer the OTN link bandwidth availability for ODUflex LSPs.

The OTN link bandwidth definitions for ODUflex LSPs also depend on the number of tributary slots (TS) and on the type of ODTU used to compute the number of TS required to set up an ODUflex LSP, according to the rules defined in Section 19.6 and Section 20.5 of [ITU-T_G.709], as described above.

Similarly, bandwidth constraints for ODUflex LSPs of the OTN connectivity matrix and of the OTN local link connectivity entries depend also on the number of tributary slots (TS) and on the type of ODTU used to compute the number of TS required to set up an ODUflex LSP along the underlay path, according to the rules defined in Section 19.6 and Section 20.5 of [ITU-T_G.709], as described above. For example, with reference to Figure 1 of [RFC7139], the connectivity matrix entry or the local link connectivity entry corresponding to the A-C underlay path, would report 2 Tributary Slots (TS) with ODTU4.ts ODTU type.

4.4.1. Resizable ODUflex

Resizable ODUflex is a special type of ODUflex that supports the procedures defined in [ITU-T_G.7044] for hitless resizing of the ODUflex nominal bit rate.

Two odu-type identities have been defined for ODUflex:

* The ODUflex identity, which is used with any type of non-resizable ODUflex, as defined in Table 7-2 of [ITU-T_G.709].

* The ODUflex-resizable identity, which is used only with resizable ODUflex(GFP,n,k).

These two identities are used to identify whether an ODUflex(GFP,n,k) LSP does or does not support the [ITU-T_G.7044] hitless resizing procedures. They also identify whether an OTN link only supports the set up of non-resizable ODUflex LSPs or also supports the set up of resizable ODUflex(GFP,n,k) LSP but with different capabilities (e.g., a lower number of LSPs).

5. YANG Tree for Layer1 Types

```
   module: ietf-layer1-types

     grouping otn-link-bandwidth:
       +-- otn-bandwidth
          +-- odulist* [odu-type]
             +-- odu-type?    identityref
             +-- number?      uint16
             +-- ts-number?   uint16
     grouping otn-path-bandwidth:
       +-- otn-bandwidth
          +-- odu-type?                      identityref
          +-- (oduflex-type)?
             +--:(generic)
             |  +-- nominal-bit-rate        union
             +--:(cbr)
             |  +-- client-type             identityref
             +--:(gfp-n-k)
             |  +-- gfp-n                   uint8
             |  +-- gfp-k?                  gfp-k
             +--:(flexe-client)
             |  +-- flexe-client            flexe-client-rate
             +--:(flexe-aware)
             |  +-- flexe-aware-n           uint16
             +--:(packet)
                +-- opuflex-payload-rate    union
     grouping otn-max-path-bandwidth:
       +-- otn-bandwidth
          +-- odu-type?        identityref
          +-- max-ts-number?   uint16
     grouping otn-label-range-info:
       +-- otn-label-range
          +-- range-type?      otn-label-range-type
          +-- tsg?             identityref
          +-- odu-type-list*   identityref
          +-- priority?        uint8
     grouping otn-label-start-end:
       +-- otn-label
          +-- tpn?   otn-tpn
          +-- ts?    otn-ts
     grouping otn-label-hop:
       +-- otn-label
          +-- tpn?       otn-tpn
          +-- tsg?       identityref
          +-- ts-list?   string
     grouping otn-label-step:
       +-- otn-label-step
```

```
          +-- tpn?   otn-tpn
          +-- ts?    otn-ts
```

