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Applicability of GMPLS for B100G Optical Transport Network
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Abstract

This document examines the applicability of using current existing GMPLS routing and signaling to set up ODUk/ODUflex over ODUCn link, as a result of the introduction of OTU/ODU links with rates larger than 100G in the 2016 version of G.709.

Status of This Memo

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Table of Contents

1. Introduction

The current GMPLS routing [RFC7138] and signaling extensions [RFC7139] only supports the control of OTN signals and capabilities that were defined in the 2012 version of G.709 [ITU-T_G709_2012].

Since the publishment of the latest 2016 version of G.709 [ITU-T_G709_2016], which introduces support for new higher rate ODU signals, termed ODUCn (which have a nominal rate of n x 100 Gbps), how to applied GMPLS to ODUCn case should be taken into consideration. As OTUCn and ODUCn only perform section layer role only according to the definition in G.709 [ITU-T_G709_2016], which means the OTUCn and ODUCn are only used to provide for the transfer of information between two adjacent upper layer cross-connects, i.e., ODUk/ODUflex cross connects, it's not appropriate to apply GMPLS to

OTUCn and ODUCn. Therefore, this document mainly focuses on the use of GMPLS mechanisms to set up ODUk/ODUflex over an existing ODUCn link.

This document first presents an overview of the changes introduced in [ITU-T_G709_2016] to motivate the present topic and then analyzes how the current GMPLS routing and signalling mechanisms can be utilized to setup ODUk/ODUflex connections over ODUCn links. In order to make the description in this document clear, how to set up ODUCn link is also mentioned.

1.1. Scope

For the purposes of the B100G control plane discussion, the OTN should be considered as a combination of ODU and OTSi layers. Note that [ITU-T_G709_2016] is deprecating the use of the term "OCh" for B100G entities, and leaving it intact only for maintaining continuity in the description of the signals with bandwidth upto 100G.

This document only focuses on the control of the ODU layer. The control of the OTSi layer is out of scope of this document. But in order to facilitate the description of the challenges brought by [ITU-T_G709_2016] to B100G GMPLS routing and signalling, some general description about OTSi is included in section 4 of this document.

2. OTN terminology used in this document

a. OPUCn: Optical Payload Unit -Cn.

b. ODUCn: Optical Data Unit - Cn.

c. OTUCn: Fully standardized Optical Transport Unit - Cn.

d. OTUCn-M: This signal is an extension of the OTUCn signal introduced above. This signal contains the same amount of overhead as the OTUCn signal, but contains a reduced amount of payload area. Specifically the payload area consists of M 5G tributary slots (where M is strictly less than 20*n).

e. PSI: OPU Payload structure Indicator. This is a multi-frame message and describes the composition of the OPU signal. This field is a concatenation of the Payload type (PT) and the Multiplex Structrure Indicator (MSI) defined below.

f. MSI: Multiplex Structure Indicator. This structure indicates the grouping of the tributary slots in an OPU payload area to realize a client signal that is multiplexed into an OPU. The individual

clients multiplexed into the OPU payload area are distinguished by the Tributary Port number (TPN).

g. GMP: Generic Mapping Procedure.

h. OTSiG: The set of OTSi that supports a single digital client.

i. OTSiA: The OTSiG together with the non-associated overhead (OTSiG-O).

Detailed description of these terms can be found in [ITU-T_G709_2016] and [ITU-T_G807].

3. Overview of B100G in G.709

This section provides an overview of new features in [ITU-T_G709_2016].

3.1. OTUCn

In order to carry client signals with rates greater than 100Gbps, [ITU-T_G709_2016] takes a general and scalable approach that decouples the rates of OTU signals from the client rate. The new OTU signal is called OTUCn, and this signal is defined to have a rate of (approximately) n*100G. The following are the key characteristics of the OTUCn signal:

a. The OTUCn signal contains one ODUCn. The OTUCn and ODUCn signals perform digital section roles only (see [ITU-T_G709_2016]:Section 6.1.1)

b. The OTUCn signals can be viewed as being formed by interleaving n OTUC signals (which are labeled 1, 2, ..., n), each of which has the format of a standard OTUk signal without the FEC columns (per [ITU-T_G709_2016]Figure 7-1). The ODUCn have a similar structure, i.e. they can be seen as being formed by interleaving n instances of ODUC signals (respectively). The OTUC signal contains the ODUC signals, just as in the case of fixed rate OTUs defined in G.709 [ITU-T_G709_2016].

c. Each of the OTUC "slices" have the same overhead as the standard OTUk signal in G.709 [ITU-T_G709_2016]. The combined signal OTUCn has n instances of OTUC overhead, ODUC overhead.

d. The OTUC signal has a slightly higher rate compared to the OTU4 signal (without FEC); this is to ensure that the OPUC payload area can carry an ODU4 signal.

