GMPLS Signalling Extensions for G.709 Optical Transport Networks Control
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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 RFC-2119 [2].

Abstract
This document is a companion to the Generalized MPLS (GMPLS) signalling documents [GMPLS-SIG], [GMPLS-RSVP] and [GMPLS-LDP]. It describes the G.709 technology specific information needed to extend GMPLS signalling to control Optical Transport Networks (OTN) including the so-called pre-OTN developments both described in [G709-FRM].

1. Introduction

Generalized MPLS extends MPLS from supporting Packet Switching Capable (PSC) interfaces and switching to include support of three new classes of interfaces and switching: Time-Division Multiplex (TDM), Lambda Switch (LSC) and Fiber-Switch (FSC). A functional description of the extensions to MPLS signaling needed to support this new classes of interfaces and switching is provided in [GMPLS-SIG]. [GMPLS-RSVP] describes RSVP-TE specific formats and mechanisms needed to support all four classes of interfaces, and CR-LDP extensions can be found in [GMPLS-LDP].

This document presents the technology details that are specific to G.709 Optical Transport Networks (OTN) as specified in the ITU-T G.709 recommendation [ITUT-G709] including pre-OTN developments. Per [GMPLS-SIG], G.709 specific parameters are carried through the signaling protocol in traffic parameter specific objects.

Note: by pre-OTN developments, one refers to the following cases which applies when the client signal is Gigabit Ethernet, ESCON, FICON or Fiber Channel (FC):
- pre-OTN digital wrapper frame terminated; service signal is bit stream oriented and transparently passed throughout the network
- pre-OTN case FEC frame terminated; service signal is bit stream oriented and transparently passed through

The other kinds of ‘optical SDH/Sonet’ semi-transparent switching are respectively covered in [GMPLS-SSS-EXT] and [GMPLS-SSS]:
- SONET/SDH interfaces terminating RS/Section and MS/Line overhead: the network is capable to transport transparently HOVC/STS-SPE signals and STM-N/STS-N signals limited to a single contiguously concatenated VC-4-Nc/STS-Nc SPE
- SONET/SDH pre-OTN interfaces terminating RS/Section overhead with MS/Line overhead transparency: the pre-OTN network is capable to transport transparently MSn STM-N/STS-N signals
- SONET/SDH pre-OTN interfaces with RS/Section and MS/Line overhead transparency: the pre-OTN network is capable to transport transparently RSn STM-N/STS-N signals

2. GMPLS Extensions for G.709

Although G.709 defines several networking layers (OTS, OMS, OPS, OCh, OChr constituting the optical transport hierarchy and OTUk, ODUk constituting the digital transport hierarchy) only the OCh (Optical Channel) and the ODUk (Optical Channel Data Unit) layer are defined as switching layers. Both OCh (but not OChr) and ODUk layers include the overhead for supervision and management. The OCh
overhead is transported in a non-associated manner (so also referred to as non-associated overhead â‘¨ naOH) in the OTM Overhead Signal (OOS), together with the OTS and OMS non-associated overhead. The OOS is transported via a dedicated wavelength referred to as the Optical Supervisory Channel (OSC). It should be noticed that the naOH is only functionally specified and as such open to vendor specific solutions. The ODUk overhead is transported in an associated manner as part of the digital ODUk frame.

Therefore, adapting GMPLS to control G.709 OTN, can be achieved by considering:
- a Digital Path layer by extending the previously defined â‘¨Digital Wrapperâ‘¨ in [GMPLS-SIG] corresponding to the ODUk switching layer.
- an Optical Path layer by extending the â‘¨Lambdaâ‘¨ concept defined in [GMPLS-SIG] to the OCh switching layer.

