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D. Ceccarelli
D. Caviglia
Ericsson
F. Zhang
D. Li
Huawei Technologies
Y. Xu
CATR

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

Recent revisions of ITU-T Recommendation G.709 have introduced new features for OTNs:ODU0, ODU4, ODU2e, ODU3e1, ODU3e2 and ODUflex. The new features for the evolutive OTNs are described in separate ITU-T documents. ODU0, ODU2e and ODU4 ODUflex are described in [G709-V3]. ODU3e1 and ODU3e2 are described in [Gsup43]. This document describes OSPF routing protocol extensions to support the evolutive Optical Transport Networks (OTN) under the control of Generalized MPLS (GMPLS).

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1. Introduction

An Opaque OSPF (Open Shortest Path First) LSA (Link State Advertisements) carrying application-specific information can be generated and advertised to other nodes following the flooding procedures defined in [RFC5250]. Three types of opaque LSA are defined, i.e. type 9 - link-local flooding scope, type 10 - area-local flooding scope, type 11 - AS flooding scope.

Traffic Engineering (TE) LSA using type 10 opaque LSA is defined in [RFC3630] for TE purpose. This type of LSA is composed of a standard LSA header and a payload including one top-level TLV (Type/Length/Value triplet) and possible several nested sub-TLVs. [RFC3630] defines two top-level TLVs: Router Address TLV and Link TLV; and nine possible sub-TLVs for the Link TLV, used to carry link related TE information.

The Link type sub-TLVs are enhanced by [RFC4203] in order to support GMPLS networks and related specific link information.

In GMPLS networks each node generates TE LSAs to advertise its TE information and capabilities (link-specific or node-specific), through the network. The TE information carried in the LSAs are collected by the other nodes of the network and stored into their local Traffic Engineering Databases (TED).

In the GMPLS based G.709 Optical Transport Networks (OTNs), in order to automatically establish ODUk connections through GMPLS RSVP-TE signaling, routing is the foundation.

OTN networks provide flexible and various multiplexing relationships (e.g., ODUj multiplexed into ODUk (j<k)), two different tributary slots for ODUk (K=1, 2, 3) and ODUflex signal type, which is being standardized in ITU-T. In order to present this information in the routing process, the OSPF protocol needs to be extended.

This document describes OSPF routing protocol extensions to support the evolutive OTNs under the control of GMPLS. Please note that 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.

2. OSPF Requirements

ITU-T has introduced in the recently approved G.709 [2009] new fixed size ODU containers and a new variable size ODUflex container that can be used to transport either CBR signals or packets. OTN serves

as the convergence layer for transporting a wide range of services, including those whose bit rates do not allow efficient usage of the entire bandwidth associated with a single lambda. In the latter case, OTN allows aggregation (and protection) of traffic to support optimization of overall network bandwidth allocation; i.e., OTN allows the aggregate service rate to be decoupled from the OTN line system capacity.

For example, within a given networking domain, you can think of LSPs (ODUs) serving different roles (service and line). A line rate LSP only uses the line rate capacity (OTUk capacity) and cannot be further electrically multiplexed (e.g., a line rate 10Gbit/s can only traverse OTU2 links). On the other hand, a service LSP may be electrically multiplexed and it is able to cross any kind of link regardless of the line rate. From a routing scalability perspective, it is also necessary to have the possibility to group/map information about certain physical resources (e.g., links) and their properties.

Thus, it is necessary to define a maximally scalable control plane solution that is able to fully exploit OTN flexibility (both in terms of aggregation and survivability). This leads the authors to view it as critical to fulfill the following requirements:

- Support G.709 ODUs including ODUflex. As opposed to fixed size containers, for ODUflex it is necessary to declare the maximum LSP bandwidth. Support all standard (fixed and flexible) ODUs.

- Be able to differentiate multiplexed capacity from line rate capacity. This allows support of the scenarios in the OTN framework draft (in particular, the hybrid scenario).

- Be capable of bundling links either at the same line rate or different line rates (e.g. 40G and 10G). Bundling links at different rates makes the control plane more scalable and permits better networking flexibility.

- Support priority for restoration.

3. Overview of the Evolutive G.709

The traditional OTN specification [G709] describes the Optical Transport Hierarchy (OTH) and introduces three types of ODU (Optical Channel Data Unit) signal (i.e. ODU1, ODU2 and ODU3). The ODUj can be mapped into one or more Tributary Slots (with granularity of 2.5Gbps) of OPUk (Optical Channel Payload Unit-k) where j<k. The ODUj can also be mapped into OTUj (Optical Channel Transport Unit-j, j=1, 2 or 3) directly.

