

Network Working Group
Internet Draft
Category: Informational

Fatai Zhang
Dan Li
Huawei
Han Li
CMCC
S.Belotti
Alcatel-Lucent
February 27, 2010

Expires: August 26, 2010

**Framework for GMPLS and PCE Control of
G.709 Optical Transport Networks**

[draft-zhang-ccamp-gmpls-g709-framework-02.txt](#)

Status of this Memo

This Internet-Draft is submitted to IETF in full conformance with the provisions of [BCP 78](#) and [BCP 79](#).

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF), its areas, and its working groups. Note that other groups may also distribute working documents as Internet-Drafts.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

The list of current Internet-Drafts can be accessed at <http://www.ietf.org/ietf/1id-abstracts.txt>.

The list of Internet-Draft Shadow Directories can be accessed at <http://www.ietf.org/shadow.html>.

This Internet-Draft will expire on June 16, 2010.

Abstract

This document provides a framework to allow the development of protocol extensions to support Generalized Multi-Protocol Label Switching (GMPLS) and Path Computation Element (PCE) control of Optical Transport Networks (OTN) as specified in ITU-T Recommendation G.709 as consented in October 2009.

Table of Contents

1. Introduction	2
2. Terminology	3
3. G.709 Optical Transport Network (OTN)	4
3.1. OTN Layer Network	4
4. Connection management in OTN	10
4.1. Connection management of the ODU	10
5. GMPLS/PCE Implications	13
5.1. Implications for LSP Hierarchy with GMPLS TE	13
5.2. Implications for GMPLS Signaling	13
5.2.1. Identifying OTN signals	13
5.2.2. Tributary Port Number	14
5.3. Implications for GMPLS Routing	15
5.3.1. Requirement for conveying Interface Switching Capability specific information	15
5.4. Implications for Link Management Protocol (LMP)	16
5.4.1. Correlating the Granularity of the TS	16
5.4.2. Correlating the Supported LO ODU Signal Types	16
5.5. Implications for Path Computation Elements	17
6. Security Considerations	17
7. IANA Considerations	17
8. Acknowledgments	17
9. References	18
9.1. Normative References	18
9.2. Informative References	19
10. Authors' Addresses	19
11. Contributors	20
APPENDIX A: Description of LO ODU terminology and ODU connection examples	21

1. Introduction

OTN has become a mainstream layer 1 technology for the transport network. Operators want to introduce control plane capabilities based on Generalized Multi-Protocol Label Switching (GMPLS) to OTN networks, to realize the benefits associated with a high-function control plane (e.g., improved network resiliency, resource usage efficiency, etc.).

GMPLS extends MPLS to encompass time division multiplexing (TDM) networks (e.g., SONET/SDH, PDH, and G.709 sub-lambda), lambda switching optical networks, and spatial switching (e.g., incoming port or fiber to outgoing port or fiber). The GMPLS architecture is provided in [[RFC3945](#)], signaling function and Resource ReserVation Protocol-Traffic Engineering (RSVP-TE) extensions are described in

[RFC3471] and [[RFC3473](#)], routing and OSPF extensions are described in [[RFC4202](#)] and [[RFC4203](#)], and the Link Management Protocol (LMP) is described in [[RFC4204](#)].

The GMPLS protocol suite including provision [[RFC4328](#)] provides the mechanisms for basic GMPLS control of OTN networks based on the 2003 revision of the G.709 specification [[G709-V1](#)]. Later revisions of the G.709 specification [[G709-V3](#)] have included some new features; for example, various multiplexing structures, two types of Tributary Slots (i.e., 1.25Gbps and 2.5Gbps), and extension of the Optical Data Unit (ODU) ODUj definition to include the ODUflex function.

This document reviews relevant aspects of OTN technology evolution that affect the GMPLS control plane protocols and examines why and how to update the mechanisms described in [[RFC4328](#)]. This document additionally provides a framework for the GMPLS control of OTN networks and includes a discussion of the implication for the use of the Path Computation Element (PCE) [[RFC4655](#)].

For the purposes of the control plane the OTN can be considered as being comprised of sub-wavelength (ODU) and wavelength (OCh) layers. This document focuses on the control of the sub-wavelength layer, with control of the wavelength layer considered out of the scope. Please refer to [WSON-Frame] for further information about the wavelength layer.

[Note: It is intended to align this draft with G.709 (consented in 10/2009), G.872 and G.8080 (planned for consent in 6/2010)]

2. Terminology

OTN: Optical Transport Network

ODU: Optical Channel Data Unit

OTU: Optical channel transport unit

OMS: Optical multiplex section

MSI: Multiplex Structure Identifier

TPN: Tributary Port Number

LO ODU: Lower Order ODU. The LO ODUj (j can be 0, 1, 2, 2e, 3, 4, Flex.) represents the container transporting a client of the OTN that is either directly mapped into an OTUk (k = j) or multiplexed into a server HO ODUk (k > j) container.

HO ODU: Higher Order ODU. The HO ODU_k (k can be 1, 2, 2e, 3, 4.) represents the entity transporting a multiplex of LO ODU_j tributary signals in its OPU_k area.

ODUflex: Flexible ODU. A flexible ODU_k can have any bit rate and a bit rate tolerance up to 100 ppm.

3. G.709 Optical Transport Network (OTN)

This section provides an informative overview of those aspects of the OTN impacting control plane protocols. This overview is based on the ITU-T Recommendations that contain the normative definition of the OTN. Technical details regarding OTN architecture and interfaces are provided in the relevant ITU-T Recommendations.

