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Traffic Engineering Extensions to OSPF for Generalized MPLS (GMPLS)
Control of Evolving G.709 OTN Networks
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Abstract

The recent revision of ITU-T Recommendation G.709 [G709-V3] has introduced new fixed and flexible ODU containers, enabling optimized support for an increasingly abundant service mix.

This document describes OSPF routing protocol extensions to support Generalized MPLS (GMPLS) control of all currently defined ODU containers, in support of both sub-lambda and lambda level routing granularity.

Status of this Memo

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Internet-Draft

OSPF-TE extensions for OTN support

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1. Introduction

G.709 OTN [G709-V3] includes new fixed and flexible ODU containers, two types of Tributary Slots (i.e., 1.25Gbps and 2.5Gbps), and supports various multiplexing relationships (e.g., ODU_j multiplexed into ODU_k (j<k)), two different tributary slots for ODU_k (K=1, 2, 3) and ODUflex service type, which is being standardized in ITU-T. In order to present this information in the routing process, this document provides OTN technology specific encoding for OSPF-TE.

For a short overview of OTN evolution and implications of OTN requirements on GMPLS routing please refer to [OTN-FWK]. The information model and an evaluation against the current solution are provided in [OTN-INFO].

The routing information for Optical Channel Layer (OCh) (i.e., wavelength) is out of the scope of this document. Please refer to [WSON-Frame] for further information.

1.1. 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].

2. OSPF-TE Extensions

In terms of GMPLS based OTN networks, each OTU_k can be viewed as a component link, and each component link can carry one or more types of ODU_j (j<k).

Each TE LSA can carry a top-level link TLV with several nested sub-TLVs to describe different attributes of a TE link. Two top-level TLVs are defined in [RFC 3630]. (1) The Router Address TLV (referred to as the Node TLV) and (2) the TE link TLV. One or more sub-TLVs

can be nested into the two top-level TLVs. The sub-TLV set for the two top-level TLVs are also defined in [[RFC 3630](#)] and [[RFC 4203](#)].

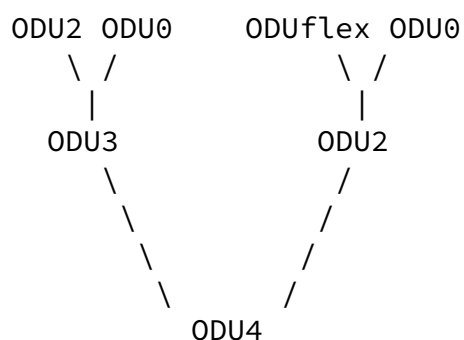
As discussed in [[OTN-FWK](#)] and [[OTN-INFO](#)], the OSPF-TE must be extended so to be able to advertise the termination and switching capabilities related to each different ODUj and ODUk/OTUk and the advertisement of related multiplexing capabilities. This leads to the need of defining a new Switching Capability value for the ISCD with related new sub-sub-TLVs.

In the following we will use ODUj to indicate a service type that is multiplexed into an higher order ODU, ODUk an higher order ODU

including an ODUj and ODUk/OTUk to indicate the layer mapped into the OTUk. Moreover ODUj(S) and ODUk(S) are used to indicate ODUj and ODUk with switching capability only, and the ODUj->ODUk format is used to indicate the ODUj into ODUk multiplexing capability.

This notation can be iterated dependently from the number of multiplexing levels. In the following the term "multiplexing tree" is used to identify a multiplexing hierarchy where the root is always a server ODUk/OTUk and any other multiplexed container is represented with increasing granularity till the leaf of the tree. The tree can be structured with more than one branch if the server ODUk/OTUk supports more than one hierarchy.

If for example a multiplexing hierarchy like the following one is considered:



The ODU4 is the root of the muxing tree, ODU3 and ODU2 are containers directly multiplexed into the server and then ODU2, ODU0 are the leaves of ODU3 branch, while ODUflex and ODU0 are the leaves of the ODU2 one. This means that on this traffic card it is possible to have the following multiplexing capabilities:

```

ODU2->ODU3->ODU4
ODU0->ODU3->ODU4
ODUflex->ODU2->ODU4
ODU0->ODU2->ODU4

```

3. TE-Link Representation

G.709 ODUk/OTUk Links are represented as TE-Links in GMPLS Traffic Engineering Topology for supporting ODUj layer switching. These TE-Links can be modeled in multiple ways. Some of the prominent

representations are captured below.

OTUk physical Link(s) can be modeled as a TE-Link(s). The TE-Link is termed as ODUk-TE-Link. The ODUk-TE-Link advertises ODUj Switching Capacity. The advertised capacity could include ODUk switching capacity. Figure-1 below provides an illustration of one hop ODUk TE-links.