Recent revisions of ITU-T Recommendation G.709 have introduced new features for OTNs:ODU0, ODU4, ODU2e, ODU3e1, ODU3e2 and ODUflex. The new features for the evolutive OTNs are described in separate ITU-T documents. ODU0, ODU2e and ODU4 ODUflex are described in [G709-V3]. ODU3e1 and ODU3e2 are described in [Gsup43].

The ITU-T documents also define the new multiplexing hierarchy for the evolutive OTN. In this multiplexing hierarchy, LO (Lower Order) ODUj can be mapped into an OTUj, or multiplexed into an HO (Higher Order) ODUk (where j<k) occupying several TSs (Tributary Slots).

In the case of LO ODUj mapping into OTUj, the following mappings are defined:

- ODU1 into OTU1 mapping

- ODU2 into OTU2 mapping

- ODU3 into OTU3 mapping

- ODU4 into OTU4 mapping

- ODU2e into OTU2e mapping

In the case of LO ODUj multiplexing into HO ODUk, a new Tributary Slot granularity (i.e. 1.25Gbps) is introduced in [G709-V3]. For the evolutive OTN, the multiplexing of ODUj (j = 0, 1, 2, 2e, 3, flex) into an ODUk (k > j) signal can be depicted as follows:

- ODU0 into ODU1 multiplexing (with 1,25Gbps TS granularity)

- ODU0, ODU1, ODUflex into ODU2 multiplexing (with 1.25Gbps TS granularity)

- ODU1 into ODU2 multiplexing (with 2.5Gbps TS granularity)

- ODU0, ODU1, ODU2, ODU2e and ODUflex into ODU3 multiplexing (with 1.25Gbps TS granularity)

- ODU1, ODU2 into ODU3 multiplexing (with 2.5Gbps TS granularity)

- ODU0, ODU1, ODU2, ODU2e, ODU3 and ODUflex into ODU4 multiplexing (with 1.25Gbps TS granularity)

- ODU2e into ODU3e1 multiplexing (with 2.5Gbps TS granularity)

- ODU2e into ODU3e2 multiplexing (with 1.25Gbps TS granularity)

In order to be backward compatible with the 2.5Gbps TS defined in [G709-V3], both the 2.5Gbps TS and the 1.25Gbps TS can be used in the two cases listed below:

o ODU1 into ODU2 multiplexing

o ODU1 and ODU2 into ODU3 multiplexing

From the link perspective, it can only work under one TS type. For example, if the both ends (or interfaces) of the link can support 2.5Gbps TS and 1.25Gbps TS, then it can work under 2.5Gbps TS or 1.25Gbps TS. If one end can support 1.25Gbps TS, and another end can support 2.5Gbps TS, the end with 1.25Gbps TS MUST adopt a 2.5Gbps TS).

4. G.709 Digital Layer TE Information

This document only considers the TE information needed for LO ODU path computation. WSON TE information is out of scope. Please refer to [WSON-OSPF] for more information about WSON routing information.

From the perspective of [G709-V3], there are two different cases for LO ODU:

(1) A LO ODUk mapped into an OTUk. In this case, the server layer of this LO ODU is an OTUk. For example, if a STM-16 signal is encapsulated into an ODU1 and then mapped into OTU1, the ODU1 is a LO ODU.

(2) A LO ODUj multiplexed into a HO (Higher Order) ODUk (j < k) occupying several TSs. In this case, the server layer of this LO ODU is a HO ODUk. For example, if an ODU1 is multiplexed into ODU2 and then mapped into an OTU2, the ODU1 is a LO ODU and the ODU2 is a HO ODU.

In order to compute a suitable path the PCE (centralized or distributed) needs a set of data that should be advertised by the routing protocol. In the following sections each type of data is listed and analyzed, while the possible values are shown in section 5.

4.1. Tributary Slot type

ITU-T recommendations define two types of TS but, from the link perspective, it can only work under one of them. For example, if the both ends (or interfaces) of a link can support 2.5Gbps TS or 1.25Gbps TS, then the link will work under 2.5Gbps TS or 1.25Gbps TS.

If one end can support the 1.25Gbps TS, and another end the 2.5Gbps TS, the former end SHOULD adopt the 2.5Gbps TS.