6. YANG Code for Layer1 Types

```
<CODE BEGINS>
file "ietf-layer1-types@2024-02-22.yang"
module ietf-layer1-types {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-layer1-types";
  prefix "l1-types";

  import ietf-routing-types {
    prefix rt-types;
    reference
      "RFC 8294: Common YANG Data Types for the Routing Area";
  }

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

     Editor: Haomian Zheng
             <mailto:zhenghaomian@huawei.com>

     Editor: Italo Busi
             <mailto:Italo.Busi@huawei.com>";

  description
    "This module defines Layer 1 YANG types. The model fully conforms
     to the Network Management Datastore Architecture (NMDA).

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     identified as authors of the code.  All rights reserved.

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     Relating to IETF Documents
     (https://trustee.ietf.org/license-info).

     This version of this YANG module is part of RFC XXXX; see
     the RFC itself for full legal notices.
```

```
      The key words 'MUST', 'MUST NOT', 'REQUIRED', 'SHALL', 'SHALL
      NOT', 'SHOULD', 'SHOULD NOT', 'RECOMMENDED', 'NOT RECOMMENDED',
      'MAY', and 'OPTIONAL' in this document are to be interpreted as
      described in BCP 14 (RFC 2119) (RFC 8174) when, and only when,
      they appear in all capitals, as shown here.";

    revision "2024-02-22" {
      description
        "Initial Version";
      reference
        "RFC XXXX: A YANG Data Model for Layer 1 Types";
      // RFC Editor: replace RFC XXXX with actual RFC number,
      // update date information and remove this note.
    }

    /*
     * Identities
     */

    identity tributary-slot-granularity {
      description
        "Tributary Slot Granularity (TSG).";
      reference
        "ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
         Transport Network (OTN)";
    }

      identity tsg-1.25G {
        base tributary-slot-granularity;
        description
          "1.25G tributary slot granularity.";
      }

      identity tsg-2.5G {
        base tributary-slot-granularity;
        description
          "2.5G tributary slot granularity.";
      }

      identity tsg-5G {
        base tributary-slot-granularity;
        description
          "5G tributary slot granularity.";
      }

    identity odu-type {
      description
        "Base identity from which specific Optical Data Unit (ODU)
```

```
          type is derived.";
        reference
          "RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)";
      }

        identity ODU0 {
          base odu-type;
          description
            "ODU0 type (1.24Gb/s).";
          reference
            "RFC7139: GMPLS Signaling Extensions for Control of Evolving
            G.709 Optical Transport Networks

            ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
            Transport Network (OTN)";
        }

        identity ODU1 {
          base odu-type;
          description
            "ODU1 type (2.49Gb/s).";
          reference
            "RFC7139: GMPLS Signaling Extensions for Control of Evolving
            G.709 Optical Transport Networks

            ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
            Transport Network (OTN)";
        }

        identity ODU2 {
          base odu-type;
          description
            "ODU2 type (10.03Gb/s).";
          reference
            "RFC7139: GMPLS Signaling Extensions for Control of Evolving
            G.709 Optical Transport Networks

            ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
            Transport Network (OTN)";
        }

        identity ODU2e {
          base odu-type;
          description
```

```
          "ODU2e type (10.39Gb/s).";
        reference
          "RFC7139: GMPLS Signaling Extensions for Control of Evolving
          G.709 Optical Transport Networks

          ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
          Transport Network (OTN)";
      }

      identity ODU3 {
        base odu-type;
        description
          "ODU3 type (40.31Gb/s).";
        reference
          "RFC7139: GMPLS Signaling Extensions for Control of Evolving
          G.709 Optical Transport Networks

          ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
          Transport Network (OTN)";
      }

      identity ODU4 {
        base odu-type;
        description
          "ODU4 type (104.79Gb/s).";
        reference
          "RFC7139: GMPLS Signaling Extensions for Control of Evolving
          G.709 Optical Transport Networks

          ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
          Transport Network (OTN)";
      }

      identity ODUflex {
        base odu-type;
        description
          "ODUflex type (flexible bit rate, not resizable).

          It could be used for any type of ODUflex, including
          ODUflex(CBR), ODUflex(GFP), ODUflex(GFP,n,k), ODUflex(IMP,s),
          ODUflex(IMP) and ODUflex(FlexE-aware).";
        reference
          "RFC7139: GMPLS Signaling Extensions for Control of Evolving
          G.709 Optical Transport Networks

          ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
          Transport Network (OTN)";
      }
```

```
      identity ODUflex-resizable {
        base odu-type;
        description
          "ODUflex protocol (flexible bit rate, resizable).

          It could be used only for ODUflex(GFP,n,k).";
        reference
          "RFC7139: GMPLS Signaling Extensions for Control of Evolving
          G.709 Optical Transport Networks

          ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
          Transport Network (OTN)";
      }

    identity protocol {
      description
        "Base identity from which specific protocol is derived.";
      reference
        "MEF63: Subscriber Layer 1 Service Attributes";
    }

      identity Ethernet {
        base protocol;
        description
          "Ethernet protocol.";
        reference
          "MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity Fibre-Channel {
        base protocol;
        description
          "Fibre-Channel (FC) protocol.";
        reference
          "MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity SDH {
        base protocol;
        description
          "SDH protocol.";
        reference
          "MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity SONET {
        base protocol;
        description
```

```
          "SONET protocol.";
        reference
          "MEF63: Subscriber Layer 1 Service Attributes";
      }

    identity client-signal {
      description
        "Base identity from which specific Constant Bit Rate (CBR)
        client signal is derived";
    }

    identity coding-func {
      description
        "Base identity from which specific coding function
         is derived.";
      reference
        "MEF63: Subscriber Layer 1 Service Attributes";
    }

      identity ETH-1Gb {
        base client-signal;
        description
          "Client signal type of 1GbE.";
        reference
          "IEEE 802.3-2018, Clause 36: IEEE Standard for Ethernet

          RFC7139: GMPLS Signaling Extensions for Control of Evolving
          G.709 Optical Transport Networks

          ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
          Transport Network (OTN)";
      }

      identity ETH-10Gb-LAN {
        base client-signal;
        description
          "Client signal type of ETH-10Gb-LAN (10.3 Gb/s).";
        reference
          "IEEE 802.3-2018, Clause 49: IEEE Standard for Ethernet

          RFC7139: GMPLS Signaling Extensions for Control of Evolving
          G.709 Optical Transport Networks

          ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
          Transport Network (OTN)";
      }

      identity ETH-10Gb-WAN {
```

```
    base client-signal;
    description
      "Client signal type of ETH-10Gb-WAN (9.95 Gb/s).";
    reference
      "IEEE 802.3-2018, Clause 50: IEEE Standard for Ethernet

      RFC7139: GMPLS Signaling Extensions for Control of Evolving
      G.709 Optical Transport Networks

      ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
      Transport Network (OTN)";