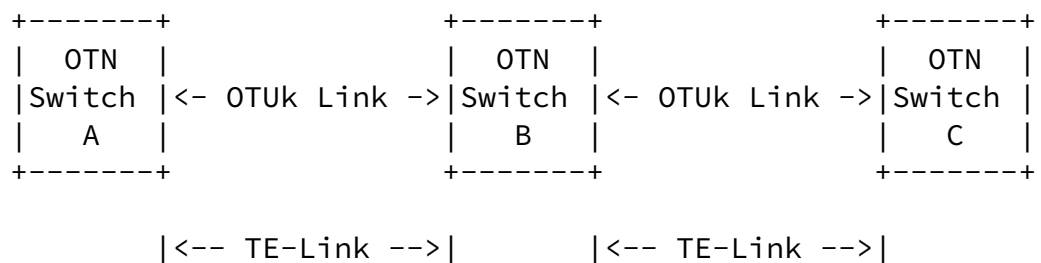


Figure 1: ODUk TE-Link

It is possible to create TE-Links that span more than one hop by creating FA between non-adjacent nodes. Such Te-Links are also

termed ODUk-TE-Links. As in one hop case, these types of ODUk-TE-Links also advertise ODUj switching capacity. The advertised capacity could include ODUk switching capacity.

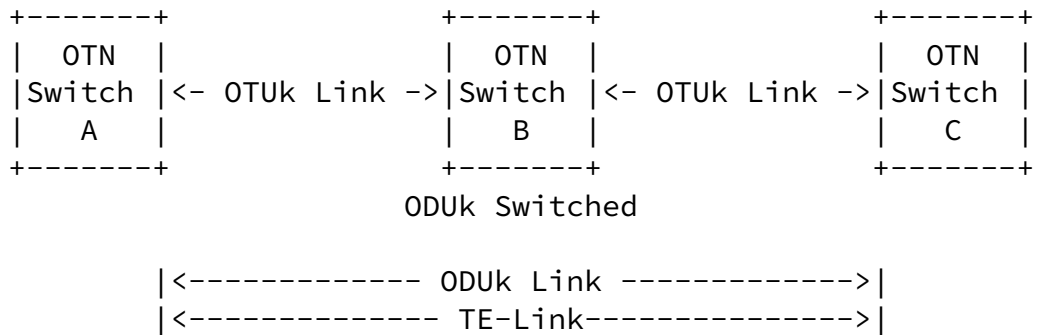


Figure 2: Multiple hops TE-Link

4. ISCD format extensions

The Interface Switching Capability Descriptor describes switching capability of an interface [RFC 4202]. This document defines a new Switching Capability value for OTN [G.709-v3] as follows:

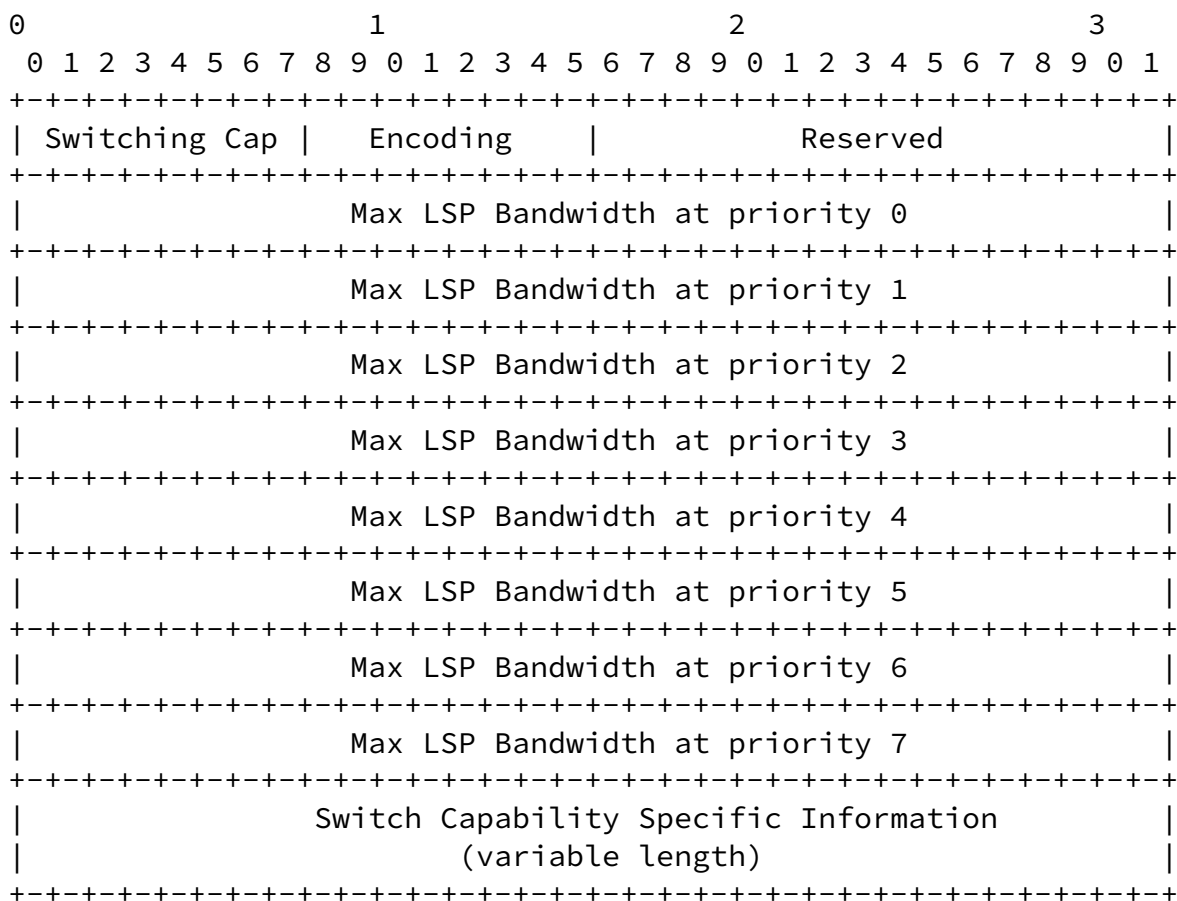
Value	Type
-----	-----
101 (TBA by IANA)	OTN-TDM capable (OTN-TDM)