In addition, the bandwidth accounting depends on the type of TS. Therefore, the type of the TS should be known during LO ODU path computation.

4.2. TE link type

The link type indicates the OTUk/HO ODUk type of the TE link.

The TS bandwidth of different types of OTUk is different; it increases along with the increasing of k (see [G709-V3]). The bandwidth of a TS in a TE link can be deduced from the TS type and link type of the TE link. For example, the bandwidth of a 1.25G TS without NJO (Negative Justification Opportunity) in an OTU2 is about 1.249409620 Gbps, while the bandwidth of a 1.25G TS without NJO in an OTU3 is about 1.254703729 Gbps.

The actual TS bandwidth of a TE link is useful to determine the number of TSs needed by an ODUflex service. And the actual TS bandwidth of a TE link can be deduced by the TE link type and TS type.

4.3. LO ODU signal type

It is possible that some equipments can not support all the LO ODU signal types. When a path computation procedure for a LO ODU is performed, it needs to check whether a link has the capability to carry a specific type of LO ODU or not. If a link can not carry this type of LO ODU, it should be excluded during the path computation. Only the links with the capability of carrying this type of LO ODU can be the candidates.

For example, in the following figure, the interfaces IF1, IF2, IF8, IF7, IF5 and IF6 can support ODUflex signals, while the interfaces IF3 and IF4 cannot. In this case, if one ODUflex connection from A to C is requested, link #1 and #2 are excluded and link #3 and link #4 are the candidates (the possible path could be A-D-C through link #3 and link #4).

```
                                 +-----+
                       link #3   |     |  link #4
               +-----------------+  D  +-----------------+
               |              IF8|     |IF7              |
               |                 +-----+                 |
               |                                         |
               |IF1                                   IF6|
            +--+--+              +-----+              +--+--+
            |     |    link #1   |     |    link #2   |     |
            |  A  +--------------+  B  +--------------+  C  |
            |     |IF2        IF3|     |IF4        IF5|     |
            +-----+              +-----+              +-----+
```

Figure 1: LO ODU signal type

Therefore, it is necessary to advertise the LO ODU types that the OTU or HO ODU TE link can support.

4.4. TE link Unreserved Bandwidth

In the GMPLS based OTN networks, the Unreserved Bandwidth of a TE link is the sum of the unreserved bandwidths of all the component links associated with the bundled link.

The unreserved bandwidth can be accounted through the unallocated Tributary Slots of the TE link.

4.5. Maximum LSP Bandwidth

The Maximum Bandwidth that an LSP can occupy in a TE link is determined by the component link with the maximum unreserved bandwidth in such TE link.

For example, if two OTU3 component links are bundled to a TE link, the unreserved bandwidth of the first component link is 20*1.25G TSs, and the unreserved bandwidth of the second component link is 24*1.25G TSs. Then the unreserved bandwidth of this TE link is 44*1.25G TSs, but the maximum TSs that a LSP can occupy in this TE link is 24, not 44.

5. OSPF Extensions

In terms of GMPLS based OTN networks, each OTUk/HO ODUk can be viewed as a component link, and each component link can carry one or more types of LO ODU.

Each TE LSA can carry a top-level 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].

A general Interface Switching Capability Descriptor (ISCD) sub-TLV is defined In [RFC 4203]. The bandwidth accounting is encoded in a 4 octets field in the IEEE floating point format. Max LSP Bandwidth is accounted at each priority X (0~7).

This document defines a new sub-TLV of the Link TLV, called OTN Interface Switching Capability Descriptor (OTN-ISCD) with value TBD by IANA. The OTN-ISCD format is described in Section 5.1.

One or more component links can be bundled as a TE link. In case of link bundling an OTN-ISCD will be used for each component link.