  }

  identity ETH-40Gb {
    base client-signal;
    description
      "Client signal type of 40GbE.";
    reference
      "IEEE 802.3-2018, Clause 82: IEEE Standard for Ethernet

      RFC7139: GMPLS Signaling Extensions for Control of Evolving
      G.709 Optical Transport Networks

      ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
      Transport Network (OTN)";
  }

  identity ETH-100Gb {
    base client-signal;
    description
      "Client signal type of 100GbE.";
    reference
      "IEEE 802.3-2018, Clause 82: IEEE Standard for Ethernet

      RFC7139: GMPLS Signaling Extensions for Control of Evolving
      G.709 Optical Transport Networks

      ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
      Transport Network (OTN)";
  }

  identity STM-1 {
    base client-signal;
    base coding-func;
    description
      "Client signal type of STM-1;
      STM-1 G.707 (N=1) coding function.";
    reference
```

```
          "ITU-T G.707 v7.0 (01/2007): Network node interface for the
          synchronous digital hierarchy (SDH)

          RFC7139: GMPLS Signaling Extensions for Control of Evolving
          G.709 Optical Transport Networks

          ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
          Transport Network (OTN)

          MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity STM-4 {
        base client-signal;
        base coding-func;
        description
          "Client signal type of STM-4;
          STM-4 G.707 (N=4) coding function.";
        reference
          "ITU-T G.707 v7.0 (01/2007): Network node interface for the
          synchronous digital hierarchy (SDH)

          RFC7139: GMPLS Signaling Extensions for Control of Evolving
          G.709 Optical Transport Networks

          ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
          Transport Network (OTN)

          MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity STM-16 {
        base client-signal;
        base coding-func;
        description
          "Client signal type of STM-16;
          STM-16 G.707 (N=16) coding function.";
        reference
          "ITU-T G.707 v7.0 (01/2007): Network node interface for the
          synchronous digital hierarchy (SDH)

          RFC7139: GMPLS Signaling Extensions for Control of Evolving
          G.709 Optical Transport Networks

          ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
          Transport Network (OTN)

          MEF63: Subscriber Layer 1 Service Attributes";
```

```
  }

  identity STM-64 {
    base client-signal;
    base coding-func;
    description
      "Client signal type of STM-64;
      STM-64 G.707 (N=64) coding function.";
    reference
      "ITU-T G.707 v7.0 (01/2007): Network node interface for the
      synchronous digital hierarchy (SDH)

      RFC7139: GMPLS Signaling Extensions for Control of Evolving
      G.709 Optical Transport Networks

      ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
      Transport Network (OTN)

      MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity STM-256 {
    base client-signal;
    base coding-func;
    description
      "Client signal type of STM-256;
      STM-256 G.707 (N=256) coding function.";
    reference
      "ITU-T G.707 v7.0 (01/2007): Network node interface for the
      synchronous digital hierarchy (SDH)

      RFC7139: GMPLS Signaling Extensions for Control of Evolving
      G.709 Optical Transport Networks

      ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
      Transport Network (OTN)

      MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity OC-3 {
    base client-signal;
    base coding-func;
    description
      "Client signal type of OC3;
      OC-3 GR-253-CORE (N=3) coding function.";
    reference
      "ANSI T1.105-2001: Synchronous Optical Network (SONET)
```

```
          Basic Description including Multiplex Structure, Rates,
          and Formats

          MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity OC-12 {
        base client-signal;
        base coding-func;
        description
          "Client signal type of OC12;
          OC-12 GR-253-CORE (N=12) coding function.";
        reference
          "ANSI T1.105-2001: Synchronous Optical Network (SONET)
          Basic Description including Multiplex Structure, Rates,
          and Formats

          MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity OC-48 {
        base client-signal;
        base coding-func;
        description
          "Client signal type of OC48;
          OC-48 GR-253-CORE (N=48) coding function.";
        reference
          "ANSI T1.105-2001: Synchronous Optical Network (SONET)
          Basic Description including Multiplex Structure, Rates,
          and Formats

          MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity OC-192 {
        base client-signal;
        base coding-func;
        description
          "Client signal type of OC192;
          OC-192 GR-253-CORE (N=192) coding function.";
        reference
          "ANSI T1.105-2001: Synchronous Optical Network (SONET)
          Basic Description including Multiplex Structure, Rates,
          and Formats

          MEF63: Subscriber Layer 1 Service Attributes";
      }
```

```
       identity OC-768 {
         base client-signal;
         base coding-func;
         description
           "Client signal type of OC768;
           OC-768 GR-253-CORE (N=768) coding function.";
         reference
           "ANSI T1.105-2001: Synchronous Optical Network (SONET)
           Basic Description including Multiplex Structure, Rates,
           and Formats

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity FC-100 {
         base client-signal;
         base coding-func;
         description
           "Client signal type of Fibre Channel FC-100;
           FC-100 FC-FS-2 (1.0625 Gb/s) coding function.";
         reference
           "ANSI INCITS 230-1994 R1999): Information Technology -
           Fibre Channel - Physical and Signaling Interface (FC-PH)

           RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)

           MEF63: Subscriber Layer 1 Service Attributes";
       }

       identity FC-200 {
         base client-signal;
         base coding-func;
         description
           "Client signal type of Fibre Channel FC-200;
           FC-200 FC-FS-2 (2.125 Gb/s) coding function.";
         reference
           "ANSI INCITS 230-1994 R1999): Information Technology -
           Fibre Channel - Physical and Signaling Interface (FC-PH)

           RFC7139: GMPLS Signaling Extensions for Control of Evolving
           G.709 Optical Transport Networks

           ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
           Transport Network (OTN)
```

```
        MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity FC-400 {
        base client-signal;
        base coding-func;
        description
          "Client signal type of Fibre Channel FC-400;
          FC-400 FC-FS-2 (4.250 Gb/s) coding function.";
        reference
          "ANSI INCITS 230-1994 R1999): Information Technology -
          Fibre Channel - Physical and Signaling Interface (FC-PH)

          RFC7139: GMPLS Signaling Extensions for Control of Evolving
          G.709 Optical Transport Networks

          ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
          Transport Network (OTN)

          MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity FC-800 {
        base client-signal;
        base coding-func;
        description
          "Client signal type of Fibre Channel FC-800;
          FC-800 FC-FS-2 (8.500 Gb/s) coding function.";
        reference
          "ANSI INCITS 230-1994 R1999): Information Technology -
          Fibre Channel - Physical and Signaling Interface (FC-PH)

          RFC7139: GMPLS Signaling Extensions for Control of Evolving
          G.709 Optical Transport Networks

          ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
          Transport Network (OTN)

          MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity FC-1200 {
        base client-signal;
        base coding-func;
        description
          "Client signal type of Fibre Channel FC-1200;