Specifically, [ITU-T-G.872] describes the functional architecture of optical transport networks providing optical signal transmission, multiplexing, routing, supervision, performance assessment, and network survivability. [G709-V1] defines the interfaces of the optical transport network to be used within and between subnetworks of the optical network. With the evolution and deployment of OTN technology many new features have been specified in ITU-T recommendations, including for example, new ODU₀, ODU_{2e}, ODU₄ and ODUflex containers as described in [G709-V3].

3.1. OTN Layer Network

The simplified signal hierarchy of OTN is shown in Figure 1, which illustrates the layers that are of interest to the control plane. Other layers below OCh (e.g. Optical Transmission Section - OTS) are not included in this Figure. The full signal hierarchy is provided in [G709-V3].

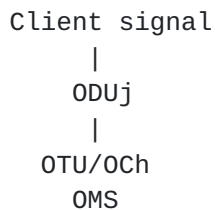


Figure 1 Basic OTN signal hierarchy

Client signals are mapped into ODU_j containers. These ODU_j containers are multiplexed onto the OTU/OCh. The individual OTU/OCh signals are combined in the Optical Multiplex Section (OMS) using WDM multiplexing, and this aggregated signal provides the link between the nodes.

3.1.1 Client signal mapping

The client signals are mapped into a Low Order (LO) ODU_j. [Appendix A](#) gives more information about LO ODU.

The current values of *j* defined in [\[G709-V3\]](#) are: 0, 1, 2, 2e, 3, 4, Flex. The approximate bit rates of these signals are defined in [\[G709-V3\]](#) and are reproduced in Tables 1 and 2.

ODU Type	ODU nominal bit rate
ODU0	1 244 160 kbits/s
ODU1	239/238 x 2 488 320 kbit/s
ODU2	239/237 x 9 953 280 kbit/s
ODU3	239/236 x 39 813 120 kbit/s
ODU4	239/227 x 99 532 800 kbit/s
ODU2e	239/237 x 10 312 500 kbit/s
ODUflex for CBR Client signals	239/238 x client signal bit rate
ODUflex for GFP-F Mapped client signal	Configured bit rate

Table 1 ODU types and bit rates

NOTE - The nominal ODU_k rates are approximately: 2 498 775.126 kbit/s (ODU1), 10 037 273.924 kbit/s (ODU2), 40 319 218.983 kbit/s (ODU3), 104 794 445.815 kbit/s (ODU4) and 10 399 525.316 kbit/s (ODU2e).

ODU Type	ODU bit-rate tolerance
ODU0	+ - 20 ppm
ODU1	+ - 20 ppm
ODU2	+ - 20 ppm
ODU3	+ - 20 ppm
ODU4	+ - 20 ppm
ODU2e	+ - 100 ppm
ODUflex for CBR Client signals	client signal bit rate tolerance, with a maximum of + - 100 ppm
ODUflex for GFP-F Mapped client signal	+ - 20 ppm

Table 2 ODU types and tolerance

One of two options are for mapping client signals into ODUflex depending on the client signal type:

- Circuit clients are proportionally wrapped. Thus the bit rate and tolerance are defined by the client signal.
- Packet clients are mapped using the Generic Framing Procedure (GFP). [G709-V3] recommends that the bit rate should be set to an integer multiplier of the High Order (HO) Optical Channel Physical Unit (OPU) OPUk Tributary Slot (TS) rate, the tolerance should be +/- 20ppm, and the bit rate should be determined by the node that performs the mapping.

3.1.1.1 ODUj types and parameters

When ODUj connections are setup, two types of information should be conveyed in a connection request:

(a)End to end:
Client payload type (e.g. STM64; Ethernet etc.)

Bit rate and tolerance: Note for j = 0, 1, 2, 2e, 3, 4 this information may be carried as an enumerated type. For the ODUflex the actual bit rate and tolerance must be provided.

(b)Hop by hop:

TS assignment and port number carried by the Multiplex Structure Identifier (MSI) bytes as described in [section 3.1.2](#).

3.1.2 Multiplexing ODUj onto Links

The links between the switching nodes are provided by one or more wavelengths. Each wavelength carries one OCh, which carries one OTU, which carries one OPU. Since all of these signals have a 1:1:1 relationship, we only refer to the OTU for clarity. The ODUjs are mapped into the Tributary Slots (TS) of the OTUk. Note that in the case where j=k the ODUj is mapped into the OTU/OCh without multiplexing.

The initial versions of G.709 [[G709-V1](#)] only provided a single TS granularity, nominally 2.5Gb/s. Amendment 3 [[G709-V3](#)], approved in 2009, added an additional TS granularity, nominally 1.25Gb/s. The number and type of TSs provided by each of the currently identified OTUk is provided below:

	2.5Gb/s	1.25Gb/s	Nominal Bit rate
OTU1	1	2	2.5Gb/s
OTU2	4	8	10Gb/s
OTU3	16	32	40Gb/s
OTU4	--	80	100Gb/s

To maintain backwards compatibility while providing the ability to interconnect nodes that support 1.25Gb/s TS at one end of a link and 2.5Gb/s TS at the other, the 'new' equipment will fall back to the use of a 2.5Gb/s TS if connected to legacy equipment. This information is carried in band by the payload type.