GMPLS extensions for G.709 need to cover the Generalized Label Request, the Generalized Label as well as the specific technology dependent fields equivalent to the one currently specified for SDH/SONET in [GMPLS-SSS]. Since the multiplexing in the digital domain (such as ODUk multiplexing) has been considered in the updated version of the G.709 recommendation (October 2001), we can already propose a label space definition suitable for that purpose. Notice also that we directly use the G.709 ODUk (i.e. Digital Path) and OCh layers in order to define the corresponding label spaces.

3. Generalized Label Request

The Generalized Label Request as defined in [GMPLS-SIG], includes a technology independent part and a technology dependent part (i.e. the traffic parameters). In this section, we suggest to adapt both parts in order to accommodate the GMPLS Signalling to the G.709 recommendation [ITUT-G709].

3.1 Technology Independent Part

As defined in [GMPLS-SIG], the LSP Encoding Type and the Generalized Protocol Identifier (Generalized-PID) constitute the technology independent part of the Generalized Label Request.

The information carried in the technology independent part of the Generalized Label Request is defined as follows:

```
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| LSP Enc. Type |Switching Type |             G-PID             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

As mentioned here above, we suggest here to adapt the LSP Encoding Type and the G-PID (Generalized-PID) to accommodate G.709 recommendation [ITUT-G709].
3.1.1 LSP Encoding Type

Since G.709 defines two networking layers (ODUk layers and OCh layer), the LSP Encoding Type code-points can reflect these two layers currently defined in [GMPLS-SIG] as “Digital Wrapper” and “Lambda” code.

The LSP Encoding Type is specified per networking layer or more precisely per group of functional networking layer: the ODUk layers and the OCh layer.

Therefore, the current “Digital Wrapper” code-point defined in [GMPLS-SIG] can be replaced by two separated code-points:
- code-point for the G.709 Digital Path layer
- code-point for the non-standard Digital Wrapper layer

In the same way, two separated code-points can replace the current defined “Lambda” code-point:
- code-point for the G.709 Optical Channel layer
- code-point for the non-standard Lambda layer (also referred to as Lambda layer which includes the pre-OTN Optical Channel layer)

Consequently, we have the following additional code-points for the LSP Encoding Type:

<table>
<thead>
<tr>
<th>Value</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>G.709 ODUk (Digital Path)</td>
</tr>
<tr>
<td>12</td>
<td>G.709 Optical Channel</td>
</tr>
</tbody>
</table>

Moreover, the code-point for the G.709 Optical Channel (OCh) layer will indicate the capability of an end-system to use the G.709 non-associated overhead (naOH) i.e. the OTM Overhead Signal (OOS) multiplexed into the OTM-n.m interface signal.

3.1.2 Switching Type

The Switching Type indicates the type of switching that should be performed at the termination of a particular link. This field is only needed for links that advertise more than one type of switching capability.

No additional values are to be considered in order to accommodate G.709 switching types since an ODUk switching belongs to the TDM class while an OCh switching to the Lambda class.

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However, in a strict layered G.709 network architecture, when a downstream node receives a Generalized Label Request with one of these values as Switching Type, this value is ignored.

3.1.3 Generalized-PID (G-PID)
The G-PID (16 bits field) as defined in [GMPLS-SIG], identifies the payload carried by an LSP, i.e. an identifier of the client layer of that LSP. This identifier is used by the endpoints of the G.709 LSP.

The G-PID can take one of the following values when the client payload is transported over the Digital Path layer, in addition to the payload identifiers already defined in [GMPLS-SIG]:
- CBRa: asynchronous Constant Bit Rate i.e. mapping of STM-16/OC-48, STM-64/OC-192 and STM-256/OC-768
- CBRb: bit synchronous Constant Bit Rate i.e. mapping of STM-16/OC-48, STM-64/OC-192 and STM-256/OC-768
- ATM: mapping at 2.5, 10 and 40 Gbps
- BSOT: non-specific client Bit Stream with Octet Timing i.e. Mapping of 2.5, 10 and 40 Gbps Bit Stream
- BSNT: non-specific client Bit Stream without Octet Timing i.e. Mapping of 2.5, 10 and 40 Gbps Bit Stream

The G-PID can take one of the following values when the client payload is transported over the Optical Channel layer, in addition to the payload identifiers already defined in [GMPLS-SIG]:
- CBR: Constant Bit Rate i.e. mapping of STM-16/OC-48, STM-64/OC-192 and STM-256/OC-768