Switching Capability and Encoding values MUST be used as follows:

Switching Capability = OTN-TDM
 Encoding Type = G.709 ODUk (Digital Path) [as defined in RFC4328]

Both fixed and flexible ODUs use the same switching type and encoding values. When Switching Capability and Encoding fields are set to values as stated above, the Interface Switching Capability Descriptor

should be interpreted as follows:



Maximum LSP Bandwidth

The MAX LSP bandwidth field is used accordingly to [RFC4204](#): i.e. $0 \leq \text{Max LSP Bandwidth} \leq \text{ODUk/OTUk}$ and intermediate values are those on

the branch of OTN switching hierarchy supported by the interface. E.g. in the OTU4 link it could be possible to have ODU4 as MAX LSP Bandwidth for some priorities, ODU3 for others, ODU2 for some others etc. The bandwidth unit is in bytes per second and the encoding is in IEEE floating point format. The discrete values for various ODUs is shown in the table below.

ODU Type	ODU nominal bit rate	Value in Byte/Sec
ODU0	1 244 160 kbits/s	0x4D1450C0
ODU1	239/238 x 2 488 320 kbit/s	0x4D94F048
ODU2	239/237 x 9 953 280 kbit/s	0x4E959129
ODU3	239/236 x 39 813 120 kbit/s	0X4F963367
ODU4	239/227 x 99 532 800 kbit/s	0x504331E3
ODU2e	239/237 x 10 312 500 kbit/s	0x4E9AF70A
ODUflex for CBR Client signals	239/238 x client signal bit rate	MAX LSP BANDWIDTH
ODUflex for GFP-F Mapped client signal	Configured bit rate	MAX LSP BANDWIDTH
ODU flex resizable	Configured bit rate	MAX LSP BANDWIDTH

The ISCD includes a variable number of SCSI TLVs as described in the following sections. A single ISCD TLV MAY be used for the advertisement of unbundled or bundled links also with different server layers. A different SCSI TLV MUST be used for each different muxing hierarchy (muxing tree in the following examples).

The Maximum LSP Bandwidth at priority 'p' field MUST be set accordingly to [RFC4204]. It MUST be set to zero for non supported priorities.

E.g. if 3 OTU3 and 4 OTU2 interfaces are bundled together, a single ISCD TLV may be advertised with a different SCSI for each muxing hierarchy.

[4.1.](#) Switch Capability Specific Information

The technology specific part of the ISCD can include a variable number of SCSI TLVs. The definitio of a SCSI TLV allows the encoding

TLV type 1 (TBA by IANA), which is used to describe a tree of the OTN muxing hierarchy. The muxing hierarchy tree is encoded as an order independent list of TLVs called Bandwidth TLVs. Two types of Bandwidth TLV are defined (TBA by IANA):

- Type 1 - Used for fixed containers
- Type 2 - Used for flexible containers

The format of the SCSI TLV is depicted in the following figure:

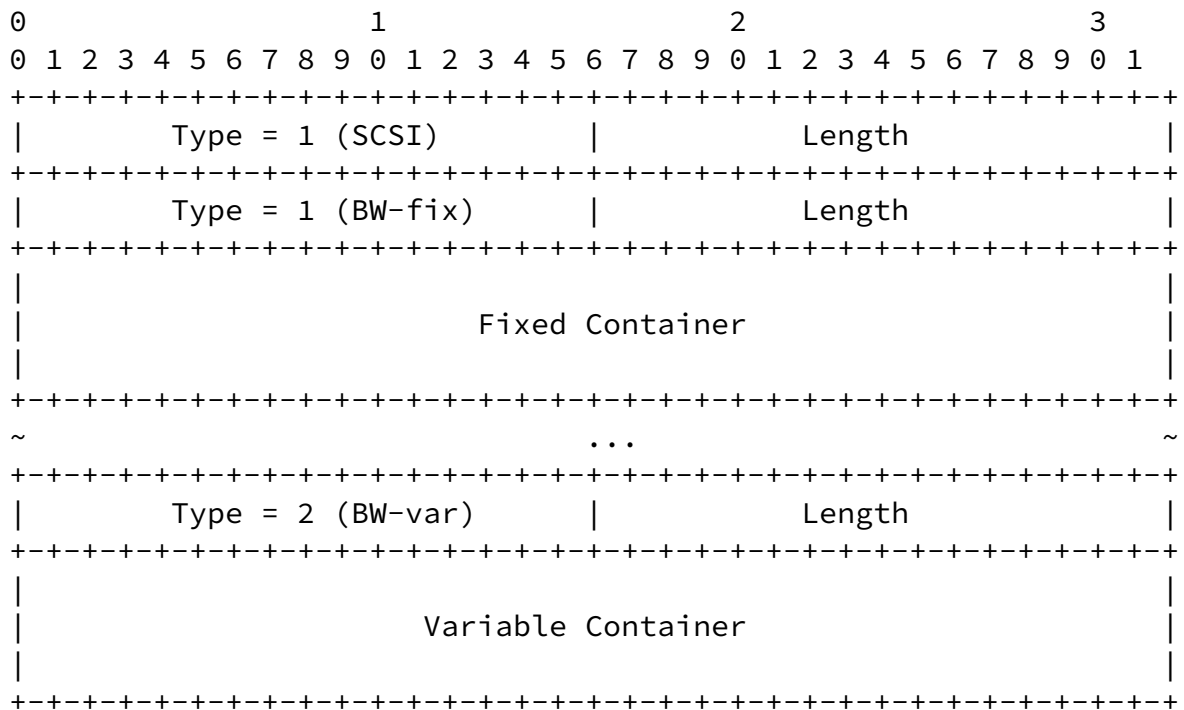


Figure 3: SCSI TLV

The formats of the two different types of Bandwidth TLV are depicted in the following figures:

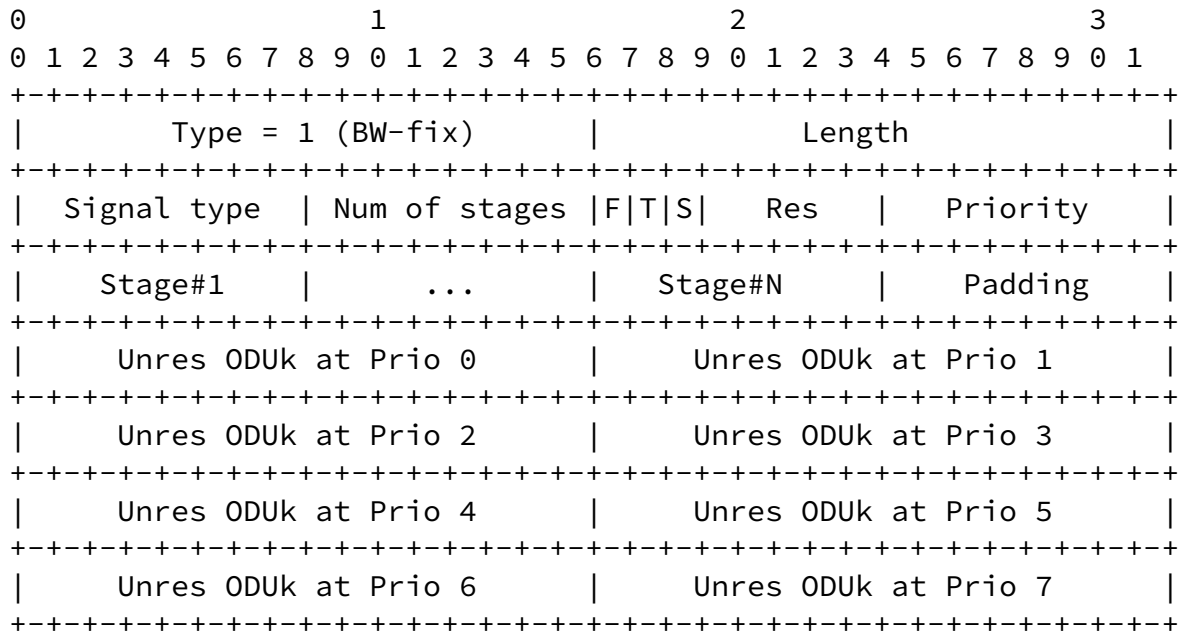


Figure 4: Bandwidth TLV - Type 1 -

The values of the fields shown in figure 4 are explained after figure 5.