The actual bit rate of the TS in an OTUk depends on the value of k. Thus the number of TS occupied by an ODUj may vary depending on the values of j and k. For example an ODU2e uses 9 TS in an OTU3 but only 8 in an OTU4. Examples of the number of TS used for various cases are provided below:

- ODU0 into ODU1, ODU2, ODU3 or ODU4 multiplexing with 1,25Gbps TS granularity
 - o ODU0 occupies 1 of the 2, 8, 32 or 80 TS for ODU1, ODU2, ODU3 or ODU4

- ODU1 into ODU2, ODU3 or ODU4 multiplexing with 1,25Gbps TS granularity
 - o ODU1 occupies 2 of the 8, 32 or 80 TS for ODU2, ODU3 or ODU4
- ODU1 into ODU2, ODU3 multiplexing with 2.5Gbps TS granularity
 - o ODU1 occupies 1 of the 4 or 16 TS for ODU2 or ODU3
- ODU2 into ODU3 or ODU4 multiplexing with 1.25Gbps TS granularity
 - o ODU2 occupies 8 of the 32 or 80 TS for ODU3 or ODU4
- ODU2 into ODU3 multiplexing with 2.5Gbps TS granularity
 - o ODU2 occupies 4 of the 16 TS for ODU3
- ODU3 into ODU4 multiplexing with 1.25Gbps TS granularity
 - o ODU3 occupies 31 of the 80 TS for ODU4
- ODUflex into ODU2, ODU3 or ODU4 multiplexing with 1.25Gbps TS granularity
 - o ODUflex occupies n of the 8, 32 or 80 TS for ODU2, ODU3 or ODU4 (n <= Total TS numbers of ODUk)
- ODU2e into ODU3 or ODU4 multiplexing with 1.25Gbps TS granularity
 - o ODU2e occupies 9 of the 32 TS for ODU3 or 8 of the 80 TS for ODU4

In general the mapping of an ODU_j (including ODUflex) into the OTUK TSs is determined locally, and it can also be explicitly controlled by a specific entity (e.g., head end, NMS) through Explicit Label Control [[RFC3473](#)].

3.1.2.1 Link Parameters

Per [[RFC4201](#)], each OTU can be treated as a component link of a link bundle. The available capacity between nodes is the sum of the available capacity on the OTUs that interconnect the nodes. This total capacity is represented as the capacity of a link bundle.

Note that there will typically be more than one OTU between a pair of nodes so that the available capacity will typically be distributed across multiple OTUs. Thus, in order to be able to determine the maximum payload that can be carried on a bundled link, the link state advertisement must also provide the largest number of TSes available on any one component OTU.

In order to compute the lowest cost path for a ODU_j connection request the critical parameters that need to be provided (for the purposes of routing) are:

- Number of TS
- Maximum number of TS available for a LSP (i.e., Maximum LSP Bandwidth)
- Bit rate of the TS. (Note: This may be efficiently encoded as a two integers representing the value of k and the granularity.)

3.1.2.2 Tributary Port Number Assignment

When multiplexing an ODU_j into a HO ODU_k ($k > j$), G.709 specifies the information that has to be transported in-band in order to allow for correct demultiplexing. This information, known as Multiplex Structure Information (MSI), is transported in the OPU_k overhead and is organized as a set of entries, with one entry for each HO ODU_j tributary slot. The information carried by each entry is:

Payload Type: the type of the transported payload

Tributary Port Number (TPN): the port number of the ODU_j transported by the HO ODU_k. The TPN is the same for all the tributary slots assigned to the transport of the same ODU_j instance.

For example, an ODU₂ carried by a HO ODU₃ is described by 4 entries in the OPU₃ overhead when the Tributary Slot (TS) size is 2.5 Gbit/s, and by 8 entries when the TS size is 1.25 Gbit/s.

The MSI information inserted in OPU₃ overhead by the source of the HO ODU_k trail is checked by the sink of the HO ODU_k trail. G.709 default behavior requires that the multiplexing structure of the HO ODU_k be provided by means of pre-provisioned MSI information, termed expectedMSI. The sink of the HO ODU trail checks the complete content of the MSI information (including the TPN) that was received in-band, termed acceptedMSI, against the expectedMSI. If the acceptedMSI is different from the expectedMSI, then the traffic is dropped and a payload mismatch alarm is generated.

Note that the values of the TPN MUST be either agreed between the source and the sink of the HO ODU trail either via control plane signaling or provisioning by the management plane.

4. Connection management in OTN

As [[ITU-T-G.872](#)] described, OTN-based transport network equipment is concerned with control of connectivity of ODU paths and optical channels and not with control of connectivity of the client layer. This document focuses on the connection management of ODU paths. The management of OCh paths is described in [[WSO-N-FRAME](#)].

Current [[ITU-T-G.872](#)] considers the ODU as a set of layers in the same way as SDH has been modeled. However, recent progress within the ITU-T on OTN architecture includes an agreement to update this Recommendation to model the ODU as a single layer network with the bit rate as a parameter of links and connections. This will allow the links and nodes to be viewed in a single topology as a common set of resources that are available to provide ODU_j connections independent of the value of j. Note that when the bit rate of ODU_j is less than the server bit rate, ODU_j connections are supported by HO-ODU (which has a one-to-one relationship with the OTU).

From an ITU-T perspective, the service layer is represented by the LO ODU and the connection topology is represented by that of the server layer; i.e., the OTU [corresponding to HO-ODU in case of multiplexing or to LO-ODU in case of direct mapping] which has the same topology as that of the OCh layer. The server layer topology is based on that of the OTU, and could be provided by a point-to-point optical connection, flexible optical connection that is fully in the optical domain, flexible optical connection involving hybrid sub-lambda/lambda nodes involving 3R, etc.

The HO-ODU/OTU and OCh layers should be visible in a single topological representation of the network, and from a logical perspective, the HO ODU/OTU and OCh may be considered as the same logical, switchable entity.

The remainder of this document assumes that the revision of G.872 will be made. The document will be updated to keep it in line with the new revision of G.872 when it is consented for publication.

4.1. Connection management of the ODU

LO ODU_j can be either mapped into the OTU_k signal ($j = k$), or multiplexed with other LO ODU_js into an OTU_k ($j < k$), and the OTU_k is mapped into an OCh. See [Appendix A](#) for more information.