- ODUk: transport of Digital Path at 2.5, 10 and 40 Gbps

When the client payloads such as Ethernet, ATM or PPP over SONET/SDH (RFC 2615), are encapsulated through the Generic Framing Procedure (GFP), we use dedicated G-PID values. Notice that additional G-PID values not defined in [GMPLS-SIG] such as ESCON, FICON and Fiber Channel could complete this list in the near future.

In order to include pre-OTN developments, the G-PID can take one of the values currently defined in [GMPLS-SIG], when the client payload is transported over an Optical Channel (i.e. a lambda):
- SDH: STM-16, STM-64 and STM-256
- Sonet: OC-48, OC-192 and OC-768
- Gigabit Ethernet: 1 Gbps and 10 Gbps

The following table summarizes the G-PID with respect to the LSP Encoding Type:

<table>
<thead>
<tr>
<th>Value</th>
<th>G-PID Type</th>
<th>LSP Encoding Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>44</td>
<td>G.709 ODUk</td>
<td>G.709 ODUk, G.709 OCh</td>
</tr>
<tr>
<td>45</td>
<td>CBR/CBRa</td>
<td>G.709 ODUk, G.709 OCh</td>
</tr>
<tr>
<td>46</td>
<td>CBRb</td>
<td>G.709 ODUk</td>
</tr>
<tr>
<td>47</td>
<td>BSOT</td>
<td>G.709 ODUk</td>
</tr>
<tr>
<td>48</td>
<td>BSNT</td>
<td>G.709 ODUk</td>
</tr>
<tr>
<td>49</td>
<td>PoS (GFP)</td>
<td>G.709 ODUk</td>
</tr>
<tr>
<td>50</td>
<td>Ethernet (GFP)</td>
<td>G.709 ODUk</td>
</tr>
</tbody>
</table>

The following table summarizes the update of the G-PID values defined in [GMPLS-SIG]:

<table>
<thead>
<tr>
<th>Value</th>
<th>G-PID Type</th>
<th>LSP Encoding Type</th>
</tr>
</thead>
</table>
3.2 G.709 Traffic-Parameters

When G.709 Digital Path Layer or G.709 Optical Channel Layer is specified in the LSP Encoding Type field, the information referred to as technology dependent information or simply traffic-parameters and carried additionally to the one included in the Generalized Label Request is defined as follows:

<table>
<thead>
<tr>
<th>Signal Type</th>
<th>RMT</th>
<th>NMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>NVC</td>
<td>Multiplier</td>
<td></td>
</tr>
<tr>
<td>Reserved</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In this frame, RMT stands for Requested Multiplexing Type, NMC for Number of Multiplexed Components and NVC for Number of Virtually multiplexed Components. Each of these fields is tailored in order to support G.709 LSP.

3.2.1 Signal Type

This field (8 bits) indicates the requested G.709 elementary Signal Type. The possible values are:

<table>
<thead>
<tr>
<th>Value</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>irrelevant</td>
</tr>
<tr>
<td>1</td>
<td>ODU1 (i.e. 2.5 Gbps)</td>
</tr>
<tr>
<td>2</td>
<td>ODU2 (i.e. 10 Gbps)</td>
</tr>
<tr>
<td>3</td>
<td>ODU3 (i.e. 40 Gbps)</td>
</tr>
<tr>
<td>4</td>
<td>Reserved for future use</td>
</tr>
<tr>
<td>5</td>
<td>Reserved for future use</td>
</tr>
<tr>
<td>6</td>
<td>OCh associated to an OTM-n.1</td>
</tr>
<tr>
<td>7</td>
<td>OCh associated to an OTM-n.2</td>
</tr>
<tr>
<td>8</td>
<td>OCh associated to an OTM-n.3</td>
</tr>
<tr>
<td>9-255</td>
<td>Reserved for future use</td>
</tr>
</tbody>
</table>

The value of the Signal Type field depends on LSP Encoding Type value defined in Section 3.1.1 and [GMPLS-SIG]:
- if the LSP Encoding Type value is the G.709 Digital Path layer then the valid values are the ODUk signals (k = 1, 2 or 3)
- if the LSP Encoding Type value is the G.709 Optical Channel layer then the valid values are the OCh associated to the OTM-n.m interface signals (m = 1, 2 or 3)
- if the LSP Encoding Type is `Lambda` (which includes the pre-OTN Optical Channel layer) then the valid value is irrelevant.
- if the LSP Encoding Type is `Digital Wrapper`, then the valid value is irrelevant (Signal Type = 0)

### 3.2.2 Requested Multiplexing Type (RMT)

The RMT field (8 bits) defined as a vector of flags indicating the type of multiplexing being requested for ODUk LSP. Each flag indicates the support of a particular type of ODU multiplexing.

These flags allow an upstream node to indicate to a downstream node the different types of multiplexing that it supports. However, the downstream node decides which one to use according to its own rules. Several flags could be set simultaneously to indicate a particular choice.

The entire field is set to zero to indicate that no multiplexing is requested at all. The possible values for these flags are defined in the following table:

**Flag 1 (bit 1): Flexible multiplexing**

When used at the ODUk layer (i.e. digital path layer), application of flexible multiplexing to ODUk elementary signal results in so called ODUk-Xc signal. In particular, ODUk multiplexing allows the multiplexing of an ODU2 into four ODU tributary slots, which can be arbitrarily selected to prevent that the bandwidth gets fragmented.