          FC-1200 FC-10GFC (10.51875 Gb/s) coding function.";
        reference
```

```
          "ANSI INCITS 230-1994 R1999): Information Technology -
          Fibre Channel - Physical and Signaling Interface (FC-PH)

          RFC7139: GMPLS Signaling Extensions for Control of Evolving
          G.709 Optical Transport Networks

          ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
          Transport Network (OTN)

          MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity FC-1600 {
        base client-signal;
        base coding-func;
        description
          "Client signal type of Fibre Channel FC-1600;
          FC-1600 FC-FS-3 (14.025 Gb/s) coding function.";
        reference
          "ANSI INCITS 230-1994 R1999): Information Technology -
          Fibre Channel - Physical and Signaling Interface (FC-PH)

          RFC7139: GMPLS Signaling Extensions for Control of Evolving
          G.709 Optical Transport Networks

          ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
          Transport Network (OTN)

          MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity FC-3200 {
        base client-signal;
        base coding-func;
        description
          "Client signal type of Fibre Channel FC-3200;
          FC-3200 FC-FS-4 (28.05 Gb/s) coding function.";
        reference
          "ANSI INCITS 230-1994 R1999): Information Technology -
          Fibre Channel - Physical and Signaling Interface (FC-PH)

          RFC7139: GMPLS Signaling Extensions for Control of Evolving
          G.709 Optical Transport Networks

          ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
          Transport Network (OTN)

          MEF63: Subscriber Layer 1 Service Attributes";
```

```
  }

  identity ETH-1000X {
    base coding-func;
    description
      "1000BASE-X PCS clause 36 coding function.";
    reference
      "IEEE 802.3-2018, Clause 36: IEEE Standard for Ethernet

      MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity ETH-10GW {
    base coding-func;
    description
      "IEEE 802.3-2018, Clause 50: IEEE Standard for Ethernet

      10GBASE-W (WAN PHY) PCS clause 49 and WIS clause 50
      coding function.";
    reference
      "MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity ETH-10GR {
    base coding-func;
    description
      "10GBASE-R (LAN PHY) PCS clause 49 coding function.";
    reference
      "IEEE 802.3-2018, Clause 49: IEEE Standard for Ethernet

      MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity ETH-40GR {
    base coding-func;
    description
      "40GBASE-R PCS clause 82 coding function.";
    reference
      "IEEE 802.3-2018, Clause 82: IEEE Standard for Ethernet

      MEF63: Subscriber Layer 1 Service Attributes";
  }

  identity ETH-100GR {
    base coding-func;
    description
      "100GBASE-R PCS clause 82 coding function.";
    reference
```

```
          "IEEE 802.3-2018, Clause 82: IEEE Standard for Ethernet

          MEF63: Subscriber Layer 1 Service Attributes";
      }

    identity optical-interface-func {
      description
        "Base identity from which optical-interface-function
         is derived.";
      reference
        "MEF63: Subscriber Layer 1 Service Attributes";
    }

      identity SX-PMD-1000 {
        base optical-interface-func;
        description
          "SX-PMD-clause-38 Optical Interface function for
          1000BASE-X PCS-36.";
        reference
          "IEEE 802.3-2018, Clause 38: IEEE Standard for Ethernet

          MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity LX-PMD-1000 {
        base optical-interface-func;
        description
          "LX-PMD-clause-38 Optical Interface function for
          1000BASE-X PCS-36.";
        reference
          "IEEE 802.3-2018, Clause 38: IEEE Standard for Ethernet

          MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity LX10-PMD-1000 {
        base optical-interface-func;
        description
          "LX10-PMD-clause-59 Optical Interface function for
          1000BASE-X PCS-36.";
        reference
          "IEEE 802.3-2018, Clause 59: IEEE Standard for Ethernet

          MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity BX10-PMD-1000 {
        base optical-interface-func;
```

```
      description
        "BX10-PMD-clause-59 Optical Interface function for
        1000BASE-X PCS-36.";
      reference
        "IEEE 802.3-2018, Clause 59: IEEE Standard for Ethernet

        MEF63: Subscriber Layer 1 Service Attributes";
    }

    identity LW-PMD-10G {
      base optical-interface-func;
      description
        "LW-PMD-clause-52 Optical Interface function for
        10GBASE-W PCS-49-WIS-50.";
      reference
        "IEEE 802.3-2018, Clause 52: IEEE Standard for Ethernet

        MEF63: Subscriber Layer 1 Service Attributes";
    }

    identity EW-PMD-10G {
      base optical-interface-func;
      description
        "EW-PMD-clause-52 Optical Interface function for
        10GBASE-W PCS-49-WIS-50.";
      reference
        "IEEE 802.3-2018, Clause 52: IEEE Standard for Ethernet

        MEF63: Subscriber Layer 1 Service Attributes";
    }

    identity LR-PMD-10G {
      base optical-interface-func;
      description
        "LR-PMD-clause-52 Optical Interface function for
        10GBASE-R PCS-49.";
      reference
        "IEEE 802.3-2018, Clause 52: IEEE Standard for Ethernet

        MEF63: Subscriber Layer 1 Service Attributes";
    }

    identity ER-PMD-10G {
      base optical-interface-func;
      description
        "ER-PMD-clause-52 Optical Interface function for
        10GBASE-R PCS-49.";
      reference
```

```
          "IEEE 802.3-2018, Clause 52: IEEE Standard for Ethernet

          MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity LR4-PMD-40G {
        base optical-interface-func;
        description
          "LR4-PMD-clause-87 Optical Interface function for
          40GBASE-R PCS-82.";
        reference
          "IEEE 802.3-2018, Clause 87: IEEE Standard for Ethernet

          MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity ER4-PMD-40G {
        base optical-interface-func;
        description
          "ER4-PMD-clause-87 Optical Interface function for
          40GBASE-R PCS-82.";
        reference
          "IEEE 802.3-2018, Clause 87: IEEE Standard for Ethernet

          MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity FR-PMD-40G {
        base optical-interface-func;
        description
          "FR-PMD-clause-89 Optical Interface function for
          40GBASE-R PCS-82.";
        reference
          "IEEE 802.3-2018, Clause 89: IEEE Standard for Ethernet

          MEF63: Subscriber Layer 1 Service Attributes";
      }

      identity LR4-PMD-100G {
        base optical-interface-func;
        description
          "LR4-PMD-clause-88 Optical Interface function for
          100GBASE-R PCS-82.";
        reference
          "IEEE 802.3-2018, Clause 88: IEEE Standard for Ethernet

          MEF63: Subscriber Layer 1 Service Attributes";
      }
```

```
  identity ER4-PMD-100G {
    base optical-interface-func;
    description
      "ER4-PMD-clause-88 Optical Interface function for
      100GBASE-R PCS-82.";
    reference
      "IEEE 802.3-2018, Clause 88: IEEE Standard for Ethernet

      MEF63: Subscriber Layer 1 Service Attributes";
  }

/*
 * Typedefs
 */

typedef otn-tpn {
  type uint16 {
    range "1..4095";
  }
  description
    "Tributary Port Number (TPN) for OTN.";
  reference
    "RFC7139: GMPLS Signaling Extensions for Control of Evolving
     G.709 Optical Transport Networks.";
}

typedef otn-ts {
  type uint16 {
    range "1..4095";
  }
  description
    "Tributary Slot (TS) for OTN.";
  reference
    "RFC7139: GMPLS Signaling Extensions for Control of Evolving
     G.709 Optical Transport Networks.";
}

typedef otn-label-range-type {
  type enumeration {
    enum trib-slot {
      description
        "Defines a range of OTN tributary slots (TS).";
    }
    enum trib-port {
      description
        "Defines a range of OTN tributary ports (TPN).";
    }
  }
```

```
      description
        "Defines the type of OTN label range: TS or TPN.";
    }

    typedef gfp-k {