As explained above, within G.709 [ITU-T_G709_2016], the OTUCn, ODUCn and OPUCn signal structures are presented in a (physical) interface independent manner, by means of n OTUC, ODUC and OPUC instances that are marked #1 to #n. Specifically, the definition of the OTUCn signal does not cover aspects such as FEC, modulation formats, etc. These details are defined as part of the adaptation of the OTUCn layer to the optical layer(s). The specific interleaving of OTUC/ODUC/OPUC signals onto the optical signals is interface specific and specified for OTN interfaces with standardized application codes in the interface specific recommendations (G.709.x).

OTUCn interfaces can be categorized as follows, based on the type of peer network element (see Figure 1):

a. inter-domain interfaces: These types of interfaces are used for connecting OTN edge nodes to (a) client equipment (e.g. routers) or (b) hand-off points from other OTN networks. ITU-T has standardized the Flexible OTN (FlexO) interfaces to support these functions. For example, Recommendation [ITU-T_G709.1] specifies a flexible interoperable short-reach OTN interface over which an OTUCn (n >=1) is transferred, using bonded FlexO interfaces which belong to a FlexO group.

b. intra-domain interfaces: In these cases, the OTUCn is transported using a proprietary (vendor specific) encapsulation, FEC etc. It may also be possible to transport OTUCn for intra-domain links using FlexO.

```
 ==================================================================


       +---------------------------------------------------------+
       |                 OTUCn signal                            |
       +---------------------------------------------------------+
       |  Inter+Domain    |  Intra+Domain    |  Intra+Domain    |
       |  Interface (IrDI)|  Interface (IaDI)|  Interface       |
       |  FlexO (G.709.1) |  FlexO (G.709.x) |  Proprietary     |
       |                  |  (Future)        |  Encap, FEC etc. |
       +---------------------------------------------------------+


 ==================================================================
```

Figure 1: OTUCn transport possibilities

3.2. ODUCn

The ODUCn signal [ITU-T_G709_2016] can be viewed as being formed by the appropriate interleaving of content from n ODUC signal instances. The ODUC frames have the same structure as a standard ODU -- in the sense that it has the same Overhead area, and the payload area -- but has a higher rate since its payload area can embed an ODU4 signal.

The ODUCn signals have a rate that is captured in Table 1.

ODU Type	ODU Bit Rate
ODUCn	n x 239/226 x 99,532,800 kbit/s = n x 105,258,138.053 kbit/s

Table 1: ODUCn rates

The ODUCn is a multiplex section ODU signal, and is mapped into an OTUCn signal which provides the regenerator section layer. In some scenarios, the ODUCn, and OTUCn signals will be co-terminated, i.e. they will have identical source/sink locations. [ITU-T_G709_2016] and [ITU-T_G872] allow for the ODUCn signal to pass through a digital regenerator node which will terminate the OTUCn layer, but will pass the regenerated (but otherwise untouched) ODUCn towards a different OTUCn interface where a fresh OTUCn layer will be initiated (see Figure 2). In this case, the ODUCn is carried by 3 OTUCn segments.

Specifically, the OPUCn signal flows through these regenerators unchanged. That is, the set of client signals, their TPNs, trib-slot allocation remains unchanged. The ODUCn Overhead might be modified if TCM sub-layers are instantiated in order to monitor the performance of the regenerator hops. In this sense, the ODUCn should NOT be seen as a general ODU which can be switched via an ODUk cross-connect.

```
   ==================================================================


    +--------+           +--------+
    |        +-----------+        |
    | OTN    |-----------| OTN    |
    | DXC    +-----------+ DXC    +
    |        |           |        |
    +--------+           +--------+
        <--------ODUCn------->
         <-------OTUCn------>

    +--------+        +--------+        +--------+          +--------+
    |        +--------+        |        |        +----------+        |
    | OTN    |--------| OTN    |        | OTN    |----------| OTN    |
    | DXC    +--------+ WXC    +--------+ WXC    +----------+ DXC    |
    |        |        | 3R     |        | 3R     |          |        |
    +--------+        +--------+        +--------+          +--------+
        <-------------------------ODUCn------------------------->
         <----------------> <----------------> <------------------>
              OTUCn               OTUCn               OTUCn


   ==================================================================
```