From the perspective of control plane, there are two kinds of network topology to be considered.

(1) ODU layer

In this case, the ODU links are presented between adjacent OTN nodes, which is illustrated in Figure 2. In this layer there are ODU links with a variety of TSes available, and nodes that are ODXCs. Lo ODU connections can be setup based on the network topology.

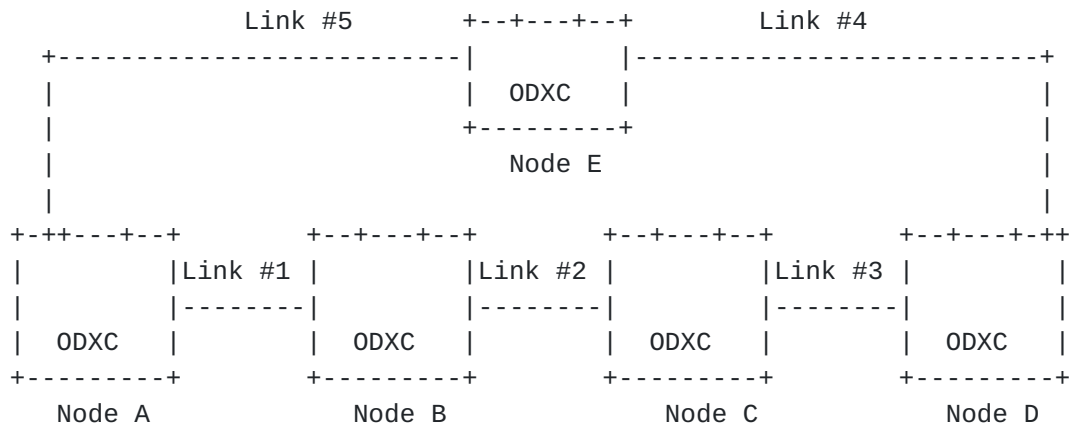


Figure 2 Example Topology for connection L0 ODU connection management

If an ODU_j connection is requested between Node C and Node E routing/path computation must select a path that has the required number of TS available and that offers the lowest cost. Signaling is then invoked to set up the path and to provide the information (e.g., selected TS) required by each transit node to allow the configuration of the ODU_j to OTU_k mapping ($j = k$) or multiplexing ($j < k$), and demapping ($j = k$) or demultiplexing ($j < k$).

(2) ODU layer with OCh switching capability

In this case, the OTN nodes interconnect with wavelength switched node (e.g., ROADM, OXC) that are capable of OCh switching, which is illustrated in Figure 3 and Figure 4. There are ODU layer and OCh layer, so it is simply a MLN. OCh connections may be created on demand, which is described in [section 5.1](#).

In this case, an operator may choose to allow the underlined OCh layer to be visible to the ODU routing/path computation process in which case the topology would be as shown in Figure 4. In Figure 3 below, instead, a cloud representing OCh capable switching nodes is represented. In Figure 3, the operator choice is to hide the real RWA network topology.