      type enumeration {
        enum 2 {
          description
            "The ODU2.ts rate (1,249,177.230 kbit/s) is used
             to compute the rate of an ODUflex(GFP,n,2).";
        }
        enum 3 {
          description
            "The ODU3.ts rate (1,254,470.354 kbit/s) is used
             to compute the rate of an ODUflex(GFP,n,3).";
        }
        enum 4 {
          description
            "The ODU4.ts rate (1,301,467.133 kbit/s) is used
             to compute the rate of an ODUflex(GFP,n,4).";
        }
      }
      description
        "The ODUk.ts used to compute the rate of an ODUflex(GFP,n,k).";
      reference
        "ITU-T G.709 v6.0 (06/2020), Table 7-8 and L.7: Interfaces for
         the Optical Transport Network (OTN)";
    }

    typedef flexe-client-rate {
      type union {
        type uint16;
        type enumeration {
          enum "10G" {
            description
              "Represents a 10G FlexE Client signal (s=2).";
          }
          enum "40G" {
            description
              "Represents a 40G FlexE Client signal (s=8).";
          }
        }
      }
      description
        "The FlexE Client signal rate (s x 5,156,250.000 kbit/s)
         used to compute the rate of an ODUflex(IMP, s).

         Valid values for s are s=2 (10G), s=4 (40G) and
```

```
          s=5 x n (n x 25G).

          In the first two cases an enumeration value
          (either 10G or 40G) is used, while in the latter case
          the value of n is used.";
      reference
        "ITU-T G.709 v6.0 (06/2020), Table 7-2: Interfaces for the
         Optical Transport Network (OTN)";
    }

    typedef odtu-flex-type {
      type enumeration {
        enum "2" {
          description
            "The ODTU2.ts ODTU type.";
        }
        enum "3" {
          description
            "The ODTU3.ts ODTU type.";
        }
        enum "4" {
          description
            "The ODTU4.ts ODTU type.";
        }
        enum "Cn" {
          description
            "The ODTUCn.ts ODTU type.";
        }
      }
      description
        "The type of Optical Data Tributary Unit (ODTU),
        whose nominal bitrate is used to compute the number of
        Tributary Slots (TS) required by an ODUflex LSP, according to
        the (19-1a) and (20-1a) formulas defined in G.709.";
      reference
        "ITU-T G.709 v6.0 (06/2020), Table 7-7, clause 19.6 and
        clause 20.5: Interfaces for the Optical Transport
        Network (OTN)";
    }

    typedef bandwidth-scientific-notation {
      type string {
        pattern
          '0(\.0?)?([eE](\+)?0?)?|'
        + '[1-9](\.[0-9]{0,6})?[eE](\+)?(9[0-6]|[1-8][0-9]|0?[0-9])?';
      }
      units "bps";
      description
```

```
        "Bandwidth values, expressed using the scientific notation
        in bits per second.

        The encoding format is the external decimal-significant
        character sequences specified in IEEE 754 and ISO/IEC 9899:1999
        for 32-bit decimal floating-point numbers:
        (-1)**(S) * 10**(Exponent) * (Significant),
        where Significant uses 7 digits.

        An implementation for this representation MAY use decimal32
        or binary32. The range of the Exponent is from -95 to +96
        for decimal32, and from -38 to +38 for binary32.
        As a bandwidth value, the format is restricted to be
        normalized, non-negative, and non-fraction:
        n.dddddde{+}dd, N.DDDDDDE{+}DD, 0e0 or 0E0,
        where 'd' and 'D' are decimal digits; 'n' and 'N' are
        non-zero decimal digits; 'e' and 'E' indicate a power of ten.
        Some examples are 0e0, 1e10, and 9.953e9.";
      reference
        "IEEE Std 754-2001: IEEE Standard for Floating-Point
        Arithmetic

        ISO/IEC 9899:1999: Information technology - Programming
        Languages - C";
    }

    /*
     * Groupings
     */

    grouping otn-link-bandwidth {
      description
        "Bandwidth attributes for OTN links.";
      container otn-bandwidth {
        description
          "Bandwidth attributes for OTN links.";
        list odulist {
          key "odu-type";
          description
            "OTN bandwidth definition";
          leaf odu-type {
            type identityref {
              base odu-type;
            }
            description "ODU type";
          }
          leaf number {
            type uint16;
```

```
            description "Number of ODUs.";
          }
          leaf ts-number {
            when 'derived-from-or-self(../odu-type,"ODUflex") or
                  derived-from-or-self(../odu-type,
                  "ODUflex-resizable")' {
              description
                "Applicable when odu-type is ODUflex or
                ODUflex-resizable.";
            }
            type uint16 {
              range "1..4095";
            }
            description
              "The number of Tributary Slots (TS) that
              could be used by all the ODUflex LSPs.";
          }
        }
      }
    }

    grouping otn-path-bandwidth {
      description
        "Bandwidth attributes for OTN paths.";
      container otn-bandwidth {
        description
          "Bandwidth attributes for OTN paths.";
        leaf odu-type {
          type identityref {
            base odu-type;
          }
          description "ODU type";
        }
        choice oduflex-type {
          when 'derived-from-or-self(./odu-type,"ODUflex") or
                derived-from-or-self(./odu-type,
                "ODUflex-resizable")' {
            description
              "Applicable when odu-type is ODUflex or
               ODUflex-resizable.";
          }
          description
            "Types of ODUflex used to compute the ODUflex
             nominal bit rate.";
          reference
            "ITU-T G.709 v6.0 (06/2020), Table 7-2: Interfaces for the
             Optical Transport Network (OTN)";
          case generic {
```

```
            leaf nominal-bit-rate {
              type union {
                type l1-types:bandwidth-scientific-notation;
                type rt-types:bandwidth-ieee-float32;
              }
              mandatory true;
              description
                "Nominal ODUflex bit rate.";
            }
          }
          case cbr {
            leaf client-type {
              type identityref {
                base client-signal;
              }
              mandatory true;
              description
                "The type of Constant Bit Rate (CBR) client signal
                of an ODUflex(CBR).";
            }
          }
          case gfp-n-k {
            leaf gfp-n {
              type uint8 {
                range "1..80";
              }
              mandatory true;
              description
                "The value of n for an ODUflex(GFP,n,k).";
              reference
                "ITU-T G.709 v6.0 (06/2020), Tables 7-8 and L.7:
                 Interfaces for the Optical Transport Network (OTN)";
            }
            leaf gfp-k {
              type gfp-k;
              description
                "The value of k for an ODUflex(GFP,n,k).

                 If omitted, it is calculated from the value of gfp-n
                 as described in Table 7-8 of G.709.";
              reference
                "ITU-T G.709 v6.0 (06/2020), Tables 7-8 and L.7:
                 Interfaces for the Optical Transport Network (OTN)";
            }
          }
          case flexe-client {
            leaf flexe-client {
              type flexe-client-rate;
```

```
            mandatory true;
            description
              "The rate of the FlexE-client for an ODUflex(IMP,s).";
          }
        }
        case flexe-aware {
          leaf flexe-aware-n {
            type uint16;
            mandatory true;
            description
              "The rate of FlexE-aware client signal
               for ODUflex(FlexE-aware)";
          }
        }
        case packet {
          leaf opuflex-payload-rate {
            type union {
              type l1-types:bandwidth-scientific-notation;
              type rt-types:bandwidth-ieee-float32;
            }
            mandatory true;
            description