5.1. OTN Interface Switching Capability Descriptor

The format of the new OTN-Interface Switching Capability Descriptor is defined in Figure 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              |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Res| T |OD(T)Uk|  Reserved     |   Signal Flags  |G|F|E|D|C|B|A|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Max lsp TS at P0     |          Unreserved TS at p0  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Max lsp TS at P1     |          Unreserved TS at p1  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Max lsp TS at P2     |          Unreserved TS at p2  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Max lsp TS at P3     |          Unreserved TS at p3  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Max lsp TS at P4     |          Unreserved TS at p4  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Max lsp TS at P5     |          Unreserved TS at p5  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Max lsp TS at P6     |          Unreserved TS at p6  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Max lsp TS at P7     |          Unreserved TS at p7  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2: OTN-Interface Switching Capability Descriptor

Where:

o T (2 bits): Indicates the type of the Tributary Slot of this TE link, value 0 means the TS type is 1.25Gbps, value 1 means the TS type is 2.5Gbps.

o OD(T)Uk (4 bits): Indicates the type of the TE link, i.e. the server layer signal that the LO ODUs can be mapped or multiplexed into. The following values are defined:

0: Reserved (for future use)

1: OTU1/HO ODU1

2: OTU2/HO ODU2

3: OTU3/HO ODU3

4: OTU4/HO ODU4

5: OTU2e/HO ODU2e

6-15: Reserved (for future use)

The bandwidth of a TS in this TE link can be deduced from T bit and OD(T)Uk field.

o Signal Flags (16 bits): This field indicates the LO ODU type supported by the TE link. A flag set to 1 indicates that the TE link supports the corresponding LO ODU signal. Currently the following flags are defined:

Flag A: indicates whether LO ODU0 is supported.

Flag B: indicates whether LO ODU1 is supported.

Flag C: indicates whether LO ODU2 is supported.

Flag D: indicates whether LO ODU3 is supported.

Flag E: indicates whether LO ODU4 is supported.

Flag F: indicates whether LO ODU2e is supported.

Flag G: indicates whether LO ODUflex is supported.

Other bits are reserved and must be set to zero when sent and should be ignored when received.

o Max lsp TS at Pi (16 bits): Indicates the maximum number of unreserved TS at priority Pi of all of the component links of the TE link.

o Unreserved TS at Pi (12 bits): Indicates the number of unreserved TSs at priority Pi inside all the component links of the TE link.

All the reserved fields must be set to zero and should be ignored when received.

6. Compatibility Considerations

The legacy nodes that do not implement the extensions defined in this document are able to ignore the LSA containing an OTN-ISCD sub-TLV. They will continue to flood the LSA to other neighbors, but will not use the information carried in this LSA.

7. Example

Based on the sub-TLVs defined in [RFC 3630], [RFC 4203] and this document, a G.709 digital TE link can be described as follows.

```
+------+ component link 1 +------+
|      +------------------+      |
|  N1  +------------------+  N2  |
|      | component link 2 |      |
+--+---+                  +---+--+
```

Figure 3: Example

This picture shows a simple example of an OTN network. The link type of the two component links are OTU2 and OTU3 respectively. The former have the capability of carrying ODU0, ODU1 and ODUflex client signals, while the latter, ODU1, ODU2, ODU3 and ODUflex. The TS type is 1.25Gbps and all the possible priorities are supported (0~7).

The two component links can be bundled as a TE link but it is also possible to consider each of them as a separate TE link.

If the two component links are bundled together, N1 and N2 should assign a link local ID to the TE link and then N1 get the link remote ID automatically or manually.

N1 can generate an LSA to describe the above attributes of the TE link. Suppose the link IDs are unnumbered, the LSA should carry a link TLV with the following nested minimal sub-TLVs:

< G.709 Digital Link > ::= < Link Type > < Link ID > < Link Local/Remote Identifiers > < OTN Interface Switching Capability Descriptor >

o Link Type sub-TLV: Defined in [RFC 3630], G.709 digital links are always type 1 - Point-to-point link.

o Link ID sub-TLV: Defined in [RFC 3630], for point-to-point link, indicates the remote router ID.

o Link Local/Remote Identifiers sub-TLV: Defined in [RFC 4203], indicates the local link ID and the remote link ID.

o OTN Interface Switching Capability Descriptor sub-TLV: Defined in this document, carries the characteristic of this G.709 digital TE link.