Node E

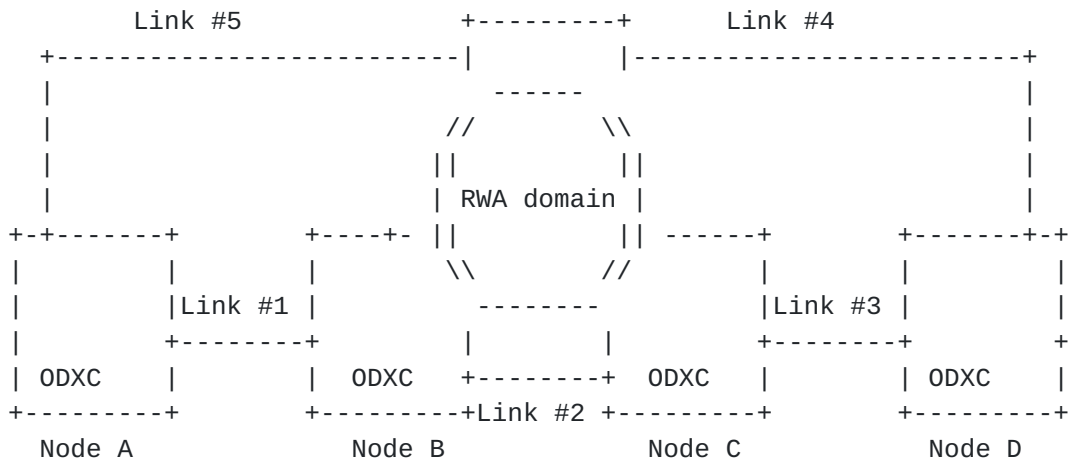


Figure 3 RWA Hidden Topology for connection L0 ODU connection management

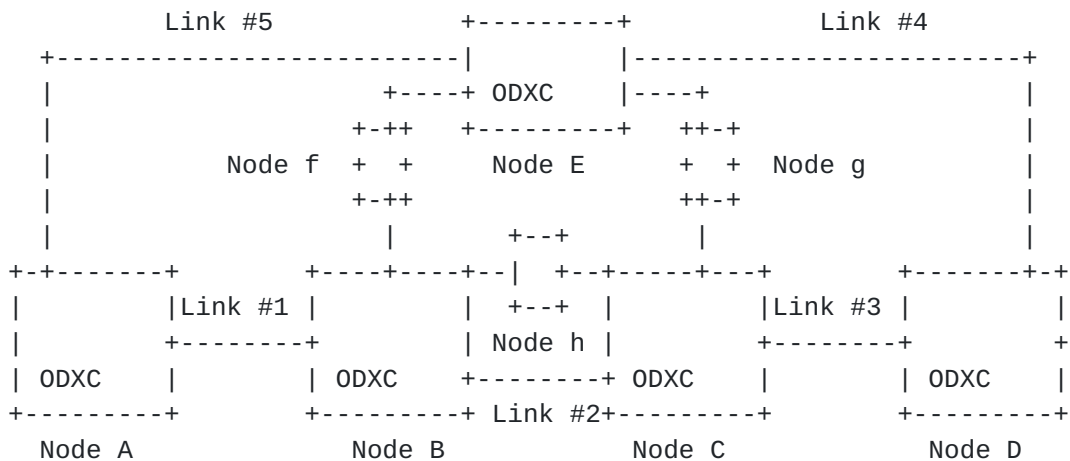


Figure 4 RWA Visible Topology for L0 ODUj connection management

In Figure 4, the cloud of previous figure is substitute by the real topology. The nodes f,g,h are nodes with OCH switching capability.

In the examples (i.e., Figure 3 and Figure 4), we have considered the case in which L0-ODUj connections are supported by OCh connection, and the case in which the supporting underlying connection can be also made by a combination of HO-ODU/OCh connections.

In this case, the ODU routing/path selection process will request an HO-ODU/OCh connection between node C to node E from the RWA domain. The connection will appear at ODU level as a Forwarding Adjacency, which will be used to create the ODU connection.

5. GMPLS/PCE Implications

The purpose of this section is to provide a framework for extensions of the current GMPLS protocol suite and the PCE applications and protocols to encompass OTN enhancements and connection management.

5.1. Implications for LSP Hierarchy with GMPLS TE

The path computation for LO ODU connection request is based on the topology of ODU layer, including OCh layer visibility.

The OTN path computation can be divided into two layers. One layer is OCh/OTUk, the other is LO ODUj. [[RFC4206](#)] defines the mechanisms to accomplish creating the hierarchy of LSPs. The LSP management of multiple layers in OTN can follow the procedures defined in [[RFC4206](#)] and related MLN drafts.

As discussed in [section 4](#), the route path computation for OCh is in the scope of WSON [WSON-Frame]. Therefore, this document only considers ODU layer for LO ODU connection request.

5.2. Implications for GMPLS Signaling

The signaling function and Resource reSerVation Protocol-Traffic Engineering (RSVP-TE) extensions are described in [[RFC3471](#)] and [[RFC 3473](#)]. For OTN-specific control, [[RFC4328](#)] defines signaling extensions to support G.709 Optical Transport Networks Control as defined in [[G709-V1](#)].

As described in [Section 2](#), [[G709-V3](#)] introduced some new features that include the ODU0, ODU2e, ODU4 and ODUFlex containers. The mechanisms defined in [[RFC4328](#)] do not support such new OTN features, and protocol extensions will be necessary to allow them to be controlled by a GMPLS control plane.

5.2.1. Identifying OTN signals

[[RFC4328](#)] defines the LSP Encoding Type, the Switching Type and the Generalized Protocol Identifier (Generalized-PID) constituting the common part of the Generalized Label Request. The G.709 Traffic Parameters are also defined in [[RFC4328](#)]. The following new signal types have been added since [[RFC4328](#)] was published:

(1) New signal types of sub-lambda layer

Optical Channel Data Unit (ODUj):

ODU0

ODU2e

ODU4

ODUflex

(2) A new Tributary Slot (TS) granularity (i.e., 1.25 Gbps)

(3) Signal type with variable bandwidth:

ODUflex has a variable bandwidth/bit rate BR and a bit rate tolerance T. As described above the (node local) mapping process must be aware of the bit rate and tolerance of the ODU_j being multiplexed in order to select the correct number of TS and the fixed/variable stuffing bytes. Therefore, bit rate and bit rate tolerance should be carried in the Traffic Parameter in the signaling of connection setup request.

(4) Extended multiplexing hierarchy (For example, ODU0 into OTU2 multiplexing (with 1,25Gbps TS granularity).)

So the encoding provided in [[RFC4328](#)] needs to be extended to support all the signal types and related mapping and multiplexing with all kinds of tributary slots. Moreover, the extensions should consider the extensibility to match future evolvement of OTN.

For item (1) and (3), new traffic parameters may need to be extended in signaling message;

For item (2) and (4), new label should be defined to carry the exact TS allocation information related to the extended multiplexing hierarchy.

5.2.2. Tributary Port Number

The tributary port number may be assigned locally by the node at the (traffic) ingress end of the link and in this case as described above must be conveyed to the far end of the link as a "transparent" parameter i.e. the control plane does not need to understand this information. The TPN may also be assigned by the control plane as a part of path computation.

5.3. Implications for GMPLS Routing

The path computation process should select a suitable route for a ODUj connection request. In order to compute the lowest cost path it must evaluate the number (and availability) of tributary slots on each candidate link. The routing protocol should be extended to convey some information to represent ODU TE topology. As described above the number of tributary slots (on a link bundle), the bandwidth of the TS and the maximum number that are available to convey a single ODUj must be provided.

GMPLS Routing [[RFC4202](#)] defines Interface Switching Capability Descriptor of TDM which can be used for ODU. However, some other issues should also be considered which are discussed below.

5.3.1. Requirement for conveying Interface Switching Capability specific information

Interface Switching Capability Descriptors present a new constraint for LSP path computation. [[RFC4203](#)] defines the switching capability and related Maximum LSP Bandwidth and the Switching Capability specific information. When the Switching Capability field is TDM the Switching Capability specific information field includes Minimum LSP Bandwidth, an indication whether the interface supports Standard or Arbitrary SONET/SDH, and padding. So routing protocol should be extended when TDM is ODU type to support representation of ODU switching information.