              "Either the GFP-F encapsulated packet client nominal
               bit rate for an ODUflex(GFP) or the 64b/66b encoded
               packet client nominal bit rate for an ODUflex(IMP).";
          }
        }
      }
    }
  }

  grouping otn-max-path-bandwidth {
    description
      "Maximum bandwidth attributes for OTN paths.";
    container otn-bandwidth {
      description
        "Maximum bandwidth attributes for OTN paths.";
      leaf odu-type {
        type identityref {
          base odu-type;
        }
        description "ODU type.";
      }
      leaf max-ts-number {
        when 'derived-from-or-self(../odu-type,"ODUflex") or
              derived-from-or-self(../odu-type,
              "ODUflex-resizable")' {
          description
```

```
              "Applicable when odu-type is ODUflex or
               ODUflex-resizable.";
          }
          type uint16 {
            range "1..4095";
          }
          description
            "The maximum number of Tributary Slots (TS) that could be
            used by an ODUflex LSP.";
        }
      }
    }

    grouping otn-label-range-info {
      description
        "Label range information for OTN.

         This grouping SHOULD be used together with the
         otn-label-start-end and otn-label-step groupings to provide
         OTN technology-specific label information to the models which
         use the label-restriction-info grouping defined in the module
         ietf-te-types.";
      container otn-label-range {
        description
          "Label range information for OTN.";
        leaf range-type {
          type otn-label-range-type;
          description "The type of range (e.g., TPN or TS)
            to which the label range applies";
        }
        leaf tsg {
          type identityref {
            base tributary-slot-granularity;
          }
          description
            "Tributary slot granularity (TSG) to which the label range
            applies.

            This leaf MUST be present when the range-type is TS.

            This leaf MAY be omitted when mapping an ODUk over an OTUk
            Link. In this case the range-type is tpn, with only one
            entry (ODUk), and the tpn range has only one value (1).";
          reference
            "ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
            Transport Network (OTN)";
        }
        leaf-list odu-type-list {
```

```
          type identityref {
            base odu-type;
          }
          description
            "List of ODU types to which the label range applies.

            An Empty odu-type-list means that the label range
            applies to all the supported ODU types.";
        }
        leaf priority {
          type uint8 {
            range 0..7;
          }
          description
            "Priority in Interface Switching Capability
            Descriptor (ISCD).";
          reference
            "RFC4203: OSPF Extensions in Support of Generalized
            Multi-Protocol Label Switching (GMPLS)";
        }
      }
    }

    grouping otn-label-start-end {
      description
        "The OTN label-start or label-end used to specify an OTN label
         range.

         This grouping is dependent on the range-type defined in the
         otn-label-range-info grouping.

         This grouping SHOULD be used together with the
         otn-label-range-info and otn-label-step groupings to provide
         OTN technology-specific label information to the models which
         use the label-restriction-info grouping defined in the module
         ietf-te-types.";
      container otn-label {
        description
          "Label start or label end for OTN.

          It is either a TPN or a TS depending on the OTN label range
          type specified in the 'range-type' leaf defined in the
          otn-label-range-info grouping.";
        leaf tpn {
          when "../../../../otn-label-range/range-type =
                'trib-port'" {
          description
            "Valid only when range-type represented by
```

```
              trib-port.";
          }
          type otn-tpn;
          description
            "Tributary Port Number (TPN).";
          reference
            "RFC7139: GMPLS Signaling Extensions for Control of
            Evolving G.709 Optical Transport Networks";
        }
        leaf ts {
          when "../../../../otn-label-range/range-type =
                'trib-slot'" {
            description
              "Valid only when range-type represented by
              trib-slot.";
          }
          type otn-ts;
          description
            "Tributary Slot (TS) number.";
          reference
            "RFC7139: GMPLS Signaling Extensions for Control of
            Evolving G.709 Optical Transport Networks";
        }
      }
    }

    grouping otn-label-hop {
      description "OTN Label";
      reference
        "RFC7139, section 6: GMPLS Signaling Extensions for Control of
         Evolving G.709 Optical Transport Networks";
      container otn-label {
        description
          "Label hop for OTN.";
        leaf tpn {
          type otn-tpn;
          description
            "Tributary Port Number (TPN).";
          reference
            "RFC7139: GMPLS Signaling Extensions for Control of
            Evolving G.709 Optical Transport Networks";
        }
        leaf tsg {
          type identityref {
            base tributary-slot-granularity;
          }
          description "Tributary Slot Granularity (TSG).";
          reference
```

```
            "ITU-T G.709 v6.0 (06/2020): Interfaces for the Optical
            Transport Network (OTN)";
          }
          leaf ts-list {
            type string {
                pattern "([1-9][0-9]{0,3}(-[1-9][0-9]{0,3})?"
                      + "(,[1-9][0-9]{0,3}(-[1-9][0-9]{0,3})?)*)";
            }
            description
              "A list of available Tributary Slots (TS) ranging
              between 1 and 4095. If multiple values or
              ranges are given, they all MUST be disjoint
              and MUST be in ascending order.
              For example 1-20,25,50-1000.";
            reference
              "RFC 7139: GMPLS Signaling Extensions for Control
              of Evolving G.709 Optical Transport Networks";
          }
        }
      }

      grouping otn-label-step {
        description
          "Label step for OTN.

           This grouping is dependent on the range-type defined in the
           otn-label-range-info grouping.

           This grouping SHOULD be used together with the
           otn-label-range-info and otn-label-start-end groupings to
           provide OTN technology-specific label information to the
           models which use the label-restriction-info grouping defined
           in the module ietf-te-types.";
        container otn-label-step {
          description
            "Label step for OTN.

             It is either a TPN or a TS depending on the OTN label range
             type specified in the 'range-type' leaf defined in the
             otn-label-range-info grouping.";
          leaf tpn {
            when "../../../otn-label-range/range-type =
                  'trib-port'" {
              description
                "Valid only when range-type represented by
                trib-port.";
            }
            type otn-tpn;
```

```
          description
            "Label step which represents possible increments for
            Tributary Port Number (TPN).";
          reference
            "RFC7139: GMPLS Signaling Extensions for Control of
            Evolving G.709 Optical Transport Networks";
        }
        leaf ts {
          when "../../../otn-label-range/range-type =
                'trib-slot'" {
          description
            "Valid only when range-type represented by
            trib-slot";
          }
          type otn-ts;
          description
            "Label step which represents possible increments for
            Tributary Slot (TS) number.";
          reference
            "RFC7139: GMPLS Signaling Extensions for Control of
            Evolving G.709 Optical Transport Networks";
        }
      }
    }
  }
  <CODE ENDS>
```

