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Generalized Multi-Protocol Label Switching (GMPLS) Signaling Extensions for the evolving G.709 Optical Transport Networks Control

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Abstract

ITU-T Recommendation G.709 [G709-2012] has introduced new Optical channel Data Unit (ODU) containers (ODU0, ODU4, ODU2e and ODUflex)

and enhanced Optical Transport Networking (OTN) flexibility.

This document updates RFC4328 to provide the extensions to the Generalized Multi-Protocol Label Switching (GMPLS) signaling to control the evolving OTN addressing ODUk multiplexing and new features including ODU0, ODU4, ODU2e and ODUflex.

Conventions used in this document

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

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1. Introduction

With the evolution and deployment of OTN technology, it is necessary that appropriate enhanced control technology support be provided for [G709-2012].

[OTN-FWK] provides a framework to allow the development of protocol extensions to support GMPLS and Path Computation Element (PCE) control of OTN as specified in [G709-2012]. Based on this framework, [OTN-INFO] evaluates the information needed by the routing and signaling process in OTNs to support GMPLS control of OTN.

[RFC4328] describes the control technology details that are specific to the 2001 revision of the G.709 specification. This document updates [RFC4328] to provide Resource ReserVation Protocol-Traffic Engineering (RSVP-TE) extensions to support of control for [G709-2012].

2. Terminology

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

3. GMPLS Extensions for the Evolving G.709 - Overview

New features for the evolving OTN, for example, new ODU0, ODU2e, ODU4 and ODUflex containers are specified in [G709-2012]. The corresponding new Signal Types are summarized below:

- Optical Channel Transport Unit (OTUk):
  . OTU4

- Optical Channel Data Unit (ODUk):
  . ODU0
  . ODU2e
  . ODU4
  . ODUflex

A new Tributary Slot Granularity (TS Granularity, TSG) (i.e., 1.25 Gbps) is also described in [G709-2012]. Thus, there are now two TS granularities for the foundation OTN ODU1, ODU2 and ODU3 containers.

The TS granularity at 2.5 Gbps is used on legacy interfaces while the new 1.25 Gbps is used on the new interfaces.

In addition to the support of ODUk mapping into OTUk (k = 1, 2, 3, 4), the evolving OTN [G.709-V3] encompasses the multiplexing of ODUj (j = 0, 1, 2, 2e, 3, flex) into an ODUk (k > j), as described in Section 3.1.2 of [OTN-FWK].

Virtual Concatenation (VCAT) of Optical channel Payload Unit-k (OPUk) (OPUk-Xv, k = 1/2/3, X = 1...256) is also supported by [G709-2012]. Note that VCAT of OPU0 / OPU2e / OPU4 / OPUflex is not supported per [G709-2012].

[RFC4328] describes GMPLS signaling extensions to support the control for the 2001 revision of the G.709 specification. However, [RFC4328] needs to be updated because it does not provide the means to signal all the new Signal Types and related mapping and multiplexing functionalities. Moreover, it supports only the deprecated auto-Multiframe Structure Identifier (MSI) mode which assumes that the Tributary Port Number (TPN) is automatically assigned in the transmit direction and not checked in the receive direction.

This document extends the G.709 Traffic Parameters described in [RFC4328] and presents a new flexible and scalable OTN label format. Additionally, procedures about Tributary Port Number assignment through control plane are also provided in this document.

4. Generalized Label Request

The Generalized Label Request, as described in [RFC3471], carries the Label Switched Path (LSP) Encoding Type, the Switching Type and the Generalized Protocol Identifier (G-PID).

[RFC4328] extends the Generalized Label Request, introducing two new code-points for the LSP Encoding Type (i.e., G.709 ODUk (Digital Path) and G.709 Optical Channel) and adding a list of G-PID values in order to accommodate the 2001 revision of the G.709 specification.

This document follows these extensions and a new Switching Type is introduced to indicate the ODUk switching capability [G709-2012] in order to support backward compatibility with [RFC4328], as described in [OTN-FWK]. The new Switching Type (OTN-TDM Switching Type) is defined in [OTN-OSPF].

This document also updates the G-PID values defined in [RFC4328]:

Value	G-PID Type
47	Type field updated from "G.709 ODUj" to "ODU-2.5G" to indicates transport of Digital Paths (e.g., at 2.5, 10 and 40 Gbps) via 2.5Gbps TSG
56	Type field updated from "ESCON" to "SBCON/ESCON" to align with [G709-2012] payload type 0x1A.

Note: Value 47 includes mapping of Synchronous Digital Hierarchy (SDH).

In the case of ODU multiplexing, the Lower Order ODU (LO ODU) (i.e., the client signal) may be multiplexed into Higher Order ODU (HO ODU) via 1.25G TSG, 2.5G TSG or any one of them (i.e., TSG Auto_Negotiation is enabled). Since the G-PID type "ODUk" defined in [RFC4328] is only used for 2.5Gbps TSG, two new G-PID types are defined as follows:

- ODU-1.25G: Transport of Digital Paths at 1.25, 2.5, 10, 40 and 100 Gbps via 1.25Gbps TSG

- ODU-any: Transport of Digital Paths at 1.25, 2.5, 10, 40 and 100 Gbps via 1.25 or 2.5Gbps TSG (i.e., the fallback procedure is enabled and the default value of 1.25Gbps TSG can be fallen back to 2.5Gbps if needed)