Figure 2: ODUCn signal

3.3. OTUCn-M

The standard OTUCn signal has the same rate as that of the ODUCn signal as captured in Table 1. This implies that the OTUCn signal can only be transported over wavelength groups which have a total capacity of multiples of (approximately) 100G. Modern DSPs support a variety of bit rates per wavelength, depending on the reach requirements for the optical link. In other words, it is possible to extend the reach of an optical link (i.e. increase the physical distance covered) by lowering the bitrate of the client signal that is modulated onto the optical signals. By the very nature of the OTUCn signal, it is constrained to rates which are multiples of (approximately) 100G. If it happens that the total rate of the LO-ODUs carried over the ODUCn is smaller than n X 100G, it is possible to "crunch" the OTUCn to remove the unused capacity. With this in mind, ITU-T supports the notion of a reduced rate OTUCn signal, termed the OTUCn-M. The OTUCn-M signal is derived from the OTUCn signal by retaining all the n instances of overhead (one per OTUC slice) but only M tributary slots of capacity.

3.4. Time Slot Granularity

[ITU-T_G709_2012] introduced the support for 1.25G granular tributary slots in OPU2, OPU3, and OPU4 signals. With the introduction of higher rate signals, it is not practical for the optical networks (and the data plane hardware) to support a very large number of connections at such a fine granularity. ITU-T has defined the OPUC with a tributary slot granularity of 5G. This means that the ODUCn signal has 20*n tributary slots (of 5Gbps capacity). It is worthwhile considering that the range of tributary port number (TPN) is 10*n instead of 20*n, which restricts the maximum client signals that could be carried over one single ODUC1.

3.5. Structure of OPUCn MSI with Payload type 0x22

As mentioned above, the OPUCn signal has 20*n 5G tributary slots. The OPUCn contains n PSI structures, one per OPUC instance. The PSI structure consists of the Payload Type (of 0x22), followed by a Reserved Field (1 byte) and the MSI. The OPUCn MSI field has a fixed length of 40*n bytes and indicates the availability of each TS. Two bytes are used for each of the 20*n tributary slots, and each such information structure has the following format ([ITU-T_G709_2016] G.709:Section 20.4.1):

a. The TS availability bit indicates if the tributary slot is available or unavailable

b. The TS occupation bit indicates if the tributary slot is allocated or unallocated

c. The tributary port bits indicates the port number of the client signal that is being carried in this specific TS. A flexible assignment of tributary port to tributary slots is possible. Numbering of tributary ports is from 1 to 10n.

3.6. Client Signal Mappings

The approach taken by the ITU-T to map non-OTN client signals to the appropriate ODU containers is as follows:

a. All client signals with rates less than 100G are mapped into ODU container as specified in clause 17 of [ITU-T_G709_2016]. These mappings are identical to those specified in the earlier revision of G.709 [ITU-T_G709_2012]. For example, the 1000BASE-X/10GBASE-R signals are mapped to ODU0/ODU2e respectively (see Table 2 -- based on Table 7-2 in [ITU-T_G709_2016])

b. New emerging client signals are usually mapped into ODUflex signals of the appropriate rates (see Table 2 according to the Table 7-2 in [ITU-T_G709_2016])

c. ODU Virtual Concatenation is not supported any more. This simplifies the network, and the supporting hardware since multiple different mappings for the same client are no longer necessary. Note that legacy implementations that transported sub-100G clients using ODU VCAT shall continue to be supported.

d. ODUflex signals are low-order signals only. If the ODUflex entities have rates of 100G or less, they can be transported over either an ODUk (k=1..4) or an ODUCn. For ODUflex connections with rates greater than 100G, ODUCn is required.

ODU Type	ODU Bit Rate
ODU0	1,244,160 Kbps
ODU1	239/238 x 2,488,320 Kbps
ODU2	239/237 x 9,953,280 Kbps
ODU2e	239/237 x 10,312,500 Kbps
ODU3	239/236 x 39,813,120 Kbps
ODU4	239/227 x 99,532,800 Kbps
ODUflex for CBR client signals	239/238 x Client signal Bit rate
ODUflex for GFP-F mapped packet traffic	Configured bit rate
ODUflex for IMP mapped packet traffic	s x 239/238 x 5 156 250 kbit/s: s=2,8,5*n, n >= 1
ODUflex for FlexE aware transport	103 125 000 x 240/238 x n/20 kbit/s, where n is total number of available tributary slots among all PHYs which have been crunched and combined.