7. Security Considerations

The YANG module specified in this document defines a schema for data that is designed to be accessed via network management protocols such as NETCONF [RFC6241] or RESTCONF [RFC8040]. The lowest NETCONF layer is the secure transport layer, and the mandatory-to-implement secure transport is Secure Shell (SSH) [RFC6242]. The lowest RESTCONF layer is HTTPS, and the mandatory-to-implement secure transport is TLS [RFC8446].

If using secure channels, such as SSH for NETCONF or TLS for RESTCONF, an array of secure validation methods are availible. These methods range from public key and password authentication to host identity verification. It is strongly advised to not use options that require no authentication. However, it is important to acknowledge that not all authentication methods offer the same level of security. For instance, password-based authentication is notably susceptible to security threats such as phishing attacks and password reuse.

The NETCONF access control model [RFC8341] provides the means to restrict access for particular NETCONF or RESTCONF users to a preconfigured subset of all available NETCONF or RESTCONF protocol operations and content.

The YANG module in this document defines layer 1 type definitions (i.e., typedef, identity and grouping statements) in YANG data modeling language to be imported and used by other layer 1 technology-specific modules. When imported and used, the resultant schema will have data nodes that can be writable, or readable. The access to such data nodes may be considered sensitive or vulnerable in some network environments. Write operations (e.g., edit-config) to these data nodes without proper protection can have a negative effect on network operations.

The security considerations spelled out in the YANG 1.1 specification [RFC7950] apply for this document as well.

8. IANA Considerations

It is proposed that IANA should assign new URIs from the "IETF XML Registry" [RFC3688] as follows:

```
URI: urn:ietf:params:xml:ns:yang:ietf-layer1-types
Registrant Contact: The IESG
XML: N/A; the requested URI is an XML namespace.
```

This document registers following YANG modules in the YANG Module Names registry [RFC7950].

```
name:         ietf-layer1-types
namespace:    urn:ietf:params:xml:ns:yang:ietf-layer1-types
prefix:       l1-types
reference:    RFC XXXX
```

RFC Editor Note: Please replace XXXX with the number assigned to the RFC once this draft becomes an RFC.

9. Acknowledgements

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Appendix A. Examples of OTN Label Ranges

This appendix provides some examples of how the TPN and TS label ranges described in Table 3 and Table 4 of [RFC7139] can be represented in YANG using the groupings defined in this document.

It also considers the OTUk links in addition to HO-ODUk links.