Just after the creation of the TE Link comprising the two component links, the two ISCDs would be 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              |            Length             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Res|T=0|OTk =2 |  Reserved     |   Signal Flags  |1|0|0|0|0|1|1|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       Max lsp TS at P0 =8     |       Unreserved TS at p0 =8  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       Max lsp TS at P1 =8     |       Unreserved TS at p1 =8  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       Max lsp TS at P2 =8     |       Unreserved TS at p2 =8  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       Max lsp TS at P3 =8     |       Unreserved TS at p3 =8  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       Max lsp TS at P4 =8     |       Unreserved TS at p4 =8  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       Max lsp TS at P5 =8     |       Unreserved TS at p5 =8  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       Max lsp TS at P6 =8     |       Unreserved TS at p6 =8  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       Max lsp TS at P7 =8     |       Unreserved TS at p7 =8  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4: Example - OTN-ISCD OTU2 LC (to)

```
    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              |           Length              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Res|T=0|OTk =3 |  Reserved     |   Signal Flags  |1|0|0|1|1|1|0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P0 =32     |     Unreserved TS at p0 =32   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P1 =32     |     Unreserved TS at p1 =32   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P2 =32     |     Unreserved TS at p2 =32   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P3 =32     |     Unreserved TS at p3 =32   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P4 =32     |     Unreserved TS at p4 =32   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P5 =32     |     Unreserved TS at p5 =32   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P6 =32     |     Unreserved TS at p6 =32   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P7 =32     |     Unreserved TS at p7 =32   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5: Example - OTN-ISCD OTU3 LC (to)

Suppose that at time t1 an LSP is created allocating 35 Gbps at priority 3. The OTN-ISCD referring to the OTU2 component link is unmodified (Figure 4 and the OTN-ISCD referring to the OTU3 component link is modified as illustrated in Figure 6):

```
    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              |             Length            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Res|T=0|OTk =3 |  Reserved     |   Signal Flags  |1|0|0|1|1|1|0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P0 =32     |     Unreserved TS at p0 =32   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P1 =32     |     Unreserved TS at p1 =32   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P2 =32     |     Unreserved TS at p2 =32   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P3 =4      |     Unreserved TS at p3 =4    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P4 =4      |     Unreserved TS at p4 =4    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P5 =4      |     Unreserved TS at p5 =4    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P6 =4      |     Unreserved TS at p6 =4    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P7 =4      |     Unreserved TS at p7 =4    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 6: Example - OTN-ISCD OTU3 LC (t1)

The last example shows how the prehemption is managed. In particular, if a time t2 a new 15 GBps LSP with priority 1 is created, the LSP with priority 3 is prehempted and its resouces (or part of them) are allocated to the LSP with higher priority. The OTN-ISCD sub-TLV related to component link 2 is updated accordingly to Figure 7:

```
    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              |             Length            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Res|T=0|OTk =3 |  Reserved     |   Signal Flags  |1|0|0|1|1|1|0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P0 =32     |     Unreserved TS at p0 =32   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P1 =20     |     Unreserved TS at p1 =20   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P2 =20     |     Unreserved TS at p2 =20   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P3 =20     |     Unreserved TS at p3 =20   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P4 =20     |     Unreserved TS at p4 =20   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P5 =20     |     Unreserved TS at p5 =20   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P6 =20     |     Unreserved TS at p6 =20   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Max lsp TS at P7 =20     |     Unreserved TS at p7 =20   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 7: Example - OTN-ISCD OTU3 LC (t2)

8. 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.

9. IANA Considerations

TBD

10. Contributors

Xiaobing Zi

Huawei Technologies

F3-5-B R&D Center, Huawei Base

Bantian, Longgang District

Shenzhen 518129 P.R.China

Email: zixiaobing@huawei.com

Francesco Fondelli

Ericsson

Via Negrone 1/A

Genova - 16145

Email: francesco.fondelli@ericsson.com

Marco Corsi

Altran Italia

Via Negrone 1/A

Genova - 16145

EMail: marco.corsi@altran.it

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12. References

12.1. Normative References

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Authors' Addresses

Daniele Ceccarelli
Ericsson
Via A. Negrone 1/A
Genova - Sestri Ponente
Italy

Email: daniele.ceccarelli@ericsson.com

Diego Caviglia
Ericsson
Via A. Negrone 1/A
Genova - Sestri Ponente
Italy

Email: diego.caviglia@ericsson.com

Fatai Zhang
Huawei Technologies
F3-5-B R&D Center, Huawei Base
Shenzhen 518129 P.R.China Bantian, Longgang District
Phone: +86-755-28972912

Email: zhangfatai@huawei.com

Dan Li
Huawei Technologies
F3-5-B R&D Center, Huawei Base
Shenzhen 518129 P.R.China Bantian, Longgang District
Phone: +86-755-28973237

Email: danli@huawei.com

Yunbin Xu
CATR
11 Yue Tan Nan Jie
Beijing
P.R.China

Email: xuyunbin@mail.ritt.com.cn