Note that this table doesn't include ODUCn -- since it cannot be generated by mapping a non-OTN signal. An ODUCn is always formed by multiplexing multiple LO-ODUs.

Table 2: Types and rates of ODUs usable for client mappings

```
   ==================================================================


                     Clients (e.g. SONET/SDH, Ethernet)
                          +       +      +
                          |       |      |
       +------------------+-------+------+-----------------------+
       |                     OPUk                                |
       +---------------------------------------------------------+
       |                     ODUk                                |
       +---------------------+---------------------------+------+
       | OTUk, OTUk.V, OTUkV |          OPUk             |      |
       +----------+----------------------------------------+      |
       | OTLk.n   |          |          ODUk             |      |
       +----------+          +---------------------+-----+      |
                             | OTUk, OTUk.V, OTUkV |   OPUCn    |
                             +----------+----------------------+
                             | OTLk.n   |          |   ODUCn    |
                             +----------+          +------------+
                                                   |   OTUCn    |
                                                   +------------+


   ==================================================================
```

Figure 3: Digital Structure of OTN interfaces (from G.709:Figure 6-1)

4. Applicability and GMPLS Implications

4.1. Applicability and Challenges

This section analyzes the OTUCn deployment scenarios to identify potential extensions to GMPLS that would be needed. When OTUCn links are established between line ports of two different network elements, two scenarios are possible. These scenarios are modeled according to those illustrated in Appendix XIII of [ITU-T_G709_2016]. Note that while this Appendix illustrates OTUCn subrating possibilities, the scenarios serve a more general purpose also. Two possible realization of OTUCn realizations between nodes are:

a. The first scenario (see Figure 4) deploys OTUCn/OTUCn-M between two line ports connecting two L1/L0 ODU cross connects (XC) within one optical transport network. As defined in [ITU-T_G807], the OTUCn/OTUCn-M signal is transported using by one OTSiG, which could be comprised of one or more OTSi. The OTSiG may have non-associated overhead (denoted as OTSiG-O); the combination of the OTSiG and OTSiG-O is represented by the OTSiA management/control abstraction. There is a 1:1 mapping

relationship between OTUCn and OTSiG or OTSiA. For example, a 400G OTUC4 signal can be carried over a single OTSi signal with a 400G capcity, or perhaps split into 4 100G digital information streams each of which is carried over a OTSi signal with a 100G capacity. In this scenario, it is clear that the OTUCn and ODUCn link can be automatically established, after/together with the setup of OTSiG or OTSiA, as both OTUCn and ODUCn perform section layer only. Once the ODUCn link is automatically established, it can be advertized as a TE-link and used for setting up ODUk/ ODUflex connections.

b. The second scenario (see depicted in Figure 5) deploys OTUCn/ OTUCn-M between transponders which are in a different domain B, and are separated from the L1 ODU XCs in domain A and/or C. In this scenario, the end-to-end ODUCn is actually supported by three different OTUCn or OTUCn-M segments, which are in turn carried by their respective OTSi(G) or OTSiA. In this example, the OTUCn links will be established automatically after/together with the setup of OTSi(G) or OTSiA. Note that until both transponder nodes in domain B have been configured, the ODUCn signal transmitted by node A doesn't reach node C. Until all the required configuration operations are completed, the ODUCn.STAT field will reflect the AIS (i.e. error) status. Once all the provisioning has been performed in domain B, and the links connecting the edge nodes to transponders in domain B are error free, the end to end ODUCn flows will be established. In this case, the receipt of a normal value for the ODUCn.STAT field can trigger the creation of the ODUCn link.

```
==================================================================


              +--------+                     +--------+
              |        +---------------------+        |
              | OTN    |---------------------| OTN    |
              |  XC    +---------------------+  XC    |
              |        |                     |        |
              +--------+                     +--------+
                <---------- ODUk/ODUflex ----------->
                 <----------- ODUCn -------------->
                  <------- OTUCn/OTUCn-M --------->
                   <--------OTSi(G)/OTSiA--------->


==================================================================
```