The JSON code examples provided in this appendix provides some embedded comments following the conventions in Section 3.2 of [I-D.ietf-ccamp-transport-nbi-app-statement] and have been folded using the tool in [RFC8792].

```
================ NOTE: '\\' line wrapping per RFC 8792 ================

{
  "// examples of label-restrictions for different OTN Links": [
    {
      "// example": "HO-ODU1 or OTU1 Link",
      "label-restrictions": {
        "label-restriction": [
          {
            "index ": 1,
            "// default restriction": "inclusive",
            "otn-label-range": {
              "range-type": "label-range-trib-port",
              "// not-present tsg": "",
              "odu-type-list": "[ ODU1 ]",
              "// default priority": 7
            },
            "// tpn-range": 1,
            "// comment": "Since no TS range and no TSG are reported\
\ for ODU1, the link is an OTU1 Link. TS allocation is not needed an\
\d TPN shall be set to '1' for mapping ODU1 over OTU1. This entry is\
\ not present if the OTN Link is an HO-ODU1 Link."
          },
          {
            "index ": 2,
            "// default restriction": "inclusive",
            "otn-label-range": {
              "range-type": "label-range-trib-slot",
              "tsg": "tsg-1.25G",
```

```
                "odu-type-list": "[ ODU0 ]",
                "// default priority": 7
              },
              "// ts-range": "1-2",
              "// comment": "Since no TPN range is reported for ODU0 w\
   \ith 1.25G TSG, the TPN allocation rule is fixed (TPN = TS#) for map\
   \ping LO-ODU0 over HO-ODU1 with 1.25G TSG. See Table 4 of [RFC7139]."
            }
          ]
        }
      },
      {
        "// example": "HO-ODU2 or OTU2 Link",
        "label-restrictions": {
          "label-restriction": [
            {
              "index ": 1,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-port",
                "// not-present tsg": "",
                "odu-type-list": "[ ODU2 ]",
                "// default priority": 7
              },
              "// tpn-range": 1,
              "// comment": "Since no TS range and no TSG are reported\
   \ for ODU2, the link is an OTU2 Link. TS allocation is not needed an\
   \d TPN shall be set to '1' for mapping ODU2 over OTU2. This entry is\
   \ not present if the OTN Link is an HO-ODU2 Link."
            },
            {
              "index ": 2,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-slot",
                "tsg": "tsg-1.25G",
                "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, OD\
   \U1 ]",
                "// default priority": 7
              },
              "// ts-range": "1-8"
            },
            {
              "index ": 3,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-port",
                "tsg": "tsg-1.25G ",
```

```
                "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0 ]",
                "// default priority": 7
              },
              "// tpn-range": "1-8",
              "// comment": "Since this TPN range is reported for ODUf\
   \lex and ODU0 with 1.25G TSG, the TPN assignment rule is flexible wi\
   \thin a common range for mapping LO-ODUflex and LO-ODU0 over HO-ODU2\
   \ with 1.25G TSG. See Table 4 of [RFC7139]."
            },
            {
              "index ": 4,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-port",
                "tsg": "tsg-1.25G",
                "odu-type-list": "[ ODU1 ]",
                "// default priority": 7
              },
              "// tpn-range": "1-4",
              "// comment": "Since this TPN range is reported for ODU1\
   \ with 1.25G TSG, the TPN assignment rule is flexible within a commo\
   \n range for mapping LO-ODU1 over HO-ODU2 with 1.25G TSG. See Table \
   \4 of [RFC7139]."
            },
            {
              "index ": 5,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-slot",
                "tsg": "tsg-2.5G",
                "odu-type-list": "[ ODU1 ]",
                "// default priority": 7
              },
              "// ts-range": "1-4",
              "// comment": "Since no TPN range is reported for ODU1 w\
   \ith 2.5G TSG, the TPN allocation rule is fixed (TPN = TS#) for mapp\
   \ing LO-ODU1 over HO-ODU2 with 2.5G TSG. See Table 3 of [RFC7139]."
            }
          ]
        }
      },
      {
        "// example": "HO-ODU3 or OTU3 Link",
        "label-restrictions": {
          "label-restriction": [
            {
              "index ": 1,
              "// default restriction": "inclusive",
```

```
              "otn-label-range": {
                "range-type": "label-range-trib-port",
                "// not-present tsg": "",
                "odu-type-list": "[ ODU3 ]",
                "// default priority": 7
              },
              "// tpn-range": 1,
              "// comment": "Since no TS range and no TSG are reported\
   \ for ODU3, the link is an OTU3 Link. TS allocation is not needed an\
   \d TPN shall be set to '1' for mapping ODU3 over OTU3. This entry is\
   \ not present if the OTN Link is an HO-ODU3 Link."
            },
            {
              "index ": 2,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-slot",
                "tsg": "tsg-1.25G",
                "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, OD\
   \U1, ODU2, ODU2e ]",
                "// default priority": 7
              },
              "// ts-range": "1-32"
            },
            {
              "index ": 3,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-port",
                "tsg": "tsg-1.25G",
                "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, OD\
   \U2e ]",
                "// default priority": 7
              },
              "// tpn-range": "1-32",
              "// comment": "Since this TPN range is reported for ODUf\
   \lex, ODU0 and ODU2e with 1.25G TSG, the TPN assignment rule is flex\
   \ible within a common range for mapping LO-ODUflex, LO-ODU0 and LO-O\
   \DU2e over HO-ODU3 with 1.25G TSG. See Table 4 of [RFC7139]."
            },
            {
              "index ": 4,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-port",
                "tsg": "tsg-1.25G",
                "odu-type-list": "[ ODU1 ]",
                "// default priority": 7
```

```
              },
              "// tpn-range": "1-16",
              "// comment": "Since this TPN range is reported for ODU1\
   \ with 1.25G TSG, the TPN assignment rule is flexible within a commo\
   \n range for mapping LO-ODU1 over HO-ODU3 with 1.25G TSG. See Table \
   \4 of [RFC7139]."
            },
            {
              "index ": 5,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-port",
                "tsg": "tsg-1.25G",
                "odu-type-list": "[ ODU2 ]",
                "// default priority": 7
              },
              "// tpn-range": "1-4",
              "// comment": "Since this TPN range is reported for ODU2\
   \ with 1.25G TSG, the TPN assignment rule is flexible within a commo\
   \n range for mapping LO-ODU2 over HO-ODU3 with 1.25G TSG. See Table \
   \4 of [RFC7139]."
            },
            {
              "index ": 6,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-slot",
                "tsg": "tsg-2.5G",
                "odu-type-list": "[ ODU1, ODU2 ]",
                "// default priority": 7
              },
              "// ts-range": "1-16"
            },
            {
              "index ": 7,
              "// default restriction": "inclusive",
              "otn-label-range": {
                "range-type": "label-range-trib-port",
                "tsg": "tsg-2.5G ",
                "odu-type-list": "[ ODU2 ]",
                "// default priority": 7
              },
              "// tpn-range": "1-4",
              "// comment": "Since this TPN range is reported for ODU2\
   \ with 2.5G TSG, the TPN assignment rule is flexible within a common\
   \ range for mapping LO-ODU2 over HO-ODU3. Since no TPN range is repo\
   \rted for ODU1 with 2.5G TSG, the TPN allocation rule is fixed (TPN \
   \= TS#) for mapping LO-ODU1 over HO-ODU3 with 2.5G TSG. See Table 3 \
```

```
   \of [RFC7139]."
             }
           ]
         }
       },
       {
         "// example": "HO-ODU4 or OTU4 Link",
         "label-restrictions": {
           "label-restriction": [
             {
               "index ": 1,
               "// default restriction": "inclusive",
               "otn-label-range": {
                 "range-type": "label-range-trib-port",
                 "// not-present tsg": "",
                 "odu-type-list": "[ ODU4 ]",
                 "// default priority": 7
               },
               "// tpn-range": 1,
               "// comment": "Since no TS range and no TSG are reported\
   \ for ODU4, the link is an OTU4 Link. TS allocation is not needed an\
   \d TPN shall be set to '1' for mapping ODU4 over OTU4. This entry is\
   \ not present if the OTN Link is an HO-ODU4 Link."
             },
             {
               "index ": 2,
               "// default restriction": "inclusive",
               "otn-label-range": {
                 "range-type": "label-range-trib-slot",
                 "tsg": "tsg-1.25G",
                 "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, OD\
   \U1, ODU2, ODU2e, ODU3 ]",
                 "// default priority": 7
               },
               "// ts-range": "1-80"
             },
             {
               "index ": 3,
               "// default restriction": "inclusive",
               "otn-label-range": {
                 "range-type": "label-range-trib-port",
                 "tsg": "tsg-1.25G",
                 "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, OD\
   \U1, ODU2, ODU2e, ODU3 ]",
                 "// default priority": 7
               },
               "// tpn-range": "1-80",
               "// comment": "Since this TPN range is reported for any \
```

```
   \LO-ODUj with 1.25G TSG, the TPN assignment rule is flexible within \
   \a common range for mapping any LO-ODUj over HO-ODU4 with 1.25G TSG.\
   \ See Table 4 of [RFC7139]."
             }
           ]
         }
       },
       {
         "// example": "ODUC1 Link",
         "label-restrictions": {
           "label-restriction": [
             {
               "index ": 1,
               "// default restriction": "inclusive",
               "otn-label-range": {
                 "range-type": "label-range-trib-slot",
                 "tsg": "tsg-5G",
                 "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, OD\
   \U1, ODU2, ODU2e, ODU3, ODU4 ]",
                 "// default priority": 7
               },
               "// ts-range": "1-20",
               "// comment": "Since the TS range is specified for any O\
   \DUk, the OTN Link is an ODUCn Link."
             },
             {
               "index ": 2,
               "// default restriction": "inclusive",
               "otn-label-range": {
                 "range-type": "label-range-trib-port",
                 "tsg": "tsg-5G",
                 "odu-type-list": "[ ODUFlex-cbr, ODUFlex-gfp, ODU0, OD\
   \U1, ODU2, ODU2e, ODU3, ODU4 ]",
                 "// default priority": 7
               },
               "// tpn-range": "1-10",
               "// comment": "Since this TPN range is reported for any \
   \ODUk with 5G TSG, the TPN assignment rule is flexible within a comm\
   \on range for mapping any ODUk over ODUCn with 5G TSG."
             }
           ]
         }
       }
     ]
   }
```

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