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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.

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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., ODUj multiplexed into ODUk (j<k)), two different tributary slots for ODUk (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 OTUk can be viewed as a component link, and each component link can carry one or more types of ODUj (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].

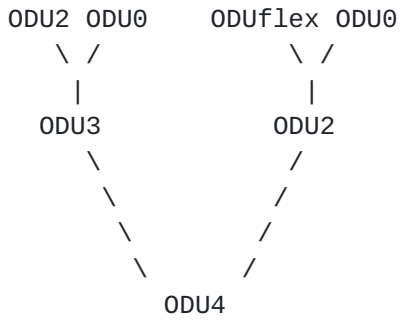
As discussed in [OTN-FWK] and [OTN-INFO], the OSPF-TE must be extended so to be able to advertise the termination and switching capabilites related to each different ODUj and ODUk/OTUk and the advertisement of related multiplexing capabilities. This leads to the need to define a new Switching Capability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

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 supporting switching capability only, and the ODUj->ODUk format is used to indicate the ODUj into ODUk multiplexing capability.

This notation can be iterated as needed depending on 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 supported multiplexed container is represented with increasing granularity until reaching 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 the 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 OTUk-TE-Link. The OTUk-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.

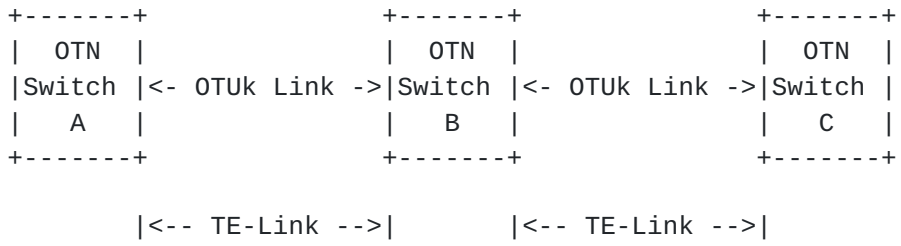


Figure 1: ODUk TE-Links

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

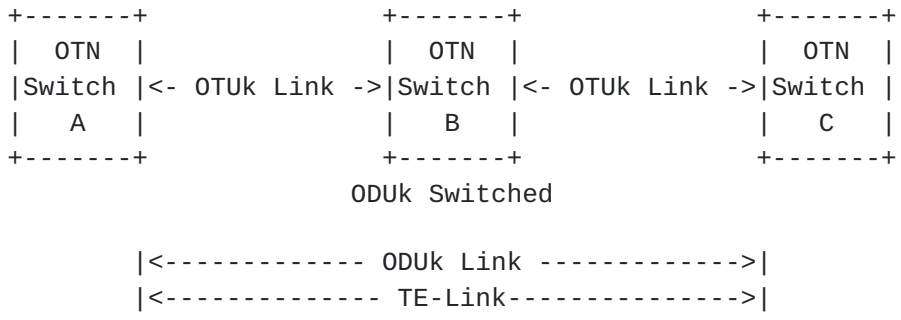


Figure 2: Multiple hop TE-Link

4. ISCD format extensions

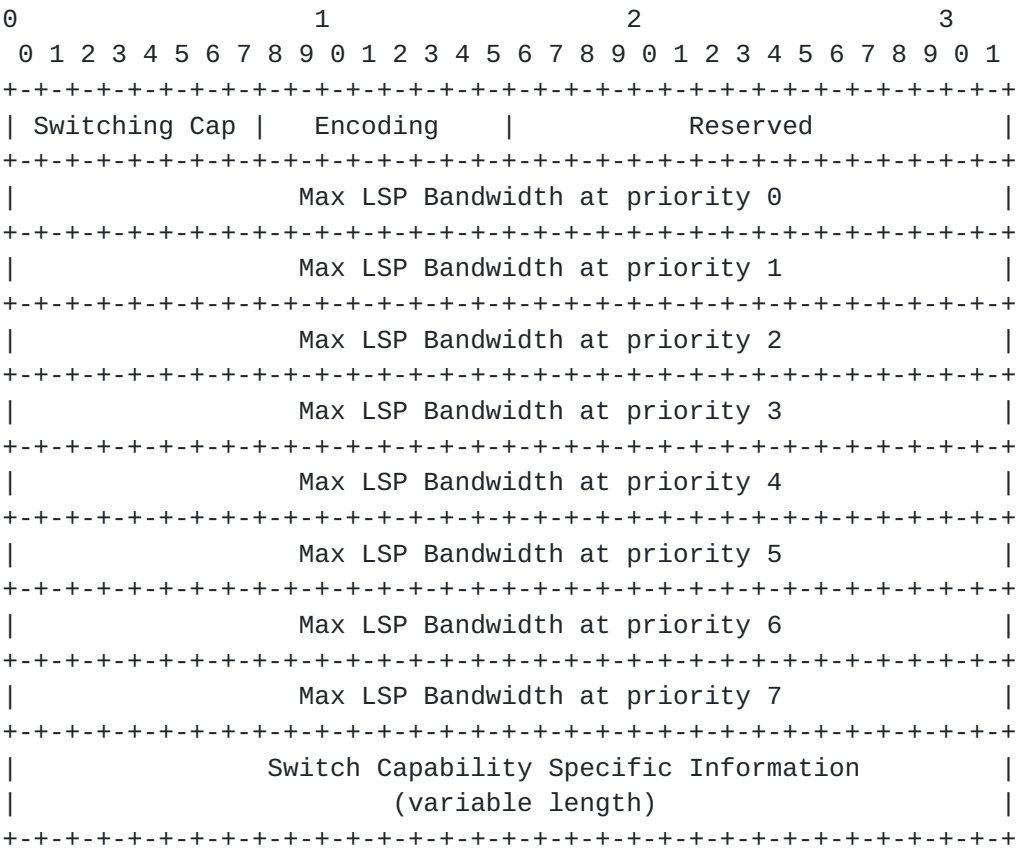
The Interface Switching Capability Descriptor describes switching capability of an interface [RFC 4202]. This document defines a new Switching Capability value for OTN [G.709-v3] as follows:

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 MUST be interpreted as follows:



Maximum LSP Bandwidth

The MAX LSP bandwidth field is used according to [RFC4203]: i.e. 0 <= Max LSP Bandwidth <= 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 MUST be in bytes per second and the encoding MUST be 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

A single ISCD MAY be used for the advertisement of unbundled or bundled links supporting homogeneous multiplexing hierarchies and the same Tributary Slot Granularity (TSG). A different ISCD MUST be used for each different muxing hierarchy (muxing tree in the following examples) and different TSG supported within the TE Link, if it includes component links with differing characteristics.

4.1. Switch Capability Specific Information

The technology specific part of the OTN ISCD may include a variable number of sub-TLVs called Bandwidth sub-TLVs. The muxing hierarchy tree MUST be encoded as an order independent list of them. Two types of Bandwidth TLV are defined (TBA by IANA):

- Type 1 - Unreserved Bandwidth for fixed containers

- Type 2 - Unreserved/MAX LSP Bandwidth for flexible containers

The format of the SCSI MUST be as depicted in the following figure:

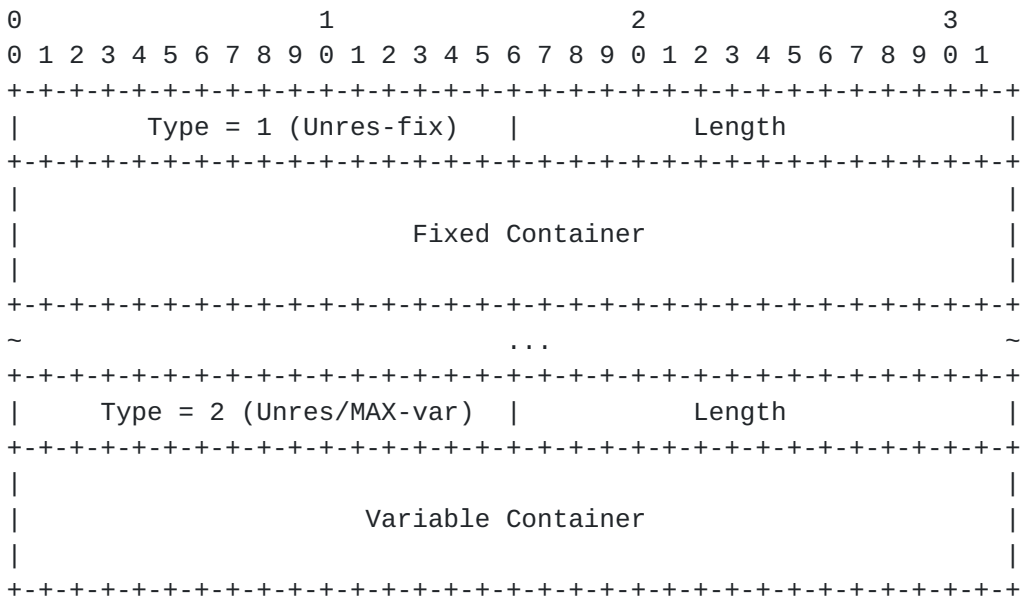


Figure 3: SCSI format

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

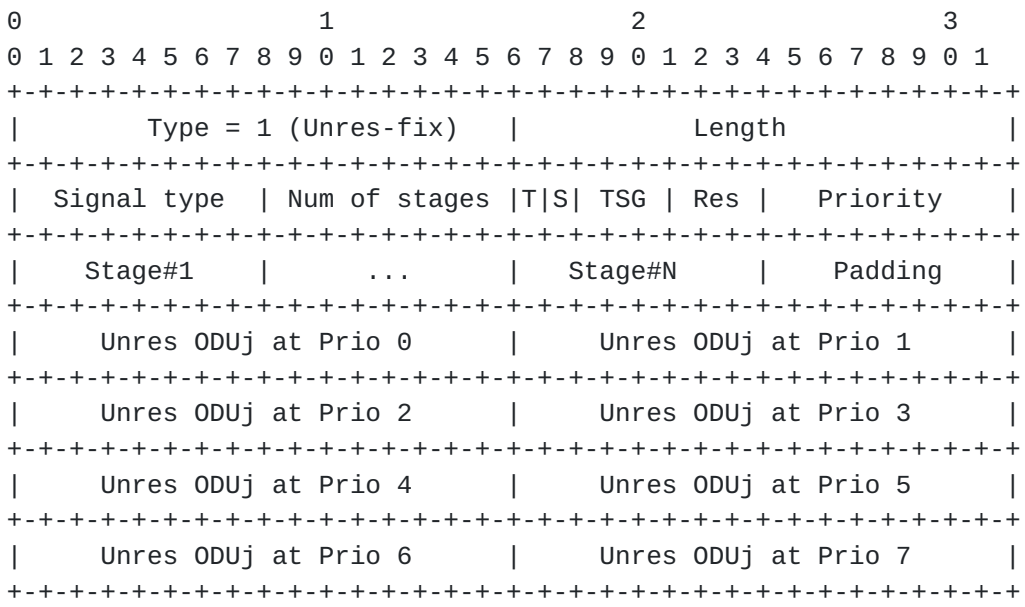


Figure 4: Bandwidth TLV - Type 1 -

The values of the fields shown in figure 4 are explained after figure 6.

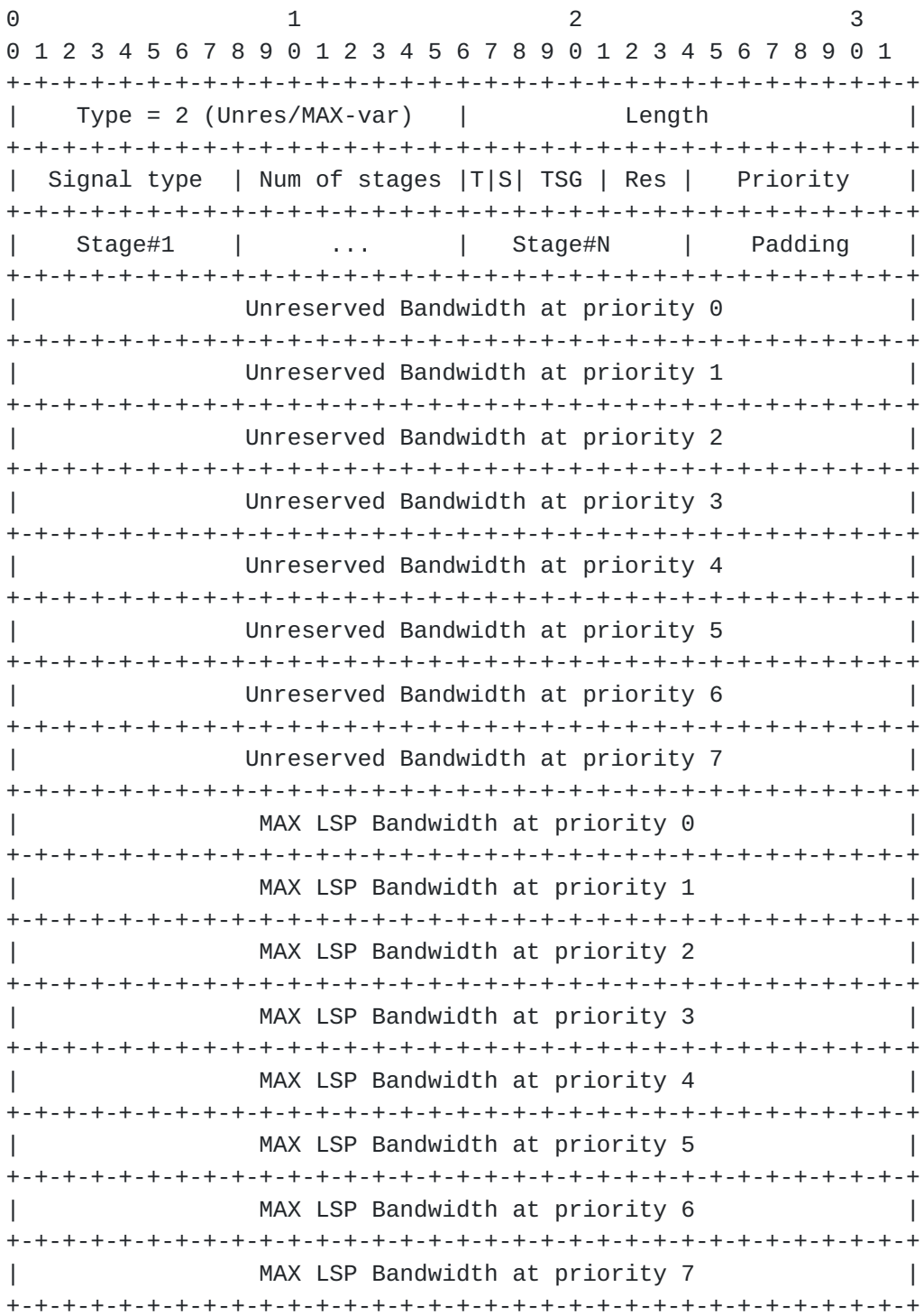


Figure 5: Bandwidth TLV - Type 2 -

- 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
230-256	Experimental

With respect to ODUflex, ODUflex CBR and ODUflex GFP-F MUST always be advertised separately as they use different adaptation functions. In the case both GFP-F resizable and non resizable (i.e. 21 and 22) are supported, Signal Type 21 implicitely supports also signal Signal Type 22, so only Signal Type 21 MUST be advertised. Signal Type 22 MUST be used only for non resizable resources.

- Number of stages: Indicates the number of multiplexing stages level. It MUST be 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:

  - 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 MUST NOT be used.

- TSG: Tributary Slot Granularity (3bit): Used for the advertisement of the supported Tributary Slot granularity

  - 0 - Reserved

  - 1 - 1.25 Gbps/2.5Gbps

  - 2 - 2.5 Gbps only

- 3 - 1.25 Gbps only

- 4 - Don't care

- 5-7 - Reserved

Where value 1 is used on those interfaces where the fallback procedure is enabled and the default value of 1.25 Gbps can be falled back to 2.5 if needed. Values 2 and 3 are used where there is no chance to modify the TSG. In the former case the interface being advertised is a G.709v1 and in the latter the interface is a G.709v3 with fallback procedure disabled or unavailable. Value 4 is used for non multiplexed signal (i.e. non OTN client).

- Priority :8 bits field with 1 flag for each priority. Bit set indicates priority supported, bit cleared means 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 MUST always indicate the server ODU container (ODUk/OTUk). The values of the Stage fields MUST be the same ones defined for the Signal Type field. If the number of stages is 0, then no Stage fields MUST be included.