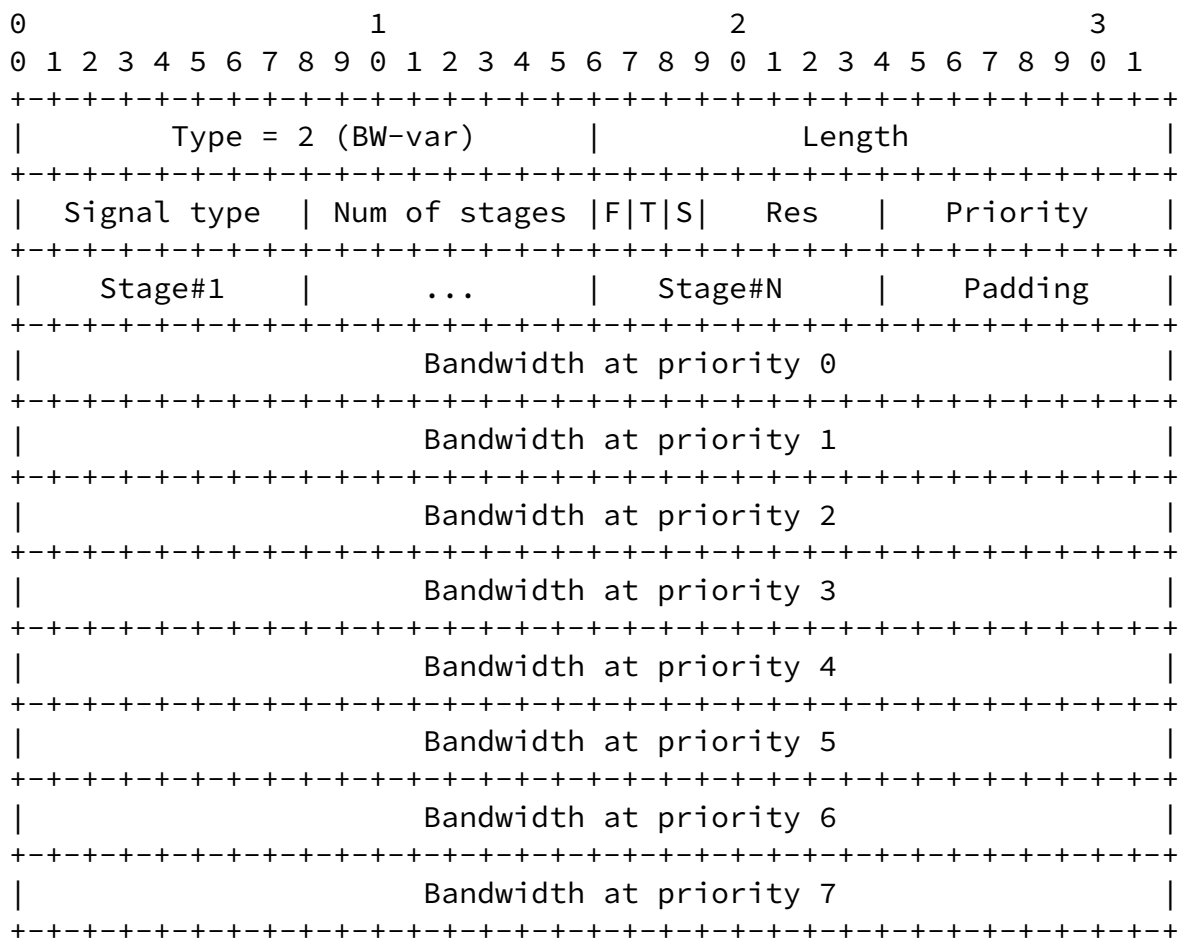


Figure 5: Bandwidth TLV - Type 2 -

- Signal Type: Indicates the ODU type being advertised

Value	Type
1	ODU1
2	ODU2
3	ODU3
4	ODU4
10	ODU0

11	ODU2e
20	ODUflex CBR
21	ODUflex GFP-F resizable
22	ODUflex GFP-F non resizable
60000-65535	Experimental

- Number of stages: Indicates the number of multiplexing stages level. It is equal to 0 when a server layer is being advertised, 1 in case of single stage muxing, 2 in case of dual stage muxing, etc.
- Flags:
 - F flag : This flag defines the meaning of the Bandwidth being advertised. When the F bit is cleared, the type of bandwidth being advertised is the Unreserved Bandwidth of the given signal type. On the other side, when the F bit is set, the Bandwidth fields represent the MAX LSP bandwidth.
 - T Flag (bit 17): Indicates whether the advertised bandwidth can be terminated. When T=1, the signal type can be terminated, when T=0, the signal type cannot be terminated.
 - S Flag (bit 18): Indicates whether the advertised bandwidth can be switched. When S=1, the signal type can be switched, when S=0, the signal type cannot be switched.

The value 00 in both T and S bits is not permitted.
- Priority :8 bits field with 1 flag for each priority. Bit set indicates priority supported, bit cleared priority not supported. The priority 0 is related to the most significant bit. When no priority is supported, priority 0 MUST be advertised.
- Stage#1 ... Stage#N : These fields are 8 bits long. Their number is variable and a field is present for each stage of the muxing hierarchy. The last one is always indicating the server ODU container (ODUK/OTUK). The values of the Stage fields are the

same ones defined for the Signal Type field.

- Padding: Given that the number of Stages is variable, a padding to 32 bits field might be needed.

- Unreserved Bandwidth/Max LSP BW : In case of fixed containers the Bandwidth field is 16 bits long and indicates the Unreserved Bandwidth in number of available containers, while in case of variable container the Bandwidth field (both in case of Unreserved or MAX LSP) is 32 bits long and expressed in IEEE floating point format. Only Unreserved/MAX LSP bandwidth for supported priorities MUST be advertised.

[EDITOR NOTE]: TO BE MOVED TO THE INFO MODEL DRAFT Please note that in case of multi stage muxing hierarchy (e.g. ODU1->ODU2->ODU3), not only the ODUk/OTUK bandwidth (ODU3) and service layer bandwidth

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(ODU1) are needed, but also the intermediate one (ODU2). This is a typical case of spatial allocation problem.