The full list of payload types defined in [G709-2012] and their mapping to existing and new G-PID types are as follows:

G.709 Payload Type	G-PID	Type/Comment	LSP Encoding
0x01		No standard value	
0x02	49	CBRa	G.709 ODUk
0x03	50	CBRb	G.709 ODUk
0x04	32	ATM	G.709 ODUk
0x05	59(TBA)	Framed GFP	G.709 ODUk
	54	Ethernet MAC (framed GFP)	G.709 ODUk
	70(TBA)	64B/66B GFP-F Ethernet	G.709 ODUk (k=2)
0x06		Not signaled	
0x07	55	Ethernet PHY (transparent GFP)	G.709 ODUk (k=0,3,4)
0x08	58	Fiber Channel	G.709 ODUk (k=2e)
0x09	59(TBA)	Framed GFP	G.709 ODUk (k=2)
	70(TBA)	64B/66B GFP-F Ethernet	G.709 ODUk (k=2)

0x0A	60(TBA)	STM-1	G.709 ODUk (k=0)
0x0B	61(TBA)	STM-4	G.709 ODUk (k=0)
0x0C	58	Fiber Channel	G.709 ODUk (k=0)
0x0D	58	Fiber Channel	G.709 ODUk (k=1)
0x0E	58	Fiber Channel	G.709 ODUflex
0x0F	58	Fiber Channel	G.709 ODUflex
0x10	51	BSOT	G.709 ODUk
0x11	52	BSNT	G.709 ODUk
0x12	62(TBA)	InfiniBand	G.709 ODUflex
0x13	62(TBA)	InfiniBand	G.709 ODUflex
0x14	62(TBA)	InfiniBand	G.709 ODUflex
0x15	63(TBA)	Serial Digital Interface	G.709 ODUk (k=0)
0x16	64(TBA)	Serial Digital Interface/1.001	G.709 ODUk (k=1)
0x17	63(TBA)	Serial Digital Interface	G.709 ODUk (k=1)
0x18	64(TBA)	Serial Digital Interface/1.001	G.709 ODUflex
0x19	63(TBA)	Serial Digital Interface	G.709 ODUflex
0x1A	56 (IANA to update Type field)	SBCON/ESCON	G.709 ODUk (k=0)
0x1B	65(TBA)	DVB_ASI	G.709 ODUk (k=0)
0x1C	58	Fiber Channel	G.709 ODUk
0x20	47 (IANA to update Type field)	G.709 ODU-2.5G	G.709 ODUk (k=2,3)
	66(TBA)	G.709 ODU-1.25G	G.709 ODUk (k=1)
0x21	66(TBA)	G.709 ODU-1.25G	G.709 ODUk (k=2,3,4)
	67(TBA)	G.709 ODU-Any	G.709 ODUk (k=2,3)
0x55		No standard value	
0x66		No standard value	
0x80-0x8F		No standard value	
0xFD	68(TBA)	Null Test	G.709 ODUk
0xFE	69(TBA)	Random Test	G.709 ODUk
0xFF		No standard value	

Note: Values 59 and 70 include mapping of SDH.

Note that the mapping types for ODUj into OPUk are unambiguously per Table 7-10 of [G709-2012], so it does not need to carry mapping type information in the signaling.

Note also that additional information on G.709 client mapping can be found in [G7041].

5. Extensions for Traffic Parameters for the Evolving G.709

The Traffic Parameters for OTN-TDM capable Switching Type are carried

in the OTN-TDM SENDER_TSPEC and FLOWSPEC objects. The objects have the following class and type:

- OTN-TDM SENDER_TSPEC Object: Class = 12, C-Type = 7 (TBA)
- OTN-TDM FLOWSPEC Object: Class = 9, C-Type = 7 (TBA)

The format of Traffic Parameters in these two objects is defined as follows:

Signal Type: 8 bits

As defined in [RFC4328] Section 3.2.1, with the following additional values:

Value	Type
4	ODU4 (i.e., 100 Gbps)
9	OCh at 100 Gbps
10	ODU0 (i.e., 1.25 Gbps)
11	ODU2e (i.e., 10Gbps for FC1200 and GE LAN)
12~19	Reserved (for future use)
20	ODUflex(CBR) (i.e., 1.25*N Gbps)
21	ODUflex(Generic Framing Procedure-Framed (GFP-F)), resizable (i.e., 1.25*N Gbps)
22	ODUflex(GFP-F), non resizable (i.e., 1.25*N Gbps)
23~255	Reserved (for future use)

NVC: 16 bits

As defined in [RFC4328] Section 3.2.3. This field MUST be set to 0 for ODUflex Signal Types.

Multiplier (MT): 16 bits

As defined in [RFC4328] Section 3.2.4. This field MUST be set to 1 for ODUflex Signal Types.

Bit_Rate: 32 bits

In case of ODUflex including ODUflex(CBR) and ODUflex(GFP) Signal Types, this field indicates the nominal bit rate of ODUflex expressed in bytes per second, encoded as a 32-bit IEEE single-precision floating-point number (referring to [RFC4506] and [IEEE]). For other Signal Types, this field MUST be set to zero on transmission and MUST be ignored on receipt and SHOULD be passed unmodified by transit nodes.