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

- Unreserved Bandwidth/Max LSP BW : In case of fixed containers (Type=1) the Unreserved Bandwidth field MUST be 16 bits long and indicates the Unreserved Bandwidth in number of available containers. Only Unreserved/MAX LSP BW fields for supported priorities MUST be included, in order of increasing prioritiy (0 to 7). In case the number of supported priorities is odd, a 16 bits all zeros padding field MUST be added. On the other hand, in case of variable containers (Type 2) the Unreserved/MAX LSP Bandwidth fields MUST be 32 bits long and expressed in IEEE floating point format. The advertisement of the MAX LSP bandwidth MUST take into account HO OPUk bit rate tolerance and be calculated according to the following formula:

Max LSP BW = (# available TS) * (ODTUk.ts nominal bit rate) * (1-HO OPUk bit rate tolerance)

Only Unreserved/MAX LSP bandwidth for supported priorities MUST be advertised.

5. Examples

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

5.1. MAX LSP Bandwidth fields in the ISCD

This example shows how the MAX LSP Bandwidth fields of the ISCD are filled accordingly to the evolving of the TE-link bandwidth occupancy. In the example an OTU4 link is considered, with supported priorities 0,2,4,7 and muxing hierarchy ODU1->ODU2->ODU3->ODU4.

At time T0, with the link completely free, the advertisement would be:

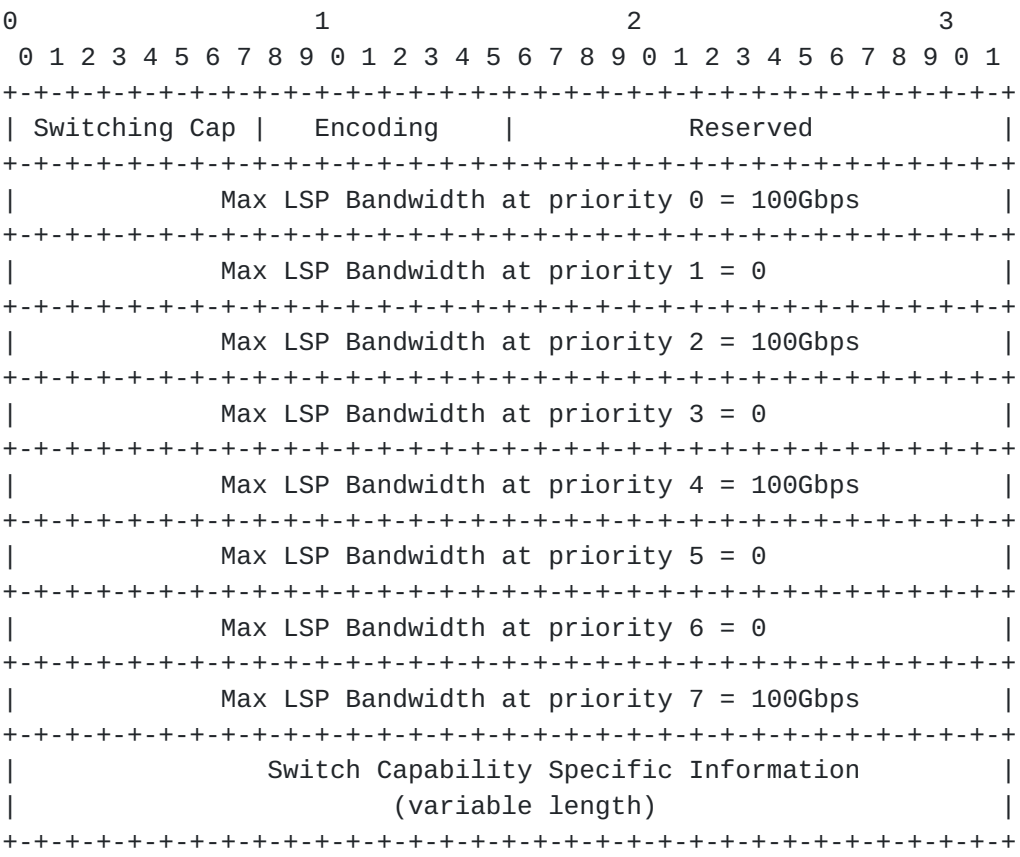


Figure 6: Example 1 - MAX LSP Bandwidth fields in the ISCD @T0

At time T1 an ODU3 at priority 2 is set-up, so for priority 0 the MAX LSP Bandwidth is still equal to the ODU4 bandwidth, while for priorities from 2 to 7 (excluding the non supported ones) the MAX LSP Bandwidth is equal to ODU3, as no more ODU4s are available and the

next supported ODUj in the hierarchy is ODU3.The advertisement is updated as follows:

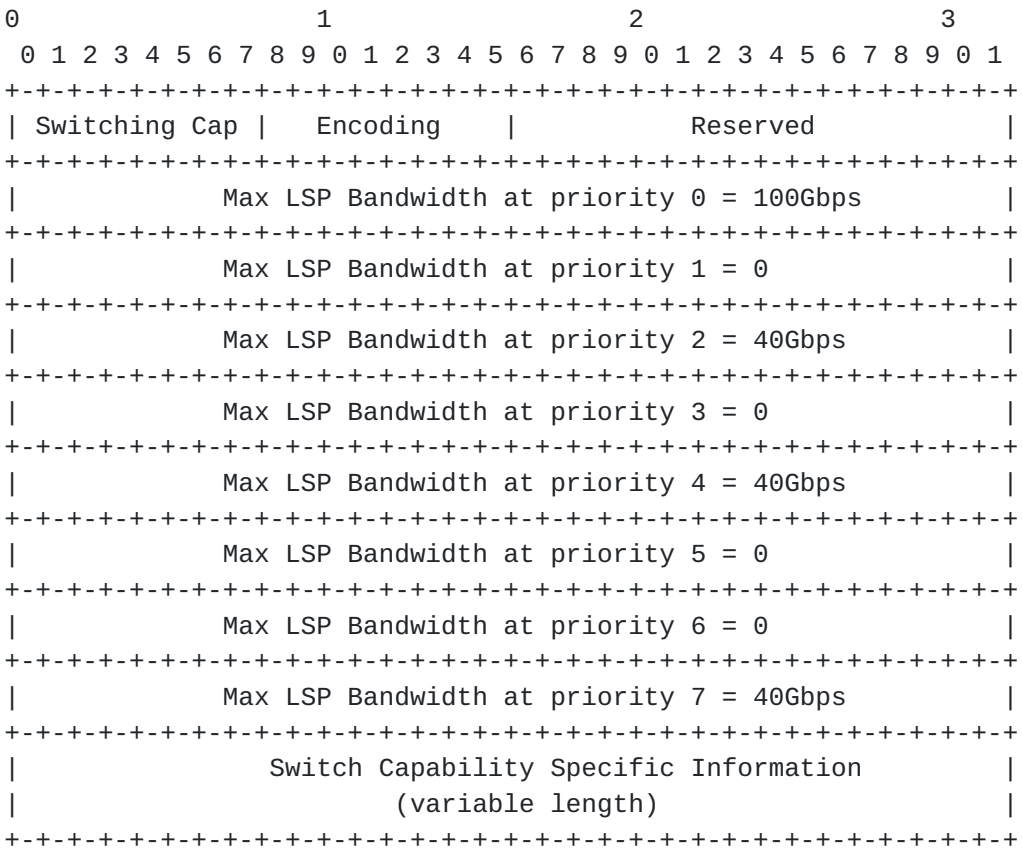


Figure 7: Example 1 - MAX LSP Bandwidth fields in the ISCD @T1

At time T2 an ODU2 at priority 4 is set-up. The first ODU3 is no longer available since T1 as it was kept by the ODU3 LSP, while the second is no more available and just 3 ODU2 are left in it. ODU2 is now the MAX LSP bandwidth for priorities higher than 4. The advertisement is updated as follows:

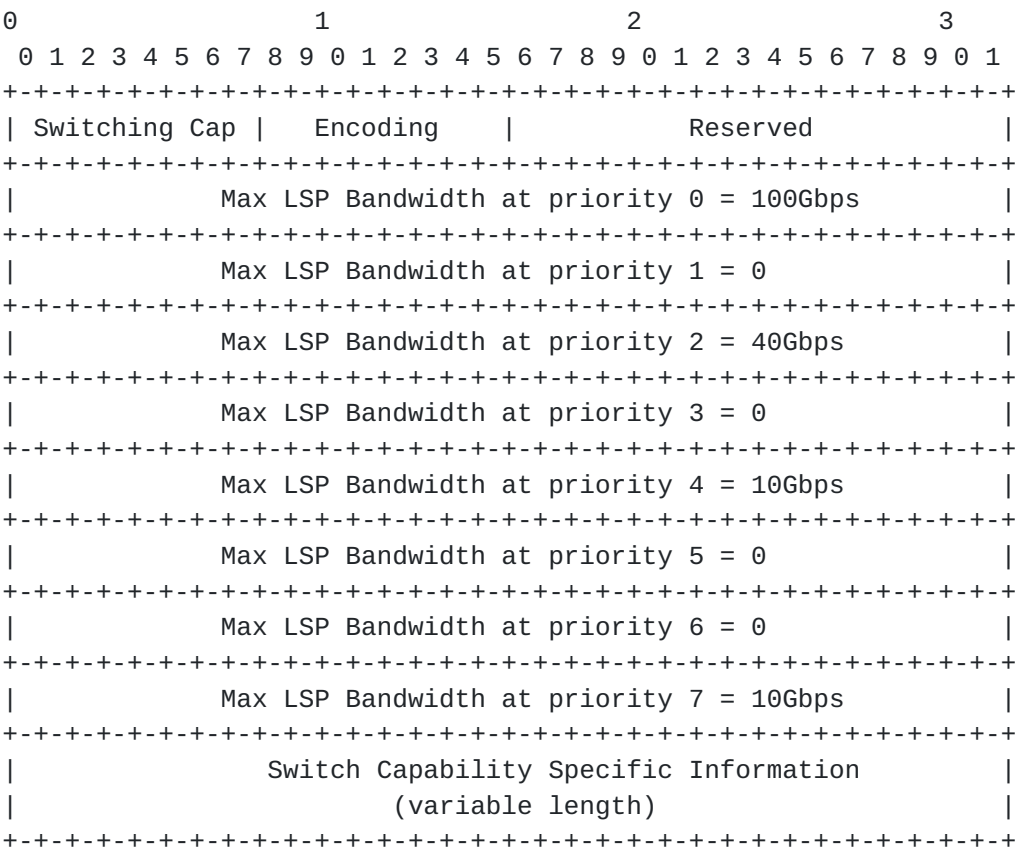


Figure 8: Example 1 - MAX LSP Bandwidth fields in the ISCD @T2

5.2. Example of T,S and TSG utilization

In this example an interface with Tributary Slot Type 1.25 Gbps and fallback procedure enabled is considered (TSG=1). It supports the simple ODU1->ODU2->ODU3 hierarchy and priorities 0 and 3. Suppose that in this interface the ODU3 signal type can be both switched or terminated, the ODU2 can only be terminated and the ODU1 switched only. For the advertisement of the capabilities of such interface a single ISCD is used and its format is as follows:

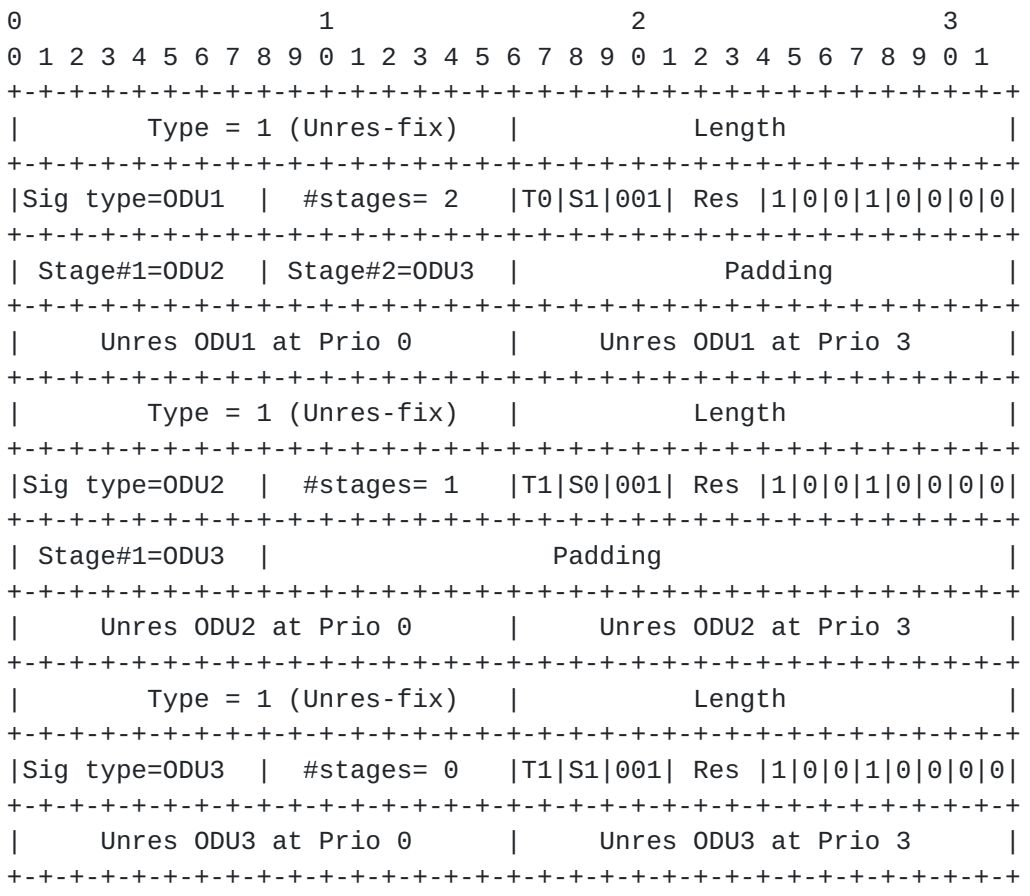


Figure 9: Example 2 - TSG, T and S utilization

5.2.1. Example of different TSGs

In this example two interfaces with homogeneous hierarchies but different Tributary Slot Types are considered. The first one supports a G.709v1 interface (TSG=2) while the second one a G.709v3 interface with fallback procedure disabled (TSG=3). Both of them support ODU1->ODU2->ODU3 hierarchy and priorities 0 and 3. For the advertisement of the capabilities of such interfaces two different ISCDs are used and the format of their SCSIs is as follows:

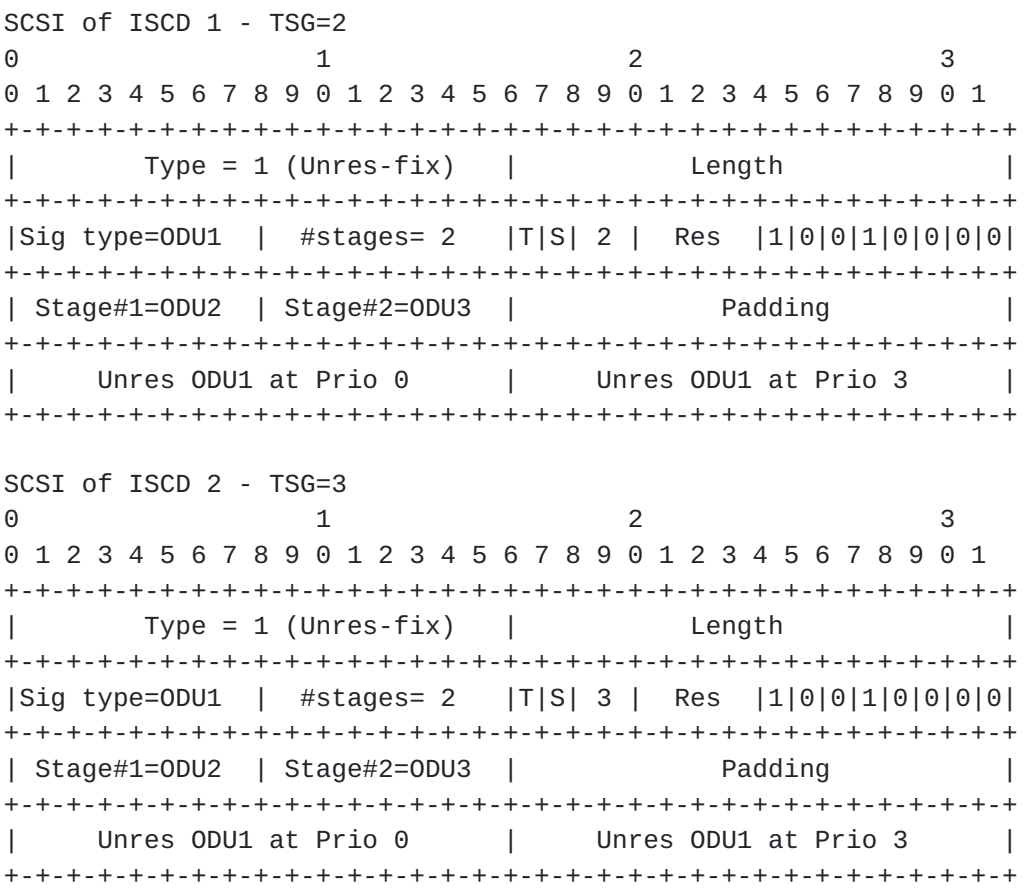


Figure 10: Example 2.1 - Different TSGs utilization

A particular case in which hierarchies with the same muxing tree but with different exported TSG must be considered as non homogenous hierarchies is the case in which an H-LPS and the client LSP are terminated on the same egress node. What can happen is that a loose ero is used at the hop where the signaled LSP is nested into the H-LSP (penultimate hop of the LSP).

In the following figure, node C receives from A a loose ERO towards node E and must choose between the ODU2 H-LSP on if1 or the one on if2. In case the H-LSP on if1 exports a TS=1,25Gbps and if2 a TS=2,5Gbps and the service LSP being signaled needs a 1,25Gbps tributary slot, only the H-LSP on if1 can be used to reach node E. For further details please see section 4.1 of the [OTN-INFO].

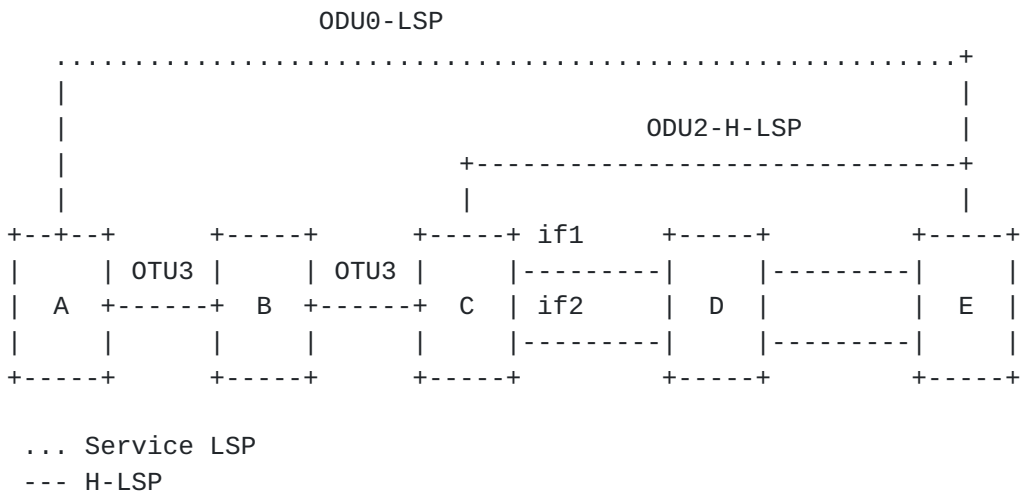


Figure 11: Example - Service LSP and H-LSP terminating on the same node

5.3. 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 and in some cases also information about the Unreserved bandwidth could be useful. The amount of Unreserved bandwidth does not give a clear indication of how many ODUflex LSP can be set up either at the MAX LSP Bandwidth or at different rates, as it gives no information about the spatial allocation of the free TSs.

An indication of the amount of Unreserved bandwidth could be useful during the path computation process, as shown in the following example. Supposing there are two TE-links (A and B) with MAX LSP Bandwidth equal to 10 Gbps each. In case 50Gbps of Unreserved Bandwidth are available on Link A, 10Gbps on Link B and 3 ODUflex LSPs of 10 GBps each, have to be restored, for sure only one can be restored along Link B and it is probable (but not sure) that two of them can be restored along Link A.

In the case of ODUflex advertisement the Type 2 Bandwidth TLV is used.

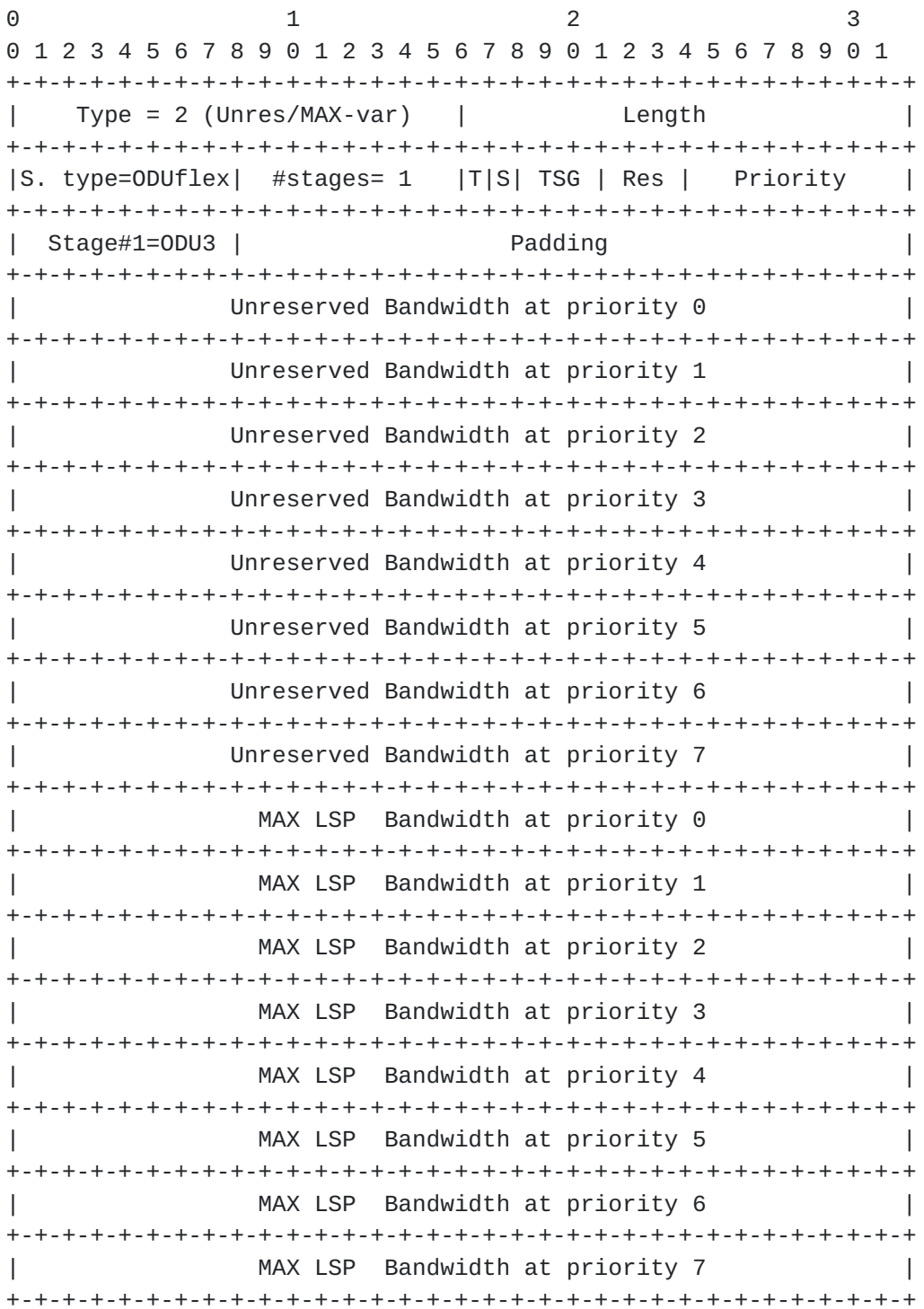
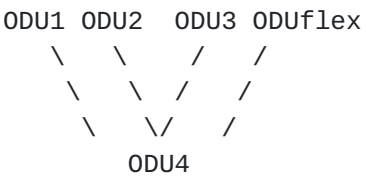