Suppose in this scenario to have the following advertisement:

Hierarchy: ODU1->ODU2->ODU3

Number of ODU1==5

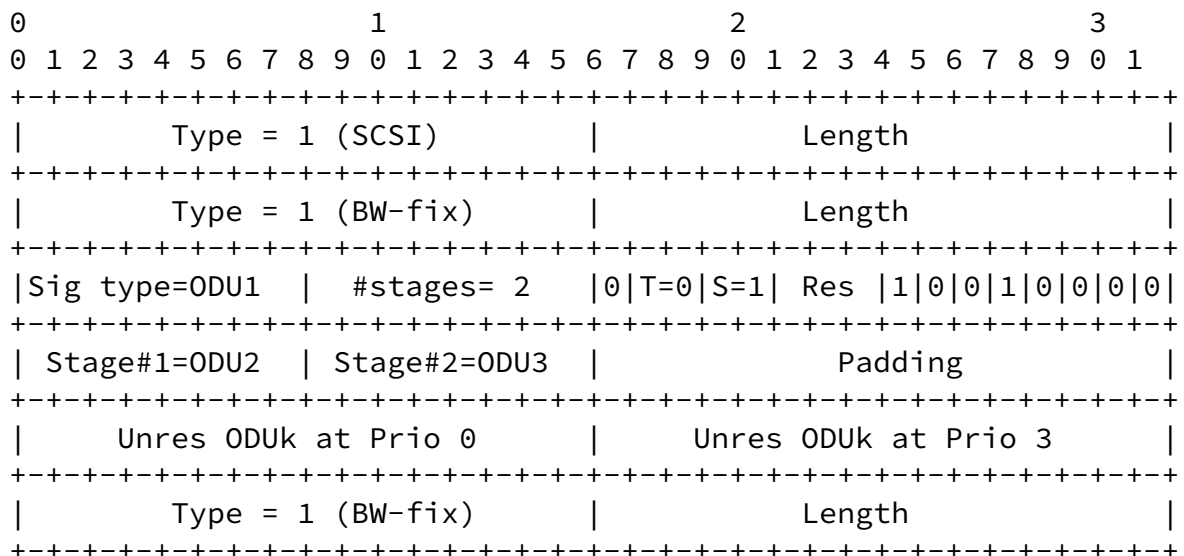
The number of ODU1 suggests that it is possible to have an ODU2 FA, but it depends on the spatial allocation of such ODU1.

It is possible that 2 links are bundled together and 3 ODU1->ODU2->ODU3 are available on a component link and 2 on the other one, in such a case no ODU2 FA could be set up. The advertisement of the ODU2 is needed because in case of ODU1 spatial allocation (3+2), the ODU2 available bandwidth would be 0 (no ODU2 FA can be created), while in case of ODU1 spatial allocation (4+1) the ODU2 available bandwidth would be 1 (1 ODU2 FA can be created).

[5.](#) Examples

The examples in the following pages are not normative and are not intended to infer or mandate any specific implementation.

[5.1.](#) Example of T and S bits utilization



```

|Sig type=ODU2 | #stages= 1 |0|T=1|S=0| Res |1|0|0|1|0|0|0|0|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Stage#1=ODU3 |                Padding                |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   Unres ODUk at Prio 0   |   Unres ODUk at Prio 3   |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   Type = 1 (BW-fix)     |   Length                   |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|Sig type=ODU3 | #stages= 0 |0|T=1|S=1| Res |1|0|0|1|0|0|0|0|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   Unres ODUk at Prio 0   |   Unres ODUk at Prio 3   |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

Figure 6: Example 1 - T and S bits utilization

5.2. Example of ODUFlex advertisement

In this example the advertisement of an ODUFlex->ODU3 hierarchy is shown. In case of ODUFlex advertisement the MAX LSP bandwidth needs to be advertised but in some cases also information about the Unreserved bandwidth could be useful. The F flag is used to distinguish between the two cases.

```

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
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   Type = 1 (SCSI)       |   Length                   |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

```

|   Type = 2 (BW-var)     |   Length                   |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|S. type=ODUFlex| #stages= 1 |F=0|T|S| Res | Priority |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Stage#1=ODU3 |                Padding                |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   Unreserved Bandwidth at priority 0   |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   Unreserved Bandwidth at priority 1   |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   Unreserved Bandwidth at priority 2   |

```

```

+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                               Unreserved Bandwidth at priority 3                               |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                               Unreserved Bandwidth at priority 4                               |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                               Unreserved Bandwidth at priority 5                               |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                               Unreserved Bandwidth at priority 6                               |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                               Unreserved Bandwidth at priority 7                               |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|          Type = 2 (BW-var)          |          Length          |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|S. type=ODUflex| #stages= 1 |F=1|T|S| Res | Priority |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Stage#1=ODU3 |          Padding          |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                               MAX LSP Bandwidth at priority 0                               |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                               MAX LSP Bandwidth at priority 1                               |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                               MAX LSP Bandwidth at priority 2                               |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                               MAX LSP Bandwidth at priority 3                               |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                               MAX LSP Bandwidth at priority 4                               |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                               MAX LSP Bandwidth at priority 5                               |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                               MAX LSP Bandwidth at priority 6                               |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                               MAX LSP Bandwidth at priority 7                               |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+

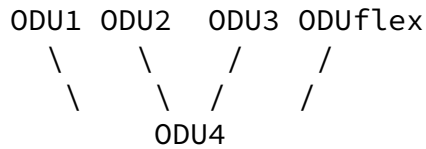
```

Figure 7: Example 2 - ODUflex advertisement

[5.3.](#) Example of single stage muxing

Supposing to have 1 OTU4 component link supporting single stage muxing of ODU1, ODU2, ODU3 and ODUflex, the supported hierarchy can

be summarized in a tree as in the following figure. For sake of simplicity we assume that also in this case only priorities 0 and 3 are supported.