5.1. Usage of ODUflex(CBR) Traffic Parameters

In case of ODUflex(CBR), the information of Bit_Rate carried in the ODUflex Traffic Parameters MUST be used to determine the actual bandwidth of ODUflex(CBR) (i.e., Bit_Rate * (1 +/- Tolerance)). Therefore the total number of tributary slots N in the HO ODUk link can be reserved correctly. Here:

N = Ceiling of

$$\frac{\text{ODUflex(CBR) nominal bit rate} * (1 + \text{ODUflex(CBR) bit rate tolerance})}{\text{ODTUk.ts nominal bit rate} * (1 - \text{HO OPUk bit rate tolerance})}$$

In this formula, the ODUflex(CBR) nominal bit rate is the bit rate of the ODUflex(CBR) on the line side, i.e., the client signal bit rate after applying the 239/238 factor (according to Clause 7.3, Table 7-2 of [G709-2012]) and the transcoding factor T (if needed) on the CBR client. According to clauses 17.7.3, 17.7.4 and 17.7.5 of [G709-2012]:

ODUflex(CBR) nominal bit rate = CBR client bit rate * (239/238) / T

The ODTUk.ts (Optical channel Data Tributary Unit k with ts tributary slots) nominal bit rate is the nominal bit rate of the tributary slot of ODUk, as shown in Table 1 (referring to Table 7-7 of [G709-2012]).

Table 1 - Actual TS bit rate of ODUk (in Kbps)

ODUk.ts	Minimum	Nominal	Maximum
ODU2.ts	1,249,384.632	1,249,409.620	1,249,434.608
ODU3.ts	1,254,678.635	1,254,703.729	1,254,728.823
ODU4.ts	1,301,683.217	1,301,709.251	1,301,735.285

Note that:

Minimum bit rate of ODUTk.ts =
ODTUk.ts nominal bit rate * (1 - HO OPUk bit rate tolerance)

Maximum bit rate of ODTUk.ts =
ODTUk.ts nominal bit rate * (1 + HO OPUk bit rate tolerance)

Where: HO OPUk bit rate tolerance = 20ppm

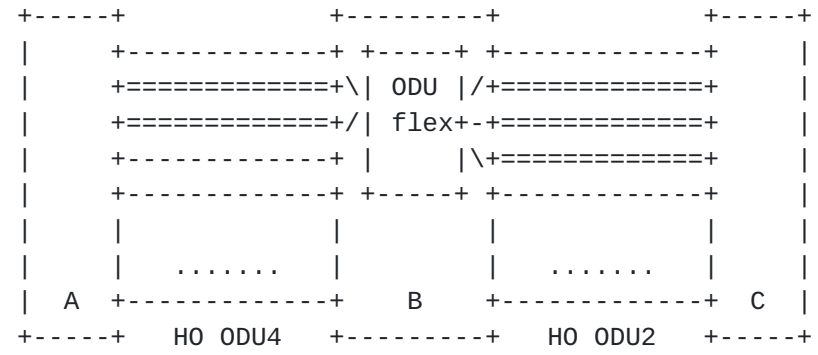
Note that the bit rate tolerance is implicit in Signal Type and the ODUflex(CBR) bit rate tolerance is fixed and it is equal to 100ppm as described in Table 7-2 of [G709-2012].

Therefore, a node receiving a PATH message containing ODUflex(CBR) nominal bit rate can allocate precise number of tributary slots and set up the cross-connection for the ODUflex service.

Note that for different ODUk, the bit rates of the tributary slots are different, and so the total number of tributary slots to be reserved for the ODUflex(CBR) MAY not be the same on different HO ODUk links.

An example is given below to illustrate the usage of ODUflex(CBR) Traffic Parameters.

As shown in Figure 1, assume there is an ODUflex(CBR) service requesting a bandwidth of (2.5Gbps, +/-100ppm) from node A to node C. In other words, the ODUflex Traffic Parameters indicate that Signal Type is 20 (ODUflex(CBR)), Bit_Rate is 2.5Gbps and Tolerance is 100ppm.



=========: TS occupied by ODUflex
---------: free TS

Figure 1 - Example of ODUflex(CBR) Traffic Parameters

- On the HO ODU4 link between node A and B:

  The maximum bit rate of the ODUflex(CBR) equals 2.5Gbps * (1 + 100ppm), and the minimum bit rate of the tributary slot of ODU4 equals 1,301,683.217 Kbps, so the total number of tributary slots N1 to be reserved on this link is:

  N1 = ceiling (2.5Gbps * (1 + 100ppm) / 1,301,683.217 Kbps) = 2

- On the HO ODU2 link between node B and C:

  The maximum bit rate of the ODUflex equals 2.5Gbps * (1 + 100ppm), and the minimum bit rate of the tributary slot of ODU2 equals 1,249,384.632 Kbps, so the total number of tributary slots N2 to be reserved on this link is:

  N2 = ceiling (2.5Gbps * (1 + 100ppm) / 1,249,384.632 Kbps) = 3

5.2. Usage of ODUflex(GFP) Traffic Parameters

[G709-2012] recommends that the ODUflex(GFP) will fill an integral number of tributary slots of the smallest HO ODUk path over which the ODUflex(GFP) may be carried, as shown in Table 2.