As described in [G709-FRM], in addition to the support of ODUk mapping into OTUk, [ITU-T G.709] supports ODUk flexible multiplexing (or simply multiplexing). It refers to the multiplexing of ODUj into an ODUk multiplexing (k > j) signal, in particular:

- ODU1 into ODU2 multiplexing
- ODU1 into ODU3 multiplexing
- ODU2 into ODU3 multiplexing
- ODU1 and ODU2 into ODU3 multiplexing

More precisely, ODUj into ODUk multiplexing (k > j) is defined when an ODUj is multiplexed into an ODUk Tributary Unit Group (i.e. an ODTUG constituted by ODU tributary slots) which is mapped into an OPUk. The resulting OPUk is mapped into an ODUk and the ODUk is mapped into an OTUk.

The RMT field is set to zero (by default) to indicate an ODUk mapping i.e. ODUk flexible multiplexing is not requested.

At the Optical Channel layer, flexible multiplexing is not defined in [ITU-T G.709]. Therefore, the entire RMT field is set by default to zero when requesting an OCh G.709 LSP.

### 3.2.3 Number of Multiplexed Components (NMC)

The NMC field (16 bits) indicates the number of ODU tributary slots used by an ODUj when multiplexed into an ODUk (k > j) for the requested LSP, as specified in the RMT field. This field is
irrelevant if no multiplexing is requested (in particular at the Optical Channel layer). In that case, it must be set to zero (NMC = 0) when sent and should be ignored when received. An RMT value different from 0 must imply a number of components greater or equal to 1.

When applied at the Digital Path layer and requesting flexible multiplexing (RMT = 1), in particular for ODU2 connections multiplexed into an ODU3 payload, the NMC field specifies the number of individual tributary slots (NMC = 4) constituting the requested connection. These components are still processed within the context of a single connection entity. For all other currently defined multiplexing cases, the NMC field is set to 1.

3.2.4 Number of Virtually concatenated Components (NVC)

The NVC field (16 bits) is dedicated to Inverse Multiplexing (i.e. ODUk virtual concatenation) purposes. It indicates the number of ODU1, ODU2 or ODU3 elementary signals that are requested to be virtually concatenated to form an ODUk-Xv signal. These signals must be of the same type by definition.

This field is set to 0 (default value) to indicate that no virtual concatenation is requested.

Note: the current usage of this field only applies for G.709 ODUk LSP. Therefore, it must be set to zero when requesting G.709 OCh LSP.

3.2.5 Multiplier

The multiplier field (16 bits) indicates the number of identical composed signals requested for the LSP. A composed signal is the resulting signal from the application of the RMT, NMC and NVC fields to an elementary Signal Type. GMPLS signalling implies today that all the composed signals must be part of the same LSP.

The multiplier field is set to one (default value) to indicate that exactly one base signal is being requested. Zero is an invalid value. When the multiplier field is greater than one, the resulting signal is referred to as a multiplied signal.

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3.2.6 Reserved

The reserved field (32 bits) is dedicated for future use. Reserved bits should be set to zero when sent and must be ignored when received.

4. Generalized Label

This section describes the Generalized Label space for the Digital Path and the Optical Channel Layer. The label distribution rules follows the ones defined in [GMPLS-SSS] and are detailed in Section 4.2.
4.1 ODUk Label Space

At the Digital Path layer (i.e. ODUk layers), G.709 defines three different client payload bit rates. An Optical Data Unit (ODU) frame has been defined for each of these bit rates. ODUk refers to the frame at bit rate k, where k = 1 (for 2.5 Gbps), 2 (for 10 Gbps) or 3 (for 40 Gbps).

In addition to the support of ODUk mapping into OTUk, the G.709 label space supports the sub-levels of ODUk flexible multiplexing (or simply ODUk multiplexing). ODUk multiplexing refers to multiplexing of ODUj (j = 1, 2) into an ODUk (k > j), in particular:
- ODU1 into ODU2 multiplexing
- ODU1 into ODU3 multiplexing
- ODU2 into ODU3 multiplexing
- ODU1 and ODU2 into ODU3 multiplexing

More precisely, ODUj into ODUk multiplexing (k > j) is defined when an ODUj is multiplexed into an ODUk Tributary Unit Group (i.e. an ODTUG constituted by ODU tributary slots) which is mapped into an OPUk. The resulting OPUk is mapped into an ODUk and the ODUk is mapped into an OTUk.

Therefore, the label space structure is a tree whose root is an OTUk signal and leaves the ODUj signals (k >= j) that can be transported via the tributary slots and switched between these slots. A G.709 Digital Path layer label identifies the exact position of a particular ODUj signal in an ODUk multiplexing structure.

The G.709 Digital Path Layer label or ODUk label has the following format:

```
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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Reserved                |     k3    | k2  |k1|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The specification of the three fields k1, k2 and k3 self-consistently characterizes the ODUk label space. The value space of the k1, k2 and k3 fields is defined as follows:

1. k1 (1-bit) indicates:
   - an unstructured client signal mapped into an ODU1 (k1 = 1) via OPU1

2. k2 (3-bit) indicates:
   - an unstructured client signal mapped into an ODU2 (k2 = 1) via OPU2
   - or the position of an ODU1 tributary slot in an ODTUG2 (k2 = 2,..,5) mapped into an ODU2 (via OPU2)

3. k3 (6-bit) indicates:
- an unstructured client signal mapped into an ODU3 \((k_3 = 1)\) via OPU3
- or the position of an ODU1 tributary slot in an ODTUG3 \((k_3 = 2, \ldots, 17)\) mapped into an ODU3 (via OPU3)
- or the position of an ODU2 tributary slot in an ODTUG3 \((k_3 = 18, \ldots, 33)\) mapped into an ODU3 (via OPU3)

If label \(k[i]=1\) \((i = 1, 2\) or 3\) and labels \(k[j]=0\) \((j = 1, 2\) and 3 with \(j\neq i)\), the corresponding ODUk signal ODU[i] is not structured and therefore simply mapped into the corresponding OTU[i]. We refer to this as the mapping of an ODUk into an OTUk. Therefore, the numbering starts at 1, zero is used to indicate a non-significant field. A label field equal to zero is an invalid value.