Figure 12: Example 3 - ODUflex advertisement

5.4. Example of single stage muxing

Supposing there is 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:

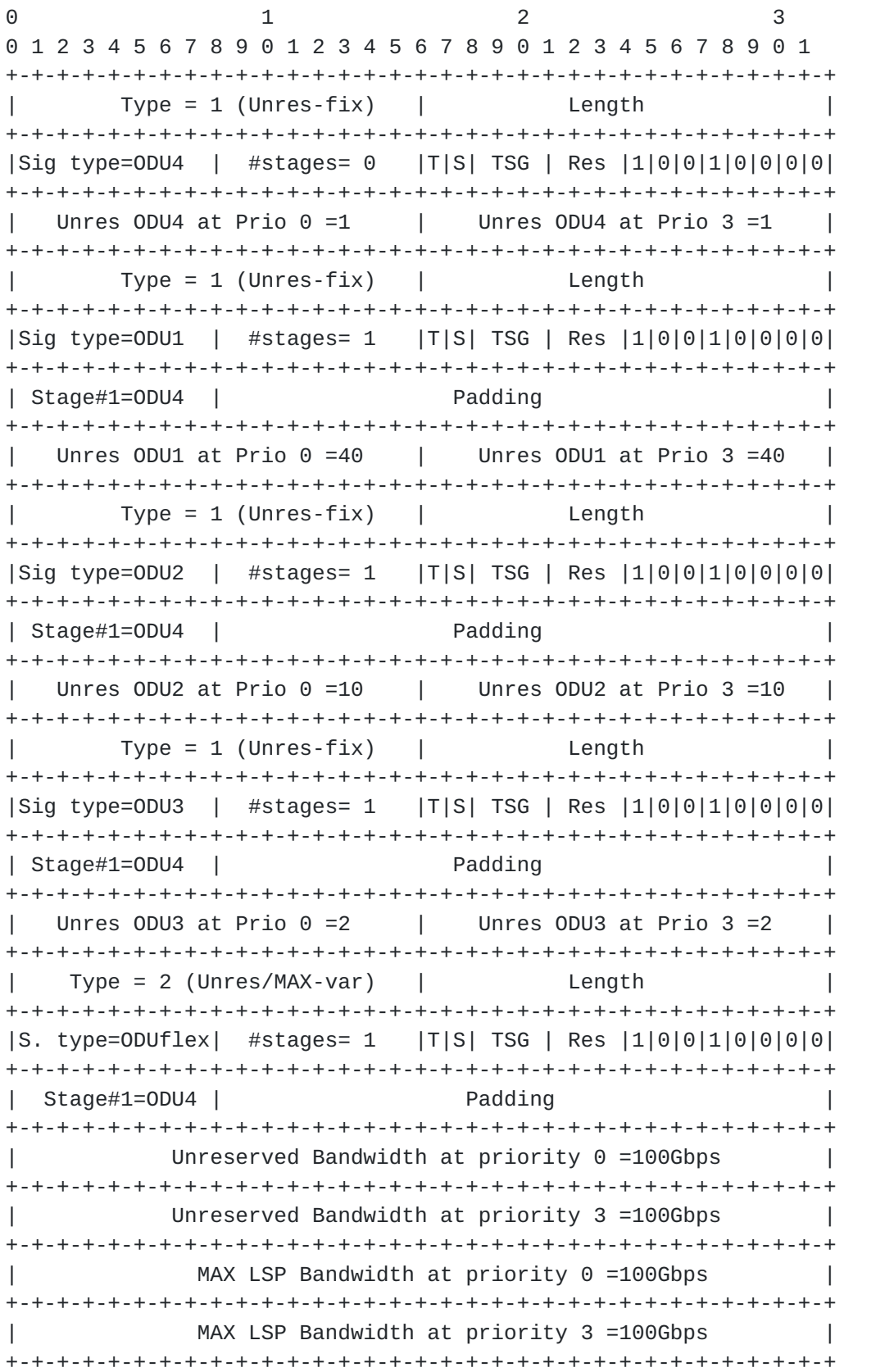
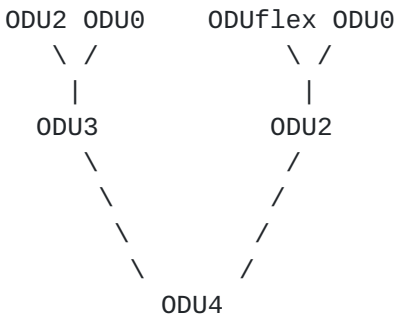

0 1 2 3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
Type = 1 (Unres-fix)
Length
Sig type=ODU4
#stages= 0
T|S| TSG
Res
1|0|0|1|0|0|0|0|
Unres ODU4 at Prio 0 =1
Unres ODU4 at Prio 3 =1
Type = 1 (Unres-fix)
Length
Sig type=ODU1
#stages= 1
T|S| TSG
Res
1|0|0|1|0|0|0|0|
Stage#1=ODU4
Padding
Unres ODU1 at Prio 0 =40
Unres ODU1 at Prio 3 =40
Type = 1 (Unres-fix)
Length
Sig type=ODU2
#stages= 1
T|S| TSG
Res
1|0|0|1|0|0|0|0|
Stage#1=ODU4
Padding
Unres ODU2 at Prio 0 =10
Unres ODU2 at Prio 3 =10
Type = 1 (Unres-fix)
Length
Sig type=ODU3
#stages= 1
T|S| TSG
Res
1|0|0|1|0|0|0|0|
Stage#1=ODU4
Padding
Unres ODU3 at Prio 0 =2
Unres ODU3 at Prio 3 =2
Type = 2 (Unres/MAX-var)
Length
S. type=ODUflex
#stages= 1
T|S| TSG
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
MAX LSP Bandwidth at priority 0 =100Gbps
MAX LSP Bandwidth at priority 3 =100Gbps

Figure 13: Example 4 - Single stage muxing

5.5. Example of multi stage muxing - Unbundled link

Supposing there is 1 OTU4 component link with muxing capabilities as shown in the following figure:



and supported pririties 0 and 3, the advertisement is composed by the following Bandwidth TLVs:

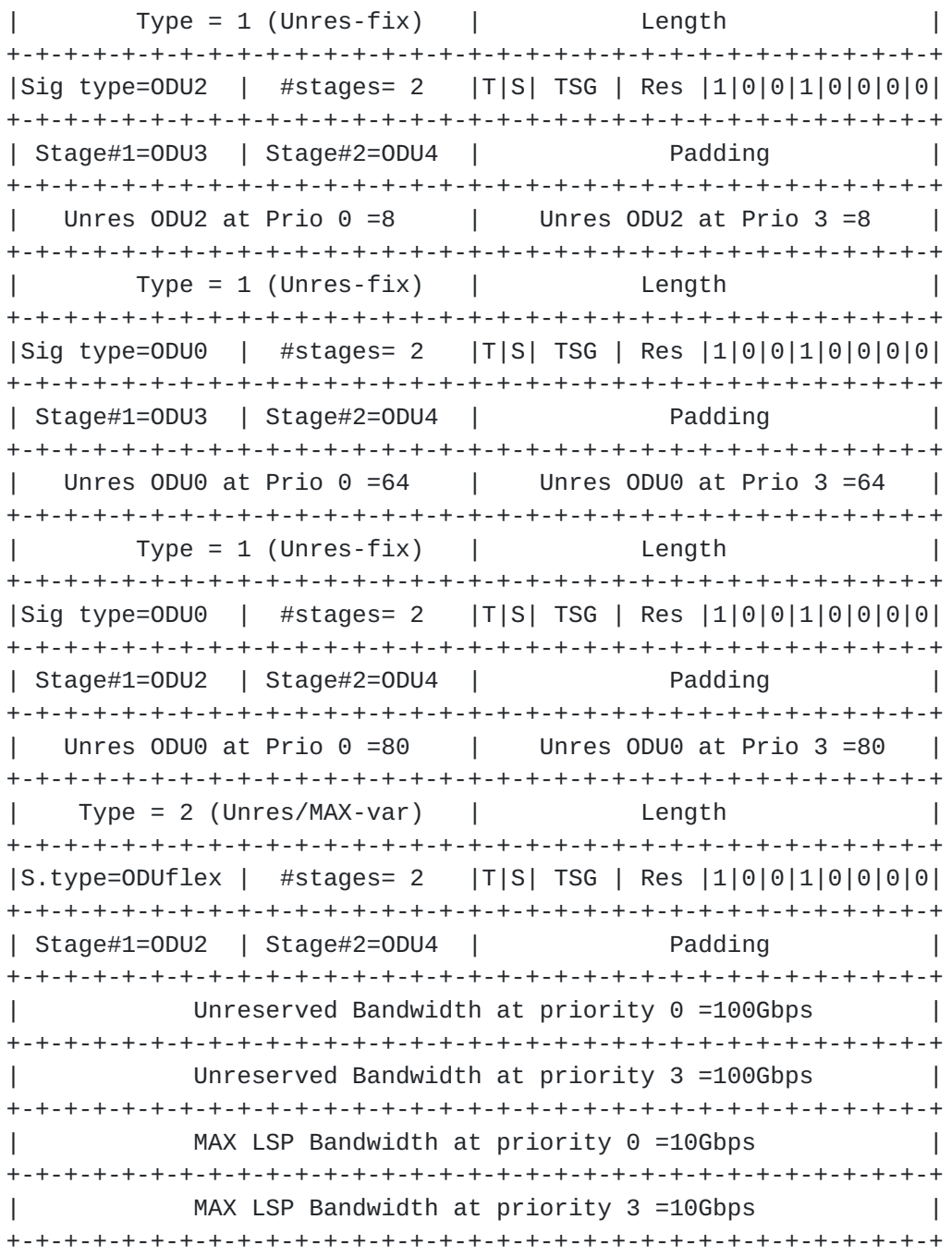
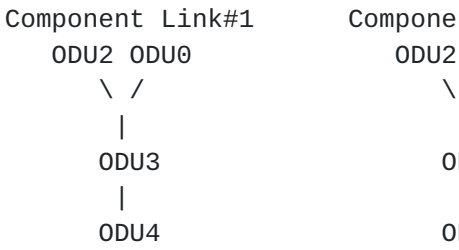


Figure 14: Example 5 - Multi stage muxing - Unbundled link

5.6. Example of multi stage muxing - Bundled links

In this example 2 OTU4 component links with the same supported TSG and homogeneous muxing hierarchies are considered. The following muxing capabilities trees are supported:



Considering only supported priorities 0 and 3, the advertisement is as follows:

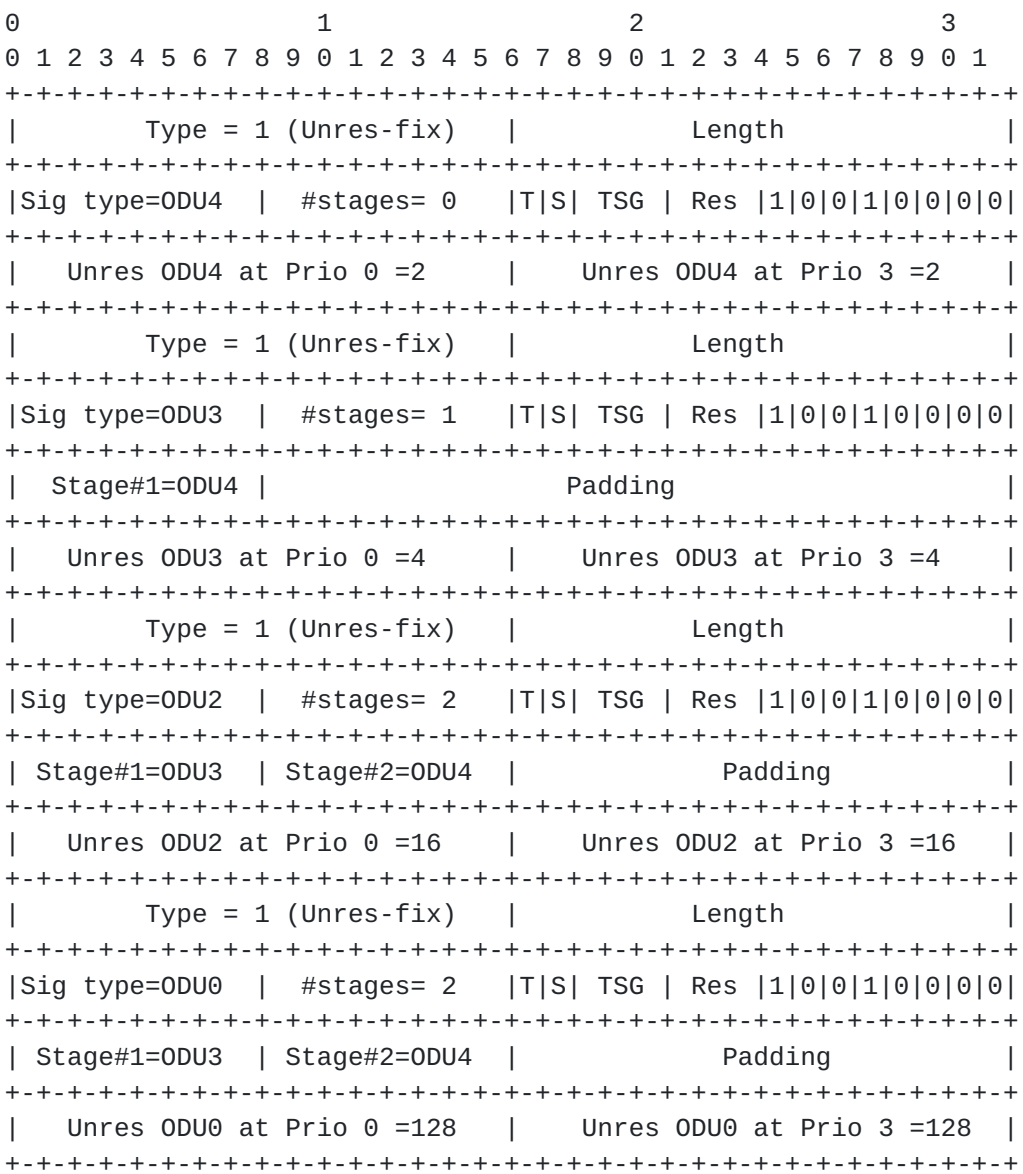
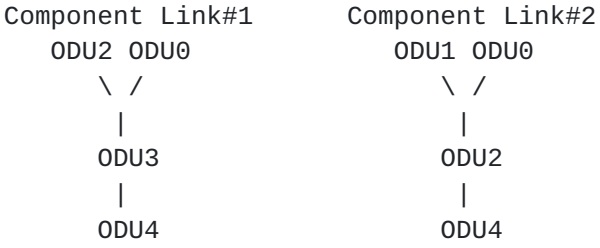