As discussed in [section 3.1.2](#), many different types of ODUj can be multiplexed into the same OTUK. For example, both ODU0 and ODU1 may be multiplexed into ODU2. An OTU link may support one or more types of ODUj signals. The routing protocol should be extended to carry this multiplexing capability. Furthermore, one type of ODUj can be multiplexed to an OTUK using different tributary slot granularity. For example, ODU1 can be multiplexed into ODU2 with either 2.5Gbps TS granularity or 1.25G TS granularity. The routing protocol should be extended to carry which TS granularity supported by the ODU interface.

Moreover, the bit rate (i.e., bandwidth) of TS can be determined by the TS granularity 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. So The routing protocol should be extended to carry the TE link type (OTUK/HO ODUK).

In OTN networks, it is simpler to use the number of Tributary Slots for the bandwidth accounting. For example, Total bandwidth of the TE link, Unreserved Bandwidth of the TE link and the Maximum LSP Bandwidth can be accounted through the number of Tributary Slots (e.g., the total number of the Tributary Slots of the TE link, the unreserved Tributary Slots of the TE link, Maximum Tributary Slots for an LSP). Thus, the routing protocol should be extended to carry the Tributary Slots information related to bandwidth of the TE link.

5.4. Implications for Link Management Protocol (LMP)

As discussed in [section 5.3](#), Path computation needs to know the interface switching capability of links. The switching capability of two ends of the link may be different, so the link capability of two ends should be correlated.

The Link Management Protocol (LMP) [[RFC4204](#)] provides a control plane protocol for exchanging and correlating link capabilities.

It is not necessary to use LMP to correlate link-end capabilities if the information is available from another source such as management configuration or automatic discovery/negotiation within the data plane.

Note that LO ODU type information can be, in principle, discovered by routing. Since in certain case, routing is not present (e.g. UNI case) we need to extend link management protocol capabilities to cover this aspect. In case of routing presence, the discovering procedure by LMP could also be optional.

5.4.1. Correlating the Granularity of the TS

As discussed in [section 3.1.2](#), the two ends of a link may support different TS granularity. In order to allow interconnection the node with 1.25Gb/s granularity must fall back to 2.5Gb/s granularity.

Therefore, it is necessary for the two ends of a link to correlate the granularity of the TS. This ensures that both ends of the link advertise consistent capabilities (for routing) and ensures that viable connections are established.

5.4.2. Correlating the Supported LO ODU Signal Types

Many new ODU signal types have been introduced [[G709-V3](#)], such as ODU0, ODU4, ODU2e and ODUflex. It is possible that equipment does not support all the LO ODU signal types introduced by those new standards or drafts. If one end of a link can not support a certain LO ODU

signal type, the link cannot be selected to carry such type of LO ODU connection.

Therefore, it is necessary for the two ends of an HO ODU link to correlate which types of LO ODU can be supported by the link. After correlating, the capability information can be flooded by IGP, so that the correct path for an ODU connection can be calculated.

5.5. Implications for Path Computation Elements

[PCE-APS] describes the requirements for GMPLS applications of PCE in order to establish GMPLS LSP. PCE needs to consider the GMPLS TE attributes appropriately once a PCC or another PCE requests a path computation. The TE attributes which can be contained in the path calculation request message from the PCC or the PCE defined in [RFC5440] includes switching capability, encoding type, signal type, etc.

As described in [section 5.2.1](#), new signal types and new signals with variable bandwidth information need to be carried in the extended signaling message of path setup. For the same consideration, PCECP also has a desire to be extended to carry the new signal type and related variable bandwidth information when a PCC requests a path computation.

6. Security Considerations

The use of control plane protocols for signaling, routing, and path computation opens an OTN to security threats through attacks on those protocols. The data plane technology for an OTN does not introduce any specific vulnerabilities, and so the control plane may be secured using the mechanisms defined for the protocols discussed.

For further details of the specific security measures refer to the documents that define the protocols ([RFC3473], [RFC4203], [RFC4205], [RFC4204], and [RFC5440]). [GMPLS-SEC] provides an overview of security vulnerabilities and protection mechanisms for the GMPLS control plane.

7. IANA Considerations

This document makes not requests for IANA action.

8. Acknowledgments

We would like to thank Maarten Vissers for his review and useful comments.

9. References

9.1. Normative References

- [RFC4328] D. Papadimitriou, Ed. "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Extensions for G.709 Optical Transport Networks Control", [RFC 4328](#), Jan 2006.
- [RFC3471] Berger, L., Editor, "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Functional Description", [RFC 3471](#), January 2003.
- [RFC3473] L. Berger, Ed., "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Resource Reservation Protocol-Traffic Engineering (RSVP-TE) Extensions", [RFC 3473](#), January 2003.
- [RFC4202] K. Kompella, Y. Rekhter, Ed., "Routing Extensions in Support of Generalized Multi-Protocol Label Switching (GMPLS)", [RFC 4202](#), October 2005.
- [RFC4203] K. Kompella, Y. Rekhter, Ed., "OSPF Extensions in Support of Generalized Multi-Protocol Label Switching (GMPLS)", [RFC 4203](#), October 2005.
- [RFC4205] K. Kompella, Y. Rekhter, Ed., "Intermediate System to Intermediate System (IS-IS) Extensions in Support of Generalized Multi-Protocol Label Switching (GMPLS)", [RFC 4205](#), October 2005.
- [RFC4204] Lang, J., Ed., "Link Management Protocol (LMP)", [RFC 4204](#), October 2005.
- [RFC4206] K. Kompella, Y. Rekhter, Ed., " Label Switched Paths (LSP) Hierarchy with Generalized Multi-Protocol Label Switching (GMPLS) Traffic Engineering (TE)", [RFC 4206](#), October 2005.
- [RFC5440] JP. Vasseur, JL. Le Roux, Ed., " Path Computation Element (PCE) Communication Protocol (PCEP)", [RFC 5440](#), March 2009.
- [G709-V3] ITU-T, "Interfaces for the Optical Transport Network (OTN)", G.709 Recommendation, December 2009.