Examples:
- \(k_3=0, k_2=0, k_1=1\) indicated an ODU1 mapped into an OTU1
- \(k_3=0, k_2=1, k_1=0\) indicated an ODU2 mapped into an OTU2
- \(k_3=1, k_2=0, k_1=0\) indicates an ODU3 mapped into an OTU3
- \(k_3=0, k_2=3, k_1=0\) indicates the second ODU1 into an ODTUG2 mapped into an ODU2 (via OPU2) mapped into an OTU2
- \(k_3=5, k_2=0, k_1=0\) indicates the fourth ODU1 into an ODTUG3 mapped into an ODU3 (via OPU3) mapped into an OTU3

4.2 Label Distribution Rules

In case of ODUk in OTUk mapping, only one of label can appear in the Label field of a Generalized Label.

In case of ODUj in ODUk \((k > j)\) multiplexing, the explicit ordered list of the labels in the multiplex is given (this list can be restricted to only one label when NMC = 1). Each label indicates a component (ODUj tributary slot) of the multiplexed signal. The order of the labels must reflect the order of the ODUj into the multiplex (not the physical order of tributary slots).

In case of ODUk virtual concatenation, the explicit ordered list of all labels in the concatenation is given. Each label indicates a component of the virtually concatenated signal. The order of the labels must reflect the order of the ODUk to concatenate (not the physical order of time-slots). This representation limits virtual concatenation to remain within a single (component) link.

In case of multiplication (i.e. when using the MT field), the explicit ordered list of all labels taking part in the composed signal is given. In case of multiplication of multiplexed/virtually concatenated signals, the first set of labels indicates the first multiplexed/virtually concatenated signal, the second set of labels indicates the second multiplexed/virtually concatenated signal, and so on. The above representation limits multiplication to remain within a single (component) link.

4.3 Optical Channel Label Space

At the Optical Channel layer, the label space must be consistently defined as a flat space whose values reflect the local assignment of
OCh identifiers corresponding to the OTM-n.m sub-interface signals (m = 1, 2 or 3). Notice that these identifiers do not cover OChr since the corresponding Connection Function (OChr-CF) between OTM-nr.m/OTM-0r.m is not yet defined in [ITUT-G798].

The OCh identifiers could be defined as specified in [GMPLS-SIG] either with absolute values: channel identifiers (Channel ID) also referred to as wavelength identifiers or relative values: channel spacing also referred to as inter-wavelength spacing. The latter is strictly confined to a per-port label space while the former could be defined as a local or a global label space. Such an OCh label space is applicable to both OTN Optical Channel layer and pre-OTN Optical Channel layer. For this layer, label distribution rules are defined in [GMPLS-SIG].

5. Applications

These applications examples are given in order to illustrate the processing described in the previous sections.

1. ODUk in OTUk mapping: when one ODU1 (ODU2 or ODU3) non-structured signal is transported into the payload of an OTU1 (OTU2 or OTU3), the upstream node requests results in a non-structured ODU1 (ODU2 or ODU3) signal request.

In such conditions, the downstream node has to return a unique label since the ODU1 (ODU2 or ODU3) is directly mapped into the corresponding OTU1 (OTU2 or OTU3). Since a single ODUk mapped signal is requested (Signal Type = 1, 2 or 3 and RMT = 0), the downstream node has to return a single ODUk label which can be for instance one of the following when the Signal Type = 1:
- k3=0, k2=0, k1=1 indicating a single ODU1 mapped into an OTU1
- k3=0, k2=1, k1=0 indicating a single ODU2 mapped into an OTU2
- k3=1, k2=0, k1=0 indicating a single ODU3 mapped into an OTU3

2. ODU1 into ODUk multiplexing (k > 1): when one ODU1 is multiplexed into the payload of a structured ODU2 (or ODU3), the upstream node requests results in a multiplexed ODU1 signal request (RMT = 1).