and the related SCSIs as follows:

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	2	3	4	5	6	7	8	9
Type = 1 (SCSI)										Length																													
Type = 1 (BW-fix)										Length																													
Sig type=ODU4										#stages= 0										F=0 T S										Res 1 0 0 1 0 0 0 0									
Unres ODUk at Prio 0 =1										Unres ODUk at Prio 3 =1																													
Type = 1 (BW-fix)										Length																													
Sig type=ODU1										#stages= 1										F=0 T S										Res 1 0 0 1 0 0 0 0									
Stage#1=ODU4										Padding																													
Unres ODUk at Prio 0 =40										Unres ODUk at Prio 3 =40																													
Type = 1 (BW-fix)										Length																													
Sig type=ODU2										#stages= 1										F=0 T S										Res 1 0 0 1 0 0 0 0									
Stage#1=ODU4										Padding																													
Unres ODUk at Prio 0 =10										Unres ODUk at Prio 3 =10																													
Type = 1 (BW-fix)										Length																													

```

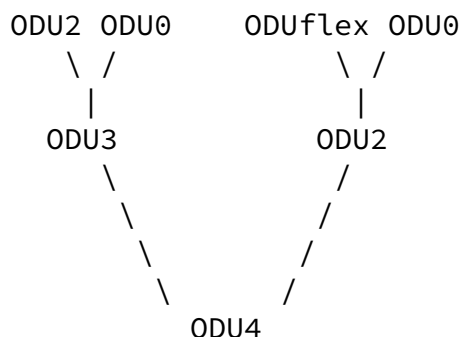
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|Sig type=ODU3 | #stages= 1 |F=0|T|S| Res |1|0|0|1|0|0|0|0|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Stage#1=ODU4 |           Padding           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   Unres ODUk at Prio 0 =2   |   Unres ODUk at Prio 3 =2   |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           Type = 2 (BW-var) |           Length           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|S. type=ODUflex| #stages= 1 |F=1|T|S| Res |1|0|0|1|0|0|0|0|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Stage#1=ODU4 |           Padding           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           MAX LSP Bandwidth at priority 0 =100Gbps           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           MAX LSP Bandwidth at priority 3 =100Gbps           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|S. type=ODUflex| #stages= 1 |F=0|T|S| Res |1|0|0|1|0|0|0|0|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Stage#1=ODU4 |           Padding           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           Unreserved Bandwidth at priority 0 =100Gbps           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           Unreserved Bandwidth at priority 3 =100Gbps           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

Figure 8: Example 3 - Single stage muxing

5.4. Example of multi stage muxing - Unbundled link

Supposing to have 1 OTU4 component link with muxing capabilities as show in the following figure:



and supported priorities 0 and 3, the advertisement is composed by the following SCSI:

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	2	3	4	5	6	7	8	9										
Type = 1 (SCSI)										Length																																							
Type = 1 (BW-fix)										Length																																							
Sig type=ODU4										#stages= 0										F T S										Res										1 0 0 1 0 0 0 0									
Unres ODUk at Prio 0 =1										Unres ODUk at Prio 3 =1																																							
Type = 1 (BW-fix)										Length																																							
Sig type=ODU3										#stages= 1										F T S										Res										1 0 0 1 0 0 0 0									
Stage#1=ODU4										Padding																																							
Unres ODUk at Prio 0 =2										Unres ODUk at Prio 3 =2																																							
Type = 1 (BW-fix)										Length																																							
Sig type=ODU2										#stages= 1										F T S										Res										1 0 0 1 0 0 0 0									
Stage#1=ODU4										Padding																																							
Unres ODUk at Prio 0 =10										Unres ODUk at Prio 3 =10																																							
Type = 1 (BW-fix)										Length																																							
Sig type=ODU2										#stages= 2										F T S										Res										1 0 0 1 0 0 0 0									
Stage#1=ODU3										Stage#2=ODU4										Padding																													
Unres ODUk at Prio 0 =10										Unres ODUk at Prio 3 =10																																							
Type = 1 (BW-fix)										Length																																							

```

+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|Sig type=ODU0 | #stages= 2 |F|T|S| Res |1|0|0|1|0|0|0|0|
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Stage#1=ODU3 | Stage#2=ODU4 | Padding |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Unres ODUk at Prio 0 =80 | Unres ODUk at Prio 3 =80 |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Type = 1 (BW-fix) | Length |

```