9.2. Informative References

- [G709-V1] ITU-T, "Interface for the Optical Transport Network (OTN)," G.709 Recommendation, March 2003.
- [ITU-T-G.872] ITU-T, "Architecture of optical transport networks", November 2001 (11 2001).
- [HZang00] H. Zang, J. Jue and B. Mukherjee, "A review of routing and wavelength assignment approaches for wavelength-routed optical WDM networks", Optical Networks Magazine, January 2000.
- [WSON-FRAME] Y. Lee, G. Bernstein, W. Imajuku, "Framework for GMPLS and PCE Control of Wavelength Switched Optical Networks (WSON)", [draft-ietf-ccamp-rwa-wson-framework](#), work in progress.
- [PCE-APS] Tomohiro Otani, Kenichi Ogaki, Diego Caviglia, and Fatai Zhang, "Requirements for GMPLS applications of PCE", [draft-ietf-pce-gmpls-aps-req-01.txt](#), July 2009.
- [GMPLS-SEC] Fang, L., Ed., "Security Framework for MPLS and GMPLS Networks", Work in Progress, October 2009.

10. Authors' Addresses

Fatai Zhang
Huawei Technologies
F3-5-B R&D Center, Huawei Base
Bantian, Longgang District
Shenzhen 518129 P.R.China

Phone: +86-755-28972912
Email: zhangfatai@huawei.com

Dan Li
Huawei Technologies Co., Ltd.
F3-5-B R&D Center, Huawei Base
Bantian, Longgang District
Shenzhen 518129 P.R.China

Phone: +86-755-28973237
Email: danli@huawei.com

Han Li
China Mobile Communications Corporation
53 A Xibianmennei Ave. Xuanwu District
Beijing 100053 P.R. China

Phone: +86-10-66006688
Email: lihan@chinamobile.com

Sergio Belotti
Alcatel-Lucent
Optics CTO
Via Trento 30 20059 Vimercate (Milano) Italy
+39 039 6863033

Email: sergio.belotti@alcatel-lucent.it

11. Contributors

Jianrui Han
Huawei Technologies Co., Ltd.
F3-5-B R&D Center, Huawei Base
Bantian, Longgang District
Shenzhen 518129 P.R.China

Phone: +86-755-28972913
Email: hanjianrui@huawei.com

Malcolm Betts
Huawei Technologies Co., Ltd.

Email: malcolm.betts@huawei.com

Pietro Grandi
Alcatel-Lucent
Optics CTO
Via Trento 30 20059 Vimercate (Milano) Italy
+39 039 6864930

Email: pietro_vittorio.grandi@alcatel-lucent.it

Eve Varma

Alcatel-Lucent
1A-261, 600-700 Mountain Av
PO Box 636
Murray Hill, NJ 07974-0636
USA
Email: eve.varma@alcatel-lucent.com

APPENDIX A: Description of LO ODU terminology and ODU connection examples.

This appendix provides a description of LO ODU terminology and ODU connection examples. This section is not normative which is just a reference in order to facilitate quicker understanding of text.

In order to transmit client signal, the LO ODU connection must be created first. From the perspective of [\[G709-V3\]](#), there are two types of LO ODU:

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

(2) A LO ODU_j multiplexed into a HO ODU_k ($j < k$) occupying several TSs. In this case, the server layer of this LO ODU is a HO ODU_k. For example, if ODU₁ is multiplexed into ODU₂, and ODU₂ is mapped into OTU₂, the ODU₁ is LO ODU and ODU₂ is HO ODU.

The LO ODU_j represents the container transporting a client of the OTN that is either directly mapped into an OTU_k ($k = j$) or multiplexed into a server HO ODU_k ($k > j$) container. Consequently, the HO ODU_k represents the entity transporting a multiplex of LO ODU_j tributary signals in its OPU_k area.

In the case of LO ODU_j mapped into an OTU_k ($k = j$) directly, Figure 5 give an example of this kind of LO ODU connection.

In Figure 5, The LO ODU_j is switched at the intermediate ODXC node. OCh and OTU_k are associated with each other. From the viewpoint of connection management, the management of OTU_k is similar with OCh. LO ODU_j and OCh/OTU_k have client/server relationships.

For example, one LO ODU₁ connection can be setup between Node A and Node C. This LO ODU₁ connection is to be supported by OCh/OTU₁ connections, which are to be set up between Node A and Node B and between Node B and Node C. LO ODU₁ can be mapped into OTU₁ at Node A,

demapped from it in Node B, switched at Node B, and then mapped into the next OTU1 and demapped from this OTU1 at Node C.