In such conditions, the downstream node has to return a unique label since the ODU1 is multiplexed into one ODTUG2 (or ODTUG3). The latter is then mapped into the ODU2 (or ODU3) via OPU2 (or OPU3) and then mapped into the corresponding OTU2 (or OTU3). Since a single ODU1 multiplexed signal is requested (Signal Type = 1, RMT = 1 and NMC = 1), the downstream node has to return a single ODU1 label which can take for instance one of the following values:
- k3=0, k2=4, k1=0 indicates the third ODU1 TS into ODTUG2
- k3=2, k2=0, k1=0 indicates the first ODU1 TS into ODTUG3
- k3=7, k2=0, k1=0 indicates the sixth ODU1 TS into ODTUG3

3. ODU2 into ODU3 multiplexing: when one unstructured ODU2 is multiplexed into the payload of a structured ODU3, the upstream node requests results in a multiplexed ODU2 signal request (RMT =
In such conditions, the downstream node has to return four labels since the ODU2 is multiplexed into one ODTUG3. The latter is mapped into an ODU3 (via OPU3) and then mapped into an OTU3.

Since a single ODU2 multiplexed signal is requested (Signal Type = 2, RMT = 1 and NMC = 4), the downstream node has to return four ODU1 label which can take for instance the following values:
- \( k_3=18, k_2=0, k_1=0 \) (first ODU1 TS into ODTUG3)
- \( k_3=22, k_2=0, k_1=0 \) (fifth ODU1 TS into ODTUG3)
- \( k_3=23, k_2=0, k_1=0 \) (sixth ODU1 TS into ODTUG3)
- \( k_3=26, k_2=0, k_1=0 \) (ninth ODU1 TS into ODTUG3)

4. When a single OCh signal of 40 Gbps is requested (Signal Type = 8 and RMT = 0), the downstream node must return a single wavelength label as specified in [GMPLS-SIG].

5. When requesting multiple ODUk LSP (i.e. multiplier MT > 1), an explicit list of labels is returned to the requestor node. When the downstream node receives a request for a 4 x ODU1 signal (Signal Type = 1, RMT = 1, NMC = 1 and MT = 4), it returns an ordered list of four labels to the upstream node: the first ODU1 label corresponding to the first signal of the LSP, the second ODU1 label corresponding to the second signal of the LSP, etc. For instance, the corresponding labels can take the following values:
- First ODU1: \( k_3=2, k_2=0, k_1=0 \) (first ODU1 TS into ODTUG3)
- Second ODU1: \( k_3=6, k_2=0, k_1=0 \) (fifth ODU1 TS into ODTUG3)
- Third ODU1: \( k_3=7, k_2=0, k_1=0 \) (sixth ODU1 TS into ODTUG3)
- Fourth ODU1: \( k_3=10, k_2=0, k_1=0 \) (ninth ODU1 TS into ODTUG3)

6. Signalling Protocol Extensions

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This section specifies the [GMPLS-RSVP] and [GMPLS-LDP] protocol extensions needed to accommodate G.709 traffic parameters.

6.1 RSVP-TE Details

For RSVP-TE, the G.709 traffic parameters are carried in the G.709 SENDER_TSPEC and FLOWSPEC objects. The same format is used both for SENDER_TSPEC object and FLOWSPEC objects. The content of the objects is defined above in Section 3.2. The objects have the following class and type for G.709:
- G.709 SENDER_TSPEC Object: Class = 12, C-Type = 4 (TBA)
- G.709 FLOWSPEC Object: Class = 9, C-Type = 4 (TBA)

There is no Adspec associated with the SONET/SDH 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 SHOULD be generated.