```

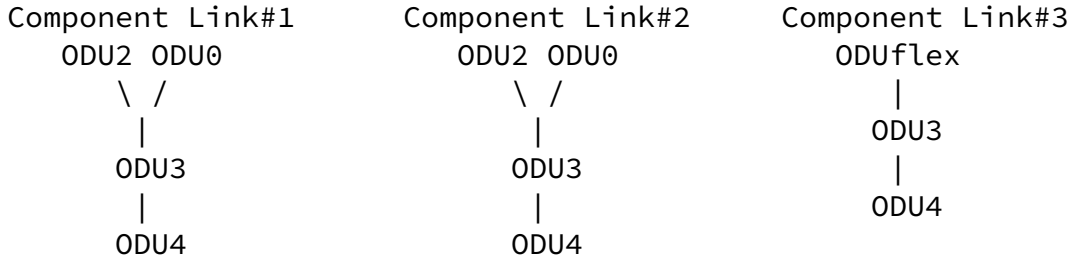
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|Sig type=ODU0 | #stages= 2 |F|T|S| Res |1|0|0|1|0|0|0|0|
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Stage#1=ODU2 | Stage#2=ODU4 | Padding |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Unres ODUk at Prio 0 =80 | Unres ODUk at Prio 3 =80 |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Type = 2 (BW-var) | Length |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|S.type=ODUflex | #stages= 2 |F=0|T|S| Res |1|0|0|1|0|0|0|0|
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Stage#1=ODU2 | Stage#2=ODU4 | Padding |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Unreserved Bandwidth at priority 0 =100Gbps |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Unreserved Bandwidth at priority 3 =100Gbps |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Type = 2 (BW-var) | Length |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|S.type=ODUflex | #stages= 2 |F=1|T|S| Res |1|0|0|1|0|0|0|0|
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Stage#1=ODU2 | Stage#2=ODU4 | Padding |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| MAX LSP Bandwidth at priority 0 =10Gbps |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| MAX LSP Bandwidth at priority 3 =10Gbps |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+

```

Figure 9: Example 4 - Multi stage muxing - Unbundled link

[5.5.](#) Example of multi stage muxing - Bundled links

In this example 3 OTU4 component links with the following muxing capabilities trees are considered



Considering only supported priorities 0 and 3, the advertisement is

composed by a single ISCD with 2 SCSI TLVs, one for the advertisement of Component Link#1 and #2 and the second one for Component Link#3:

- SCSI 1 -

```

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
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           Type = 1 (SCSI)           |           Length           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           Type = 1 (BW-fix)         |           Length           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|Sig type=ODU4 | #stages= 0 |F|T|S| Res  |1|0|0|1|0|0|0|0|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Unres ODUk at Prio 0 =2           | Unres ODUk at Prio 3 =2           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           Type = 1 (BW-fix)         |           Length           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|Sig type=ODU3 | #stages= 1 |F|T|S| Res  |1|0|0|1|0|0|0|0|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Stage#1=ODU4 |           Padding           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Unres ODUk at Prio 0 =4           | Unres ODUk at Prio 3 =4           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

```

|          Type = 1 (BW-fix)          |          Length          |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|Sig type=ODU2 | #stages= 2 |F|T|S| Res  |1|0|0|1|0|0|0|0|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Stage#1=ODU3 | Stage#2=ODU4 |          Padding          |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|  Unres ODUk at Prio 0 =20          |  Unres ODUk at Prio 3 =20          |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|          Type = 1 (BW-fix)          |          Length          |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|Sig type=ODU0 | #stages= 2 |F|T|S| Res  |1|0|0|1|0|0|0|0|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Stage#1=ODU2 | Stage#2=ODU4 |          Padding          |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|  Unres ODUk at Prio 0 =160         |  Unres ODUk at Prio 3 =160         |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

SCSI - 2 -

```

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
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

```

|          Type = 1 (SCSI)          |          Length          |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|          Type = 1 (BW-fix)          |          Length          |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|Sig type=ODU4 | #stages= 0 |F|T|S| Res  |1|0|0|1|0|0|0|0|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|  Unres ODUk at Prio 0 =1          |  Unres ODUk at Prio 3 =1          |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|          Type = 1 (BW-fix)          |          Length          |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|Sig type=ODU3 | #stages= 1 |F|T|S| Res  |1|0|0|1|0|0|0|0|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Stage#1=ODU4 |          Padding          |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|  Unres ODUk at Prio 0 =2          |  Unres ODUk at Prio 3 =2          |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|          Type = 2 (BW-var)          |          Length          |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|S. type=ODUflex| #stages= 2 |F=1|T|S| Res |1|0|0|1|0|0|0|0|

```

```

+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Stage#1=ODU3 | Stage#1=ODU4 |           Padding           |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|           MAX LSP Bandwidth at priority 0 =40Gbps           |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|           MAX LSP Bandwidth at priority 3 =40Gbps           |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|S. type=ODUflex| #stages= 2   |F=0|T|S|   Res |1|0|0|1|0|0|0|0|
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Stage#1=ODU3 | Stage#1=ODU4 |           Padding           |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|           Unreserved Bandwidth at priority 0 =80Gbps           |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|           Unreserved Bandwidth at priority 3 =80Gbps           |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+

```

Figure 10: Example 5 - Multi stage muxing - Bundled links

6. Compatibility

Backwards compatibility with implementations based on [\[RFC4328\]](#) can be achieved advertising the [\[RFC4328\]](#) based ISCDs in addition to the ISCD defined in this document.

7. Security Considerations

This document specifies the contents of Opaque LSAs in OSPFv2. As Opaque LSAs are not used for SPF computation or normal routing, the extensions specified here have no direct effect on IP routing. Tampering with GMPLS TE LSAs may have an effect on the underlying transport (optical and/or SONET-SDH) network. [\[RFC3630\]](#) suggests mechanisms such as [\[RFC2154\]](#) to protect the transmission of this information, and those or other mechanisms should be used to secure and/or authenticate the information carried in the Opaque LSAs.

[8.](#) IANA Considerations

TBD

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10. Acknowledgements

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