Figure 15: Example 6 - Multi stage muxing - Bundled links

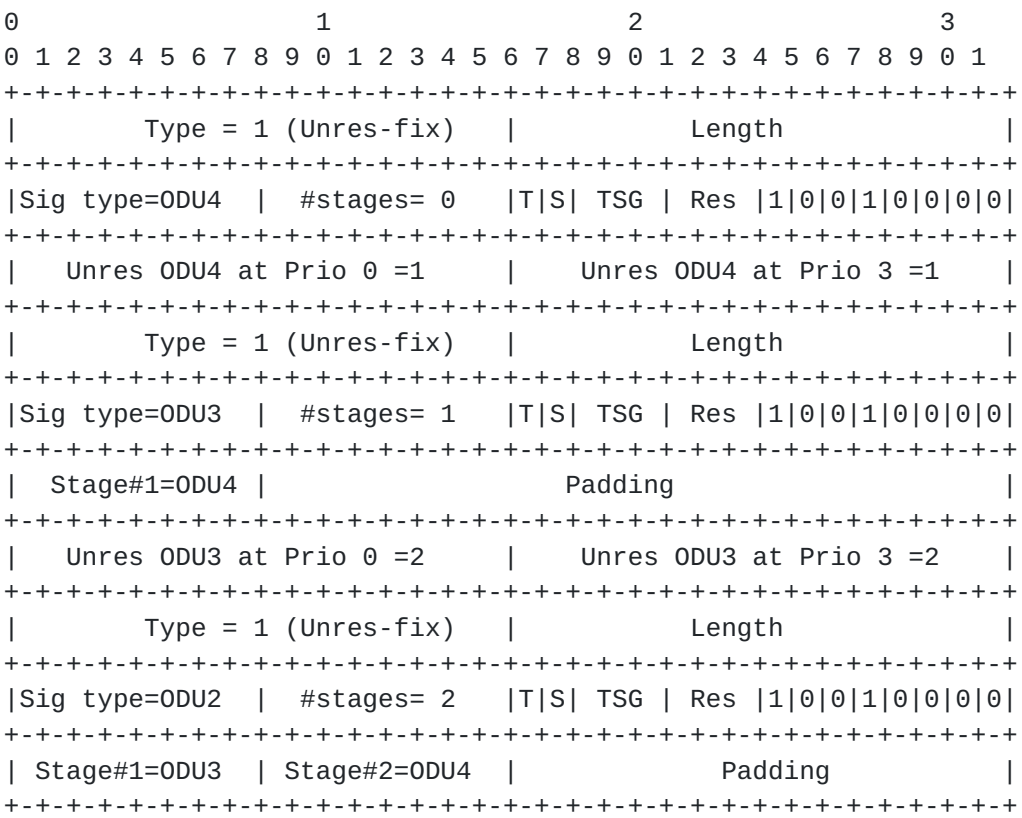
5.7. Example of component links with non homogeneous hierarchies

In this example 2 OTU4 component links with the same supported TSG and non homogeneous muxing hierarchies are considered. The following muxing capabilities trees are supported:



Considering only supported priorities 0 and 3, the advertisement uses two different ISCDs, one for each hierarchy. In the following figure, the SCSI of each ISCD is shown:

SCSI of ISCD 1 - Component Link#1



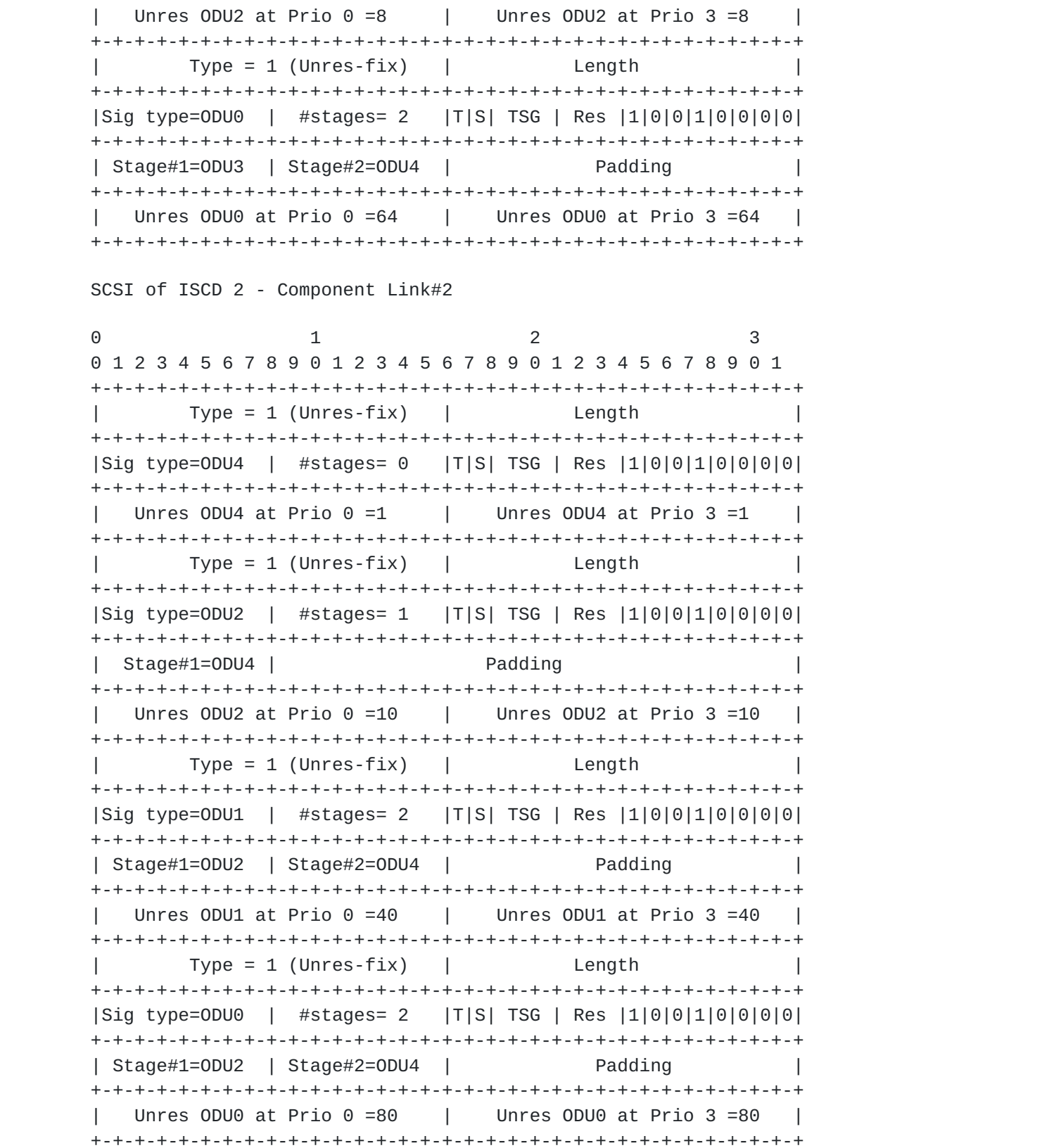

Unres ODU2 at Prio 0 =8
Unres ODU2 at Prio 3 =8
Type = 1 (Unres-fix)
Length
Sig type=ODU0
#stages= 2
T|S| TSG | Res |1|0|0|1|0|0|0|0|
Stage#1=ODU3
Stage#2=ODU4
Padding
Unres ODU0 at Prio 0 =64
Unres ODU0 at Prio 3 =64
SCSI of ISCD 2 - Component Link#2
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
Type = 1 (Unres-fix)
Length
Sig type=ODU4
#stages= 0
T|S| TSG | Res |1|0|0|1|0|0|0|0|
Unres ODU4 at Prio 0 =1
Unres ODU4 at Prio 3 =1
Type = 1 (Unres-fix)
Length
Sig type=ODU2
#stages= 1
T|S| TSG | Res |1|0|0|1|0|0|0|0|
Stage#1=ODU4
Padding
Unres ODU2 at Prio 0 =10
Unres ODU2 at Prio 3 =10
Type = 1 (Unres-fix)
Length
Sig type=ODU1
#stages= 2
T|S| TSG | Res |1|0|0|1|0|0|0|0|
Stage#1=ODU2
Stage#2=ODU4
Padding
Unres ODU1 at Prio 0 =40
Unres ODU1 at Prio 3 =40
Type = 1 (Unres-fix)
Length
Sig type=ODU0
#stages= 2
T|S| TSG | Res |1|0|0|1|0|0|0|0|
Stage#1=ODU2
Stage#2=ODU4
Padding
Unres ODU0 at Prio 0 =80
Unres ODU0 at Prio 3 =80

Figure 16: Example 7 - Multi stage muxing - Non homogeneous hierarchies

6. Compatibility

All implementations of this document MAY support also advertisement as defined in [RFC4328]. When nodes support both advertisement methods, implementations MUST support the configuration of which advertisement method is followed. The choice of which is used is based on policy and is out of scope of the document. This enables nodes following each method to identify similar supporting nodes and compute paths using only the appropriate nodes.

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

Upon approval of this document, IANA will make the assignment of a new Switching Capability value for the existing ISCD located at http://www.iana.org/assignments/ospf-traffic-eng-tlvs/ospf-traffic-eng-tlvs.xml:

15 Interface Switching Capability Descriptor [RFC4203]

Switching capability	Description	Reference
101 (suggested)	OTN-TDM capable (OTN-TDM)	[This.I-D]

This document defines the following sub-TLVs of the ISCD TLV:

Value	Sub-TLV
1	Unreserved Bandwidth for fixed containers
2	Unreserved/MAX LSP bandwidth for flexible containers

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