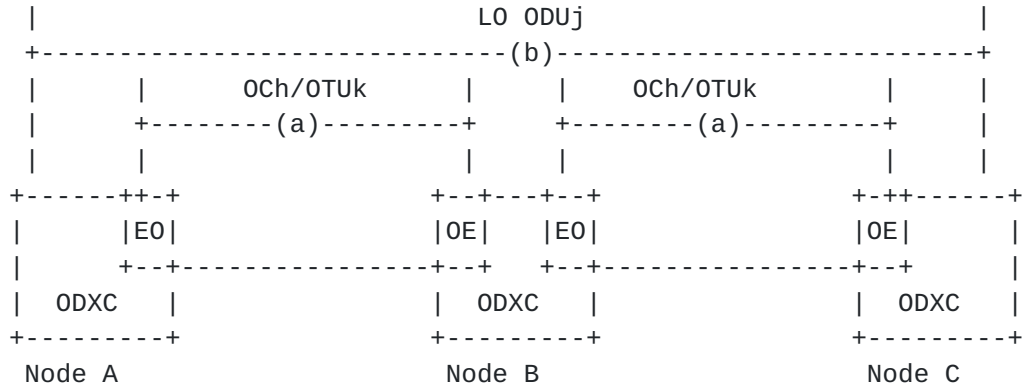


Figure 5 Connection of LO ODUj (1)

In the case of LO ODUj multiplexing into HO ODUk, Figure 6 gives an example of this kind of LO ODU connection.

In Figure 6, OCh, OTUK, HO ODUk are associated with each other. The LO ODUj is multiplexed/de-multiplexed into/from the HO ODU at each ODXC node and switched at each ODXC node (i.e. trib port to line port, line card to line port, line port to trib port). From the viewpoint of connection management, the management of these HO ODUk and OTUK are similar to OCh. LO ODUj and OCh/OTUK/HO ODUk have client/server relationships. when a LO ODU connection is setup, it will be using the existing HO ODUk (/OTUK/OCh) connections which have been set up. Those HO ODUk connections provide LO ODU links, of which the LO ODU connection manager requests a link connection to support the LO ODU connection.

For example, one HO ODU2 (/OTU2/OCh) connection can be setup between Node A and Node B, another HO ODU3 (/OTU3/OCh) connection can be setup between Node B and Node C. LO ODU1 can be generated at Node A, switched to one of the 10G line ports and multiplexed into a HO ODU2 at Node A, demultiplexed from the HO ODU2 at Node B, switched at Node B to one of the 40G line ports and multiplexed into HO ODU3 at Node B, demultiplexed from HO ODU3 at Node C and switched to its LO ODU1 terminating port at Node C.

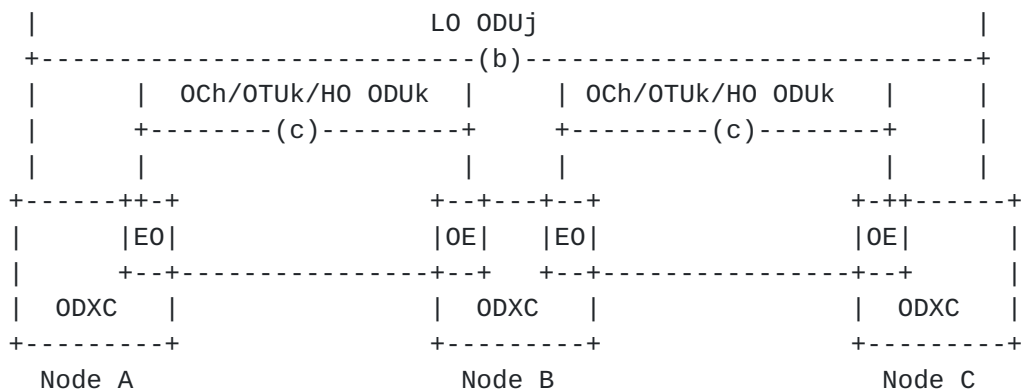


Figure 6 Connection of LO ODUj (2)

Intellectual Property

The IETF Trust takes no position regarding the validity or scope of any Intellectual Property Rights or other rights that might be claimed to pertain to the implementation or use of the technology described in any IETF Document or the extent to which any license under such rights might or might not be available; nor does it represent that it has made any independent effort to identify any such rights.

Copies of Intellectual Property disclosures made to the IETF Secretariat and any assurances of licenses to be made available, or the result of an attempt made to obtain a general license or permission for the use of such proprietary rights by implementers or users of this specification can be obtained from the IETF on-line IPR repository at <http://www.ietf.org/ipr>

The IETF invites any interested party to bring to its attention any copyrights, patents or patent applications, or other proprietary rights that may cover technology that may be required to implement any standard or specification contained in an IETF Document. Please address the information to the IETF at ietf-ipr@ietf.org.

The definitive version of an IETF Document is that published by, or under the auspices of, the IETF. Versions of IETF Documents that are published by third parties, including those that are translated into other languages, should not be considered to be definitive versions of IETF Documents. The definitive version of these Legal Provisions is that published by, or under the auspices of, the IETF. Versions of these Legal Provisions that are published by third parties, including

those that are translated into other languages, should not be considered to be definitive versions of these Legal Provisions.

For the avoidance of doubt, each Contributor to the IETF Standards Process licenses each Contribution that he or she makes as part of the IETF Standards Process to the IETF Trust pursuant to the provisions of [RFC 5378](#). No language to the contrary, or terms, conditions or rights that differ from or are inconsistent with the rights and licenses granted under [RFC 5378](#), shall have any effect and shall be null and void, whether published or posted by such Contributor, or included with or in such Contribution.

Disclaimer of Validity

All IETF Documents and the information contained therein are provided on an "AS IS" basis and THE CONTRIBUTOR, THE ORGANIZATION HE/SHE REPRESENTS OR IS SPONSORED BY (IF ANY), THE INTERNET SOCIETY, THE IETF TRUST AND THE INTERNET ENGINEERING TASK FORCE DISCLAIM ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY WARRANTY THAT THE USE OF THE INFORMATION THEREIN WILL NOT INFRINGE ANY RIGHTS OR ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

Copyright Notice

Copyright (c) 2010 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to [BCP 78](#) and the IETF Trust's Legal Provisions Relating to IETF Documents (<http://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document.