6.2 CR-LDP Details

For CR-LDP, the G.709 traffic parameters are carried in the G.709 Traffic Parameters TLV. The content of the TLV is defined in Section 3.2. The header of the TLV has the following format:

```
|U|F|          Type             |            Length             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The type field indicates G.709 OTN: 0xTBA

7. Security Considerations

This document introduces no new security considerations to either [GMPLS-RSVP] or [GMPLS-LDP].

8. References


9. Acknowledgments

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10. Author’s Addresses

Alberto Bellato
Alcatel
Via Trento 30,
I-20059 Vimercate, Italy
Phone: +39 039 686-7215
Email: alberto.bellato@netit.alcatel.it

Michele Fontana
Alcatel
Via Trento 30,
I-20059 Vimercate, Italy
Phone: +39 039 686-7053
Email: michele.fontana@netit.alcatel.it

Germano Gasparini
Alcatel
Via Trento 30,
I-20059 Vimercate, Italy
Phone: +39 039 686-7670
Email: germano.gasparini@netit.alcatel.it

Nasir Ghani
Sorrento Networks
D. Papadimitriou et al. - Internet Draft Â» Expires May 2002

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Appendix 1 Â» Abbreviations

1R  Re-amplification
2R  Re-amplification and Re-shaping
3R  Re-amplification, Re-shaping and Re-timing
AI  Adapted information
AIS  Alarm Indication Signal
APS  Automatic Protection Switching
BDI  Backward Defect Indication
BEI  Backward Error Indication
BI  Backward Indication
BIP  Bit Interleaved Parity
CBR  Constant Bit Rate
CI  Characteristic information
CM  Connection Monitoring
EDC  Error Detection Code
EXP  Experimental
ExTI  Expected Trace Identifier
FAS  Frame Alignment Signal
FDI  Forward Defect Indication
FEC  Forward Error Correction
GCC  General Communication Channel
IaDI  Intra-Domain Interface
IAE  Incoming Alignment Error
IrDI  Inter-Domain Interface
MFAS  MultiFrame Alignment Signal
MS  Maintenance Signal
naOH  non-associated Overhead
NNI  Network-to-Network interface
Appendix 2 û G.709 Indexes

- Index k: The index "k" is used to represent a supported bit rate and the different versions of OPUk, ODUk and OTUk. k=1 represents an approximate bit rate of 2.5 Gbit/s, k=2 represents an approximate bit rate of 10 Gbit/s, k = 3 an approximate bit rate of 40 Gbit/s and k = 4 an approximate bit rate of 160 Gbit/s (under definition). The exact bit-rate values are in kbits/s:
  . OPU: k=1: 2 488 320.000, k=2: 9 995 276.962, k=3: 40 150 519.322
  . ODU: k=1: 2 498 775.126, k=2: 10 037 273.924, k=3: 40 319 218.983
  . OTU: k=1: 2 666 057.143, k=2: 10 709 225.316, k=3: 43 018 413.559

- Index m: The index "m" is used to represent the bit rate or set of bit rates supported on the interface. This is a one or more digit Ä’kÄ¶, where each Ä’kÄ¶ represents a particular bit rate. The valid values for m are (1, 2, 3, 12, 23, 123).

- Index n: The index "n" is used to represent the order of the OTM, OTS, OMS, OPS, OCG and OMU. This index represents the maximum number of wavelengths that can be supported at the lowest bit rate supported on the wavelength. It is possible that a reduced number of higher bit rate wavelengths are supported. The case n=0 represents a
single channel without a specific wavelength assigned to the channel.

- Index r: The index "r", if present, is used to indicate a reduced functionality OTM, OCG, OCC and OCh (non-associated overhead is not supported). Note that for n=0 the index r is not required as it implies always reduced functionality.