Figure 4: Scenario A

```
   ==================================================================


                       +----------------------------+
        A              |             B              |         A or C
        |              |                            |            |
   +---------+         | +---------+      +---------+ |       +---------+
   |         +----------|-+         |      |         +-|--------+         |
   | OTN     |----------|-| Transp |      | Transp |-|--------| OTN     |
   |  XC     +----------|-+ onder  +-------+ onder  +-|--------+  XC     |
   |         |         | |         |      |         | |       |         |
   +---------+         | +---------+      +---------+ |       +---------+
                       |                            |
                       +----------------------------+

        <------------------------ODUk/ODUflex---------------------->
         <------------------------ ODUCn ------------------------->
          <------OTUCn------><---OTUCn/OTUCn-M---><------OTUCn------>
           <-OTSi(G)/OTSiA->  <--OTSi(G)/OTSiA-->  <-OTSi(G)/OTSiA->


   ==================================================================
```

Figure 5: Scenario B

4.2. GMPLS Implications and Applicability

4.2.1. TE-Link Representation

Section 3 of RFC7138 describes how to represent G.709 OTUk/ODUk with TE-Links in GMPLS. Similar to that, ODUCn links can also be represented as TE-Links, which can be seen in the figure below.

```
   ==================================================================


  +-----+              +-----+
  |     |              |     |
  |  A  |<-OTUCn Link->|  B  |
  |     |              |     |
  +-----+              +-----+
     |<--- ODUCn Link -->|
     |<---- TE-Link ---->|

                         3R                    3R
  +-----+              +-----+              +-----+              +-----+
  |     |              |     |              |     |              |     |
  |  A  |<-OTUCn Link->|  B  |<-OTUCn Link->|  C  |<-OTUCn Link->|  D  |
  |     |              |     |              |     |              |     |
  +-----+              +-----+              +-----+              +-----+
      |<----------------------- ODUCn Link ------------------------>|
      |<------------------------ TE-Link ------------------------->|


   ==================================================================
```

Figure 6: ODUCn TE-Links

Two endpoints of a TE-Link are configured with the supported resource information, which may include whether the TE-Link is supported by an ODUCn or an ODUk or an OTUk, as well as the link attribute information (e.g., slot granularity, number of tributary slot available).

4.2.2. Implications and Applicability for GMPLS Signalling

Once the ODUCn link is configured, the GMPLS mechanisms defined in RFC7139 can be reused to set up ODUk/ODUflex LSP with no/few changes. As the resource on the ODUCn link which can be seen by the client ODUk/ODUflex is a set of 5G slots, the label defined in RFC7139 is able to accommodate the requirement of the setup of ODUk/ODUflex over ODUCn link. In [RFC7139], the OTN-TDM GENERALIZED_LABEL object is used to indicate how the LO ODUj signal is multiplexed into the HO ODUk link. In a similar manner, the OTN-TDM GENERALIZED_LABEL object is used to indicate how the ODUk signal is multiplexed into the ODUCn link. The ODUk Signal Type is indicated by Traffic Parameters. The IF_ID RSVP_HOP object provides a pointer to the interface associated with TE-Link and therefore the two nodes terminating the TE-link know (by internal/local configuration) the attributes of the ODUCn TE Link.

One thing should be note is the TPN used in RFC7139 and defined in G.709-2016 for ODUCn link. Since the TPN currently defined in G.709 for ODUCn link has 14 bits, while this field in RFC7139 only has 12 bits, some extension work is needed, but this is not so urgent since for today networks scenarios 12 bits are enough, as it can support a single ODUCn link up to n=400, namely 40Tbit.

An example is given below to illustrate the label format defined in RFC7139 for multiplexing ODU4 onto ODUC10. One ODUC10 has 200 5G slots, and twenty of them are allocated to the ODU4. Along with the increase of "n", the label may become lengthy, an optimized label format may be needed.

```
===================================================================


    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |       TPN = 3         |   Reserved    |     Length = 200      |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0 1 1 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0 0 0 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0 0 0 0 0 0 0 0|               Padding Bits(0)                 |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+


===================================================================
```

Figure 7: Label format

4.2.3. Implications and Applicability for GMPLS Routing

For routing, it is deemed that no extension to current mechanisms defined in RFC7138 are needed. Because, once an ODUCn link is up, the resources that need to be advertised are the resources that exposed by this ODUCn link and the multiplexing hierarchy on this link. Since the ODUCn link is the ultimate hierarchy of the ODU

multiplexing, there is no need to explicitly define a new value to represent the ODUCn signal type in the OSPF-TE routing protocol.

The OSPF-TE extension defined in section 4 of RFC7138 can be reused to advertise the resource information on the ODUCn link to help finish the setup of ODUk/ODUflex.

5. Acknowledgements

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8. IANA Considerations

This memo includes no request to IANA.

9. Security Considerations

None.

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