Table 2 - Recommended ODUflex(GFP) bit rates and tolerance

ODU type	Nominal bit-rate	Tolerance
ODUflex(GFP) of n TS, 1<=n<=8	n * ODU2.ts	+/-100 ppm
ODUflex(GFP) of n TS, 9<=n<=32	n * ODU3.ts	+/-100 ppm
ODUflex(GFP) of n TS, 33<=n<=80	n * ODU4.ts	+/-100 ppm

According to this table, the Bit_Rate field for ODUflex(GFP) MUST equal to one of the 80 values listed below:

1 * ODU2.ts; 2 * ODU2.ts; ...; 8 * ODU2.ts;
9 * ODU3.ts; 10 * ODU3.ts, ...; 32 * ODU3.ts;
33 * ODU4.ts; 34 * ODU4.ts; ...; 80 * ODU4.ts.

In this way, the number of required tributary slots for the ODUflex(GFP) (i.e., the value of "n" in Table 2) can be deduced from the Bit_Rate field.

5.3. Notification on Errors of OTN-TDM Traffic Parameters

There is no Adspec associated with the OTN-TDM SENDER_TSPEC. Either the Adspec is omitted or an Int-serv Adspec with the Default General

Characterization Parameters and Guaranteed Service fragment is used, see [RFC2210].

For a particular sender in a session, the contents of the FLOWSPEC object received in a Resv message SHOULD be identical to the contents of the SENDER_TSPEC object received in the corresponding Path message. If the objects do not match, a ResvErr message with a "Traffic Control Error/Bad Flowspec value" error MUST be generated.

Intermediate and egress nodes MUST verify that the node itself, and the interfaces on which the LSP will be established, can support the requested Signal Type, NVC and Bit_Rate values. If the requested value(s) cannot be supported, the receiver node MUST generate a PathErr message with a "Traffic Control Error/Service unsupported" indication (see [RFC2205]).

In addition, if the MT field is received with a zero value, the node MUST generate a PathErr message with a "Traffic Control Error/Bad Tspec value" indication (see [RFC2205]).

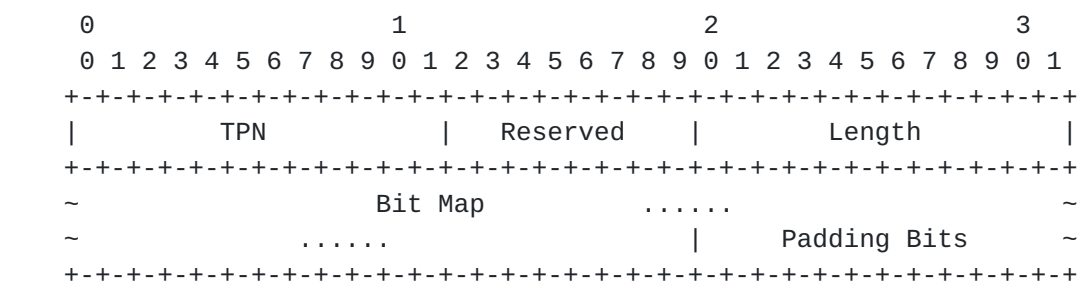
Further, if the Signal Type is not ODU1, ODU2 or ODU3, and the NVC field is not 0, the node MUST generate a PathErr message with a "Traffic Control Error/Bad Tspec value" indication (see [RFC2205]).

6. Generalized Label

This section defines the format of the OTN-TDM Generalized Label.

6.1. OTN-TDM Switching Type Generalized Label

The following is the Generalized Label format for that MUST be used with the OTN-TDM Switching Type:



The OTN-TDM Generalized Label is used to indicate how the LO ODUj signal is multiplexed into the HO ODUk link. Note that the LO OUDj signal type is indicated by Traffic Parameters, while the type of HO

ODUk link is identified by the selected interface carried in the IF_ID RSVP_HOP Object.

TPN (12 bits): indicates the TPN for the assigned Tributary Slot(s).

- In case of LO ODUj multiplexed into HO ODU1/ODU2/ODU3, only the lower 6 bits of TPN field are significant and the other bits of TPN MUST be set to 0.

- In case of LO ODUj multiplexed into HO ODU4, only the lower 7 bits of TPN field are significant and the other bits of TPN MUST be set to 0.

- In case of ODUj mapped into OTUk (j=k), the TPN is not needed and this field MUST be set to 0.

Per [G709-2012], The TPN is used to allow for correct demultiplexing in the data plane. When an LO ODUj is multiplexed into HO ODUk occupying one or more TSs, a new TPN value is configured at the two ends of the HO ODUk link and is put into the related MSI byte(s) in the OPUk overhead at the (traffic) ingress end of the link, so that the other end of the link can learn which TS(s) is/are used by the LO ODUj in the data plane.

According to [G709-2012], the TPN field MUST be set as according to the following tables:

Table 3 - TPN Assignment Rules (2.5Gbps TS granularity)

HO ODUk	LO ODUj	TPN	TPN Assignment Rules
ODU2	ODU1	1~4	Fixed, = TS# occupied by ODU1
ODU3	ODU1	1~16	Fixed, = TS# occupied by ODU1
	ODU2	1~4	Flexible, != other existing LO ODU2s' TPNs

Table 4 - TPN Assignment Rules (1.25Gbps TS granularity)

HO ODUk	LO ODUj	TPN	TPN Assignment Rules
ODU1	ODU0	1~2	Fixed, = TS# occupied by ODU0
ODU2	ODU1	1~4	Flexible, != other existing LO ODU1s' TPNs
	ODU0 & ODUflex	1~8	Flexible, != other existing LO ODU0s and ODUflexes' TPNs
	ODU1	1~16	Flexible, != other existing LO ODU1s' TPNs
ODU3	ODU2	1~4	Flexible, != other existing LO ODU2s' TPNs
	ODU0 & ODU2e & ODUflex	1~32	Flexible, != other existing LO ODU0s and ODU2es and ODUflexes' TPNs
ODU4	Any ODU	1~80	Flexible, != ANY other existing LO ODUs' TPNs

Note that in the case of "Flexible", the value of TPN MAY not be corresponding to the TS number as per [G709-2012].

Length (12 bits): indicates the number of bits of the Bit Map field, i.e., the total number of TS in the HO ODUk link. The TS granularity, 1.25Gbps or 2.5Gbps, may be derived by dividing the HO ODUk link's rate by the value of the Length field. In the context of [G709-2012], the values of 4 and 16 indicate a TS granularity of 2.5Gps, and the values 2, 8, 32 and 80 indicate a TS granularity of 1.25Gps.

In case of an ODUk mapped into OTUk, there is no need to indicate which tributary slots will be used, so the length field MUST be set to 0.

Bit Map (variable): indicates which tributary slots in HO ODUk that the LO ODUj will be multiplexed into. The sequence of the Bit Map is consistent with the sequence of the tributary slots in HO ODUk. Each bit in the bit map represents the corresponding tributary slot in HO ODUk with a value of 1 or 0 indicating whether the tributary slot will be used by LO ODUj or not.

Padding bits are added after the Bit Map to make the whole label a multiple of four bytes if necessary. Padding bits MUST be set to 0 and MUST be ignored.

6.2. Procedures

The ingress node MUST generate a Path message and specify the OTN-TDM Switching Type and corresponding G-PID in the Generalized Label Request object, which MUST be processed as defined in [RFC3473].

The ingress node of an LSP MAY include label ERO (Explicit Route Object) to indicate the label in each hops along the path. Note that the TPN in the label ERO subobject MAY not be assigned by the ingress node. In this case, the node MUST assign a valid TPN value and then put this value into TPN field of the label object when receiving a Path message.

In order to create bidirectional LSP, the ingress node and upstream node MUST generate an Upstream Label on the out outgoing interface to indicate the reserved TSs of ODUk and the assigned TPN value in the upstream direction. This Upstream Label is sent to the downstream node via Path massage for upstream resource reservation.

The ingress node or upstream node MAY generate Label Set to indicate which labels on the outgoing interface in the downstream direction are acceptable. The downstream node will restrict its choice of labels, i.e., TS resource and TPN value, to one which is in the Label Set.

The ingress node or upstream node MAY also generate Suggested Label to indicate the preference of TS resource and TPN value on the outgoing interface in the downstream direction. The downstream node is not REQUIRED to use the Suggested Label and MAY use another label based on local decision and send it to the upstream node, as described in [RFC3473].

When an upstream node receives a Resv message containing an LABEL object with an OTN-TDM label, it MUST firstly identify which ODU Signal Type is multiplexed or mapped into which ODU Signal Type accordingly to the Traffic Parameters and the IF_ID RSVP_HOP Object in the received message.

- In case of ODUj to ODUk multiplexing, the node MUST retrieve the reserved tributary slots in the ODUk by its downstream neighbor node according to the position of the bits that are set to 1 in the Bit Map field. The node determines the TS type (according to the total TS number of the ODUk, or pre-configured TS type), so that the node can multiplex the ODUj into the ODUk based on the TS type. The node MUST also retrieve the TPN value assigned by its downstream neighbor node from the label, and fill the TPN into the related MSI byte(s) in the OPUk overhead in the data plane, so

that the downstream neighbor node can check whether the TPN received from the data plane is consistent with the ExMSI and determine whether there is any mismatch defect.

- In case of ODUk to OTUk mapping, the size of Bit Map field MUST be 0 and no additional procedure is needed.

When a downstream node or egress node receives a Path message containing Generalized Label Request object for setting up an ODUj LSP from its upstream neighbor node, the node MUST generate an OTN-TDM label according to the Signal Type of the requested LSP and the free resources (i.e., free tributary slots of ODUk) that will be reserved for the LSP, and send the label to its upstream neighbor node.

- In case of ODUj to ODUk multiplexing, the node MUST firstly determine the size of the Bit Map field according to the Signal Type and the tributary slot type of ODUk, and then set the bits to 1 in the Bit Map field corresponding to the reserved tributary slots. The node MUST also assign a valid TPN, which MUST NOT collide with other TPN value used by existing LO ODU connections in the selected HO ODU link, and configure the Expected MSI (ExMSI) using this TPN. Then, the assigned TPN MUST be filled into the label.

- In case of ODUk to OTUk mapping, TPN field MUST be set to 0. Bit Map information is not REQUIRED and MUST NOT be included, so Length field MUST be set to 0 as well.

6.2.1. Notification on Label Error

When an upstream node receives a Resv message containing an LABEL object with an OTN-TDM label, the node MUST verify if the label is acceptable. If the label is not acceptable, the node MUST generate a ResvErr message with a "Routing problem/Unacceptable label value" indication. Per [RFC3473], the generated ResvErr message MAY include an ACCEPTABLE_LABEL_SET object. With the exception of label semantics, downstream node processing a received ResvErr messages and of ACCEPTABLE_LABEL_SET objects is not modified by this document.

Similarly, when a downstream node receives a Path message containing an UPSTREAM_LABEL object with an OTN-TDM label, the node MUST verify if the label is acceptable. If the label is not acceptable, the node MUST generate a PathErr message with a "Routing problem/Unacceptable label value" indication. Per [RFC3473], the generated ResvErr message MAY include an ACCEPTABLE_LABEL_SET object. With the exception of

label semantics, downstream node processing received PathErr messages and of ACCEPTABLE_LABEL_SET objects is not modified by this document.

A received label SHALL be considered unacceptable when one of the following cases occurs:

- The received label doesn't conform to local policy;

- Invalid value in the length field;

- The selected link only supports 2.5Gbps TS granularity while the Length field in the label along with ODUk Signal Type indicates the 1.25Gbps TS granularity;

- The label includes an invalid TPN value that breaks the TPN assignment rules;

- The indicated resources (i.e., the number of "1" in the Bit Map field) are inconsistent with the Traffic Parameters.

6.3. Supporting Virtual Concatenation and Multiplication

Per [RFC6344], the Virtual Concatenation Groups (VCGs) can be created using Co-Signaled style or Multiple LSPs style.

In case of Co-Signaled style, the explicit ordered list of all labels MUST reflect the order of VCG members, which is similar to [RFC4328]. In case of multiplexed virtually concatenated signals (NVC > 1), the first label MUST indicate the components of the first virtually concatenated signal; the second label MUST indicate the components of the second virtually concatenated signal; and so on. In case of multiplication of multiplexed virtually concatenated signals (MT > 1), the first label MUST indicate the components of the first multiplexed virtually concatenated signal; the second label MUST indicate components of the second multiplexed virtually concatenated signal; and so on.

Support for Virtual Concatenation of ODU1, ODU2 and ODU3 Signal Types, as defined by [RFC6344], is not modified by this document. Virtual Concatenation of other Signal Types is not supported by [G709-2012].

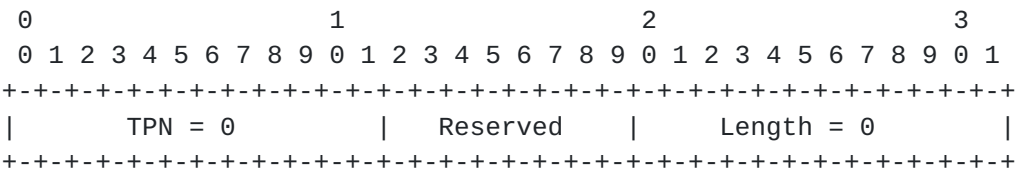
Multiplier (MT) usage is as defined in [RFC6344] and [RFC4328].

6.4. Examples

The following examples are given in order to illustrate the label format described in Section 6.1 of this document.

(1) ODUk into OTUk mapping:

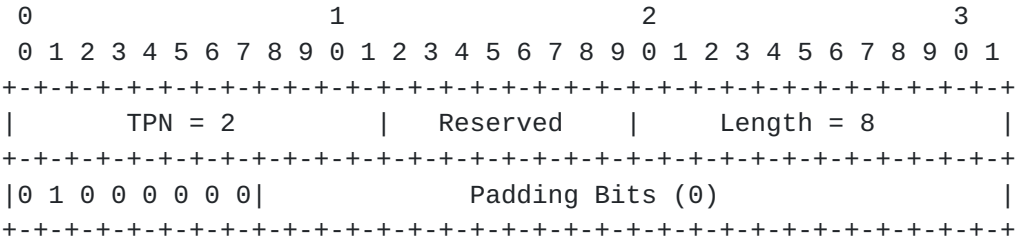
In such conditions, the downstream node along an LSP returns a label indicating that the ODUk (k=1, 2, 3, 4) is directly mapped into the corresponding OTUk. The following example label indicates an ODU1 mapped into OTU1.



(2) ODUj into ODUk multiplexing:

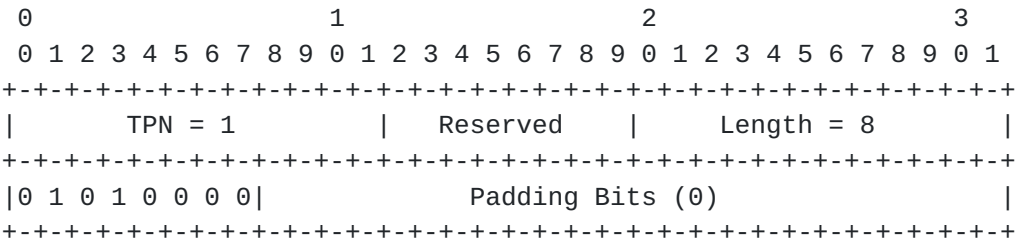
In such conditions, this label indicates that an ODUj is multiplexed into several tributary slots of OPUk and then mapped into OTUk. Some instances are shown as follow:

- ODU0 into ODU2 Multiplexing:



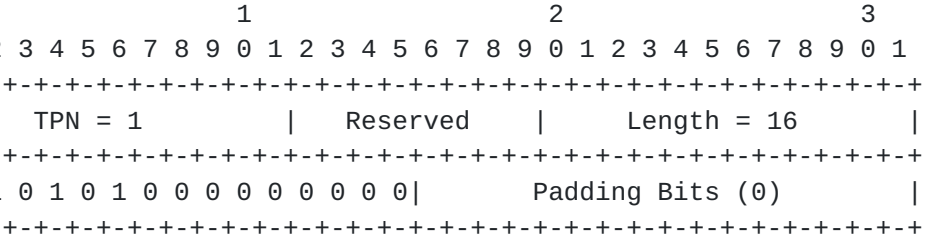
This above label indicates an ODU0 multiplexed into the second tributary slot of ODU2, wherein there are 8 TS in ODU2 (i.e., the type of the tributary slot is 1.25Gbps), and the TPN value is 2.

- ODU1 into ODU2 Multiplexing with 1.25Gbps TS granularity:



This above label indicates an ODU1 multiplexed into the 2nd and the 4th tributary slot of ODU2, wherein there are 8 TS in ODU2 (i.e., the type of the tributary slot is 1.25Gbps), and the TPN value is 1.

- ODU2 into ODU3 Multiplexing with 2.5Gbps TS granularity:



This above label indicates an ODU2 multiplexed into the 2nd, 3rd, 5th and 7th tributary slot of ODU3, wherein there are 16 TS in ODU3 (i.e., the type of the tributary slot is 2.5Gbps), and the TPN value is 1.

7. Supporting Hitless Adjustment of ODUflex (GFP)

[G7044] describes the procedure of ODUflex (GFP) hitless resizing using Link Connection Resize (LCR) and Bandwidth Resize (BWR) protocols in OTN data plane.

For the control plane, signaling messages are REQUIRED to initiate the adjustment procedure. Section 2.5 and Section 4.6.4 of [RFC3209] describe how the Shared Explicit (SE) style is used in Traffic Engineering (TE) network for bandwidth increasing and decreasing, which is still applicable for triggering the ODUflex (GFP) adjustment procedure in data plane.

Note that the SE style MUST be used at the beginning when creating a resizable ODUflex connection (Signal Type = 21). Otherwise an error with Error Code "Conflicting reservation style" MUST be generated when performing bandwidth adjustment.

- Bandwidth increasing

  For the ingress node, in order to increase the bandwidth of an ODUflex (GFP) connection, a Path message with SE style (keeping Tunnel ID unchanged and assigning a new LSP ID) MUST be sent along the path.

  The ingress node will trigger the BWR protocol when successful completion of LCR protocols on every hop after Resv message is processed. On success of BWR, the ingress node SHOULD send a

PathTear message to delete the old control state (i.e., the control state of the ODUflex (GFP) before resizing) on the control plane.

A downstream node receiving Path message with SE style compares the old Traffic Parameters (stored locally) with the new one carried in the Path message, to determine the number of TS to be added. After choosing and reserving new free TS, the downstream node MUST send back a Resv message carrying both the old and new LABEL Objects in the SE flow descriptor.

An upstream neighbor receiving Resv message with SE flow descriptor MUST determine which TS are added and trigger the LCR protocol between itself and its downstream neighbor node.

- Bandwidth decreasing

For the ingress node, a Path message with SE style SHOULD also be sent for ODUflex bandwidth decreasing.

The ingress node will trigger the BWR protocol when successful completion of LCR handshake on every hop after Resv message is processed. On success of BWR, the second step of LCR, i.e., link connection decrease procedure will be started on every hop of the connection. After completion of bandwidth decreasing, the ingress node SHOULD send a ResvErr message to tear down the old control state.

A downstream node receiving Path message with SE style compares the old Traffic Parameters with the new one carried in the Path message to determine the number of TS to be decreased. After choosing TSs to be decreased, the downstream node MUST send back a Resv message carrying both the old and new LABEL Objects in the SE flow descriptor.

An upstream neighbor receiving Resv message with SE flow descriptor MUST determine which TS are decreased and trigger the first step of LCR protocol (i.e., LCR handshake) between itself and its downstream neighbor node.

8. Control Plane Backward Compatibility Considerations

As described in [OTN-FWK], since the [RFC4328] has been deployed in the network for the nodes that support the 2001 revision of the G.709

specification, control plane backward compatibility SHOULD be taken into consideration. More specifically:

- Nodes supporting this document SHOULD support [OTN-OSPF].
- Nodes supporting this document MAY support [RFC4328] signaling.
- A node supporting both sets of procedures (i.e., [RFC4328] and this document) is not REQUIRED to signal an LSP using both procedures, i.e., to act as a signaling version translator.
- Ingress nodes that support both sets of procedures MAY select which set of procedures to follow based on routing information or local policy.
- Per [RFC3473], nodes that do not support this document will generate a PathErr message, with a "Routing problem/Switching Type" indication.

9. Security Considerations

This document introduces no new security considerations to the existing GMPLS signaling protocols. Referring to [RFC3473] and [RFC4328], further details of the specific security measures are provided. Additionally, [RFC5920] provides an overview of security vulnerabilities and protection mechanisms for the GMPLS control plane.

10. IANA Considerations

Two RSVP C-Types are defined for OTN-TDM Traffic Parameters in this document:
http://www.iana.org/assignments/rsvp-parameters

- OTN-TDM SENDER_TSPEC and FLOWSPEC objects:
  - OTN-TDM SENDER_TSPEC Object: Class = 12, C-Type = 7 (see Section 5)
  - OTN-TDM FLOWSPEC Object: Class = 9, C-Type = 7 (see Section 5)

IANA maintains the "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Parameters" registry (see

http://www.iana.org/assignments/gmpls-sig-parameters). "Generalized PIDs (G-PID)" subregistry is included in this registry, which will be extended and updated by this document as below:

- Generalized PID (G-PID):

  Name: G-PID
  Format: 16-bit number
  Values:

Value	Type/Comment	LSP Encoding/Technology
47 (IANA to update Type field)	G.709 ODU-2.5G	G.709 ODUk (k=2,3)
56 (IANA to update Type field)	SBCON/ESCON	G.709 ODUk, Lambda, Fiber
59(TBA)	Framed GFP	G.709 ODUk
60(TBA)	STM-1	G.709 ODUk (k=0)
61(TBA)	STM-4	G.709 ODUk (k=0)
62(TBA)	InfiniBand	G.709 ODUflex
63(TBA)	Serial Digital Interface	G.709 ODUk (k=0,1,flex)
64(TBA)	Serial Digital Interface/1.001	G.709 ODUk (k=1,flex)
65(TBA)	DVB_ASI	G.709 ODUk (k=0)
66(TBA)	G.709 ODU-1.25G	G.709 ODUk
67(TBA)	G.709 ODU-Any	G.709 ODUk (k=2,3)
68(TBA)	Null Test	G.709 ODUk
69(TBA)	Random Test	G.709 ODUk
70(TBA)	64B/66B GFP-F Ethernet	G.709 ODUk (k=2)

"Signal Type" subregistry to the "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Parameters" will be defined by this document as below:

Value	Signal Type	Reference
0	Not significant	[RFC4328]
1	ODU1 (i.e., 2.5 Gbps)	[RFC4328]
2	ODU2 (i.e., 10 Gbps)	[RFC4328]
3	ODU3 (i.e., 40 Gbps)	[RFC4328]
4	ODU4 (i.e., 100 Gbps)	[this document]
5	Reserved (for future use)	[RFC4328]
6	Och at 2.5 Gbps	[RFC4328]
7	OCh at 10 Gbps	[RFC4328]
8	OCh at 40 Gbps	[RFC4328]

9	OCh at 100 Gbps	[this document]
10	ODU0 (i.e., 1.25 Gbps)	[this document]
11	ODU2e (i.e., 10Gbps for FC1200 and GE LAN)	[this document]
12~19	Reserved (for future use)	[this document]
20	ODUflex(CBR) (i.e., 1.25*N Gbps)	[this document]
21	ODUflex(GFP-F), resizable (i.e., 1.25*N Gbps)	[this document]
22	ODUflex(GFP-F), non resizable (i.e., 1.25*N Gbps)	[this document]
23~255	Reserved (for future use)	[this document]

11. References

11.1. Normative References

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

[RFC2205] Braden, R., Zhang, L., Berson, S., Herzog, S., and S. Jamin, "Resource ReSerVation Protocol (RSVP) -- Version 1 Functional Specification", RFC 2205, September 1997.

[RFC2210] Wroclawski, J., "The Use of RSVP with IETF Integrated Services", RFC 2210, September 1997.

[RFC3209] D. Awduche et al, "RSVP-TE: Extensions to RSVP for LSP Tunnels", RFC3209, December 2001.

[RFC3471] Berger, L., Editor, "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Functional Description", RFC 3471, January 2003.

[RFC3473] L. Berger, Ed., "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Resource ReserVation Protocol-Traffic Engineering (RSVP-TE) Extensions", RFC 3473, January 2003.

[RFC4328] D. Papadimitriou, Ed. "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Extensions for G.709 Optical Transport Networks Control", RFC 4328, Jan 2006.

[RFC6344] G. Bernstein et al, "Operating Virtual Concatenation (VCAT) and the Link Capacity Adjustment Scheme (LCAS) with Generalized Multi-Protocol Label Switching (GMPLS)", RFC6344, August 2011.

11.2. Informative References

[OTN-FWK] Fatai Zhang et al, "Framework for GMPLS and PCE Control of G.709 Optical Transport Networks", Work in Progress: draft-ietf-ccamp-gmpls-g709-framework, February 2013.

[OTN-INFO] S. Belotti et al, "Information model for G.709 Optical Transport Networks (OTN)", Work in Progress: draft-ietf-ccamp-otn-g709-info-model, May 2013.

[OTN-OSPF] D. Ceccarelli et al, "Traffic Engineering Extensions to OSPF for Generalized MPLS (GMPLS) Control of Evolving G.709 OTN Networks", Work in Progress: draft-ietf-ccamp-gmpls-ospf-g709v3, April 2013.

[G709-2012] ITU-T, "Interfaces for the Optical Transport Network (OTN)", G.709/Y.1331 Recommendation, February 2012.

[G7044] ITU-T, "Hitless adjustment of ODUflex", G.7044/Y.1347, October 2011.

[G7041] ITU-T, "Generic framing procedure", G.7041/Y.1303, April 2011.

[RFC4506] M. Eisler, Ed., "XDR: External Data Representation Standard", RFC 4506, May 2006.

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

[IEEE] "IEEE Standard for Binary Floating-Point Arithmetic", ANSI/IEEE Standard 754-1985, Institute of Electrical and Electronics Engineers, August